THE ESSENTIALS OF RAINFALL DERIVATIVES AND INSURANCE

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Abstract

This paper investigates the use of rainfall insurance to manage agricultural production risks. A number of rainfall insurance products are presented along with a rational model which identifies the economics of rainfall. The use of rainfall insurance will increase in future years as capital markets, financial institutions, reinsurance companies, crop insurance companies, and hedge funds collectively organize to share and distribute weather risks. The focus of this paper is in fact directed towards the intermediation function of risk markets rather than on end user benefits.

The Essentials of Rainfall Insurance

For crop insurers in Canada the U.S. and elsewhere the majority of indemnities they face are weather related. Heat, rainfall, hail, and frost payouts are much more common than payouts on pestilence and disease, and even if in some jurisdictions pestilence was a high indemnity the root cause of the pestilence can often be tracked to a weather based trigger. In Ontario the forage plan offered by Agricorp, the provincial crown corporation for crop insurance, a type of rainfall insurance is offered for forage crops. Because of the complexities involved in measuring forage yields the program uses a rainfall-based simulation model called SIMFOY which requires insureds to record rainfall at the farm level. This rainfall measure is then entered into the computer program and along with heat measures a simulated yield is calculated. Indemnities are based on the relationship between the simulated yield and the previous (simulated) yield history.

Using a simulation model has its own built in hazards which can be costly to both the insurer and the insured. For example it would not be unusual for two adjacent farms to receive significantly different indemnities because one farmer might have been away when significant rainfall occurred and thus did not have this recorded for the simulation. Furthermore, because past histories are also based on simulated outcomes, the current years' payoff would include an accumulated bias from such errors uncorrected in the past. In the U.S.A. multiple and single peril crop insurance is offered for grains and oilseeds, but for forages the primary approach to insurance is based upon area yields. With area yield insurance, forage yields are recorded for a smaller acreage within a region and extrapolated to an area average. This average is then compared to area yield histories and if below a trigger an equal indemnity is paid to all of the insureds in the area. Several issues concerning the equity and efficiency of area yield insurance have been raised (Turvey and Islam 1995).

Whether the insured crop is grain, oilseed, horticultural or forage economic theory and practice recognizes that a successful insurance policy is one which adequately transfers risk between two counterparties. The efficacy of conventional stop-loss crop insurance in North America is determined by the perceived relationship between premiums and risk (Coble et al 1996, Islam 1997,Goodwin 1993, Vercammen 1995).

With the complexities, difficulties, and ambiguities associated with forage insurance and other types of insurance, it is prudent to investigate alternative insurance structures for agriculture. A market for tradeable risk management weather derivatives is emerging in the United States and to a lesser extent Canada. Weather derivatives have similar characteristics to put options, call options, and swaps and can be traded over the counter as derivative products or sold directly as insurance products.[1] In fact as traditional boundaries between financial institutions fall, insurance companies, reinsurance companies, brokerages, and investment banks all participate as insurer or counterparty to a trade. In the U.S.A., companies such as World Wide Weather Insurance Inc, American Agrisurance Inc., and NatSource Inc. (A New York City brokerage) are examples of companies which have recently entered the weather insurance or derivatives market. At least one Canadian Institution, the Royal Bank Financial Group, is marketing financially engineered weather products.

While an emerging and increasingly liquid market for weather derivatives is perhaps sufficient to motivate research into rainfall insurance there is a significant scholarly reasoning behind the investigation as well; The move from all risk/multiple peril crop insurance to rainfall based insurance requires one to segregate risk into specific event risks. Specific event risks deal with the economics of certainty, and our expected utility, mean-variance based paradigm of insurance no longer suffices as an economic model. Fortunately, as will be shown in the next section, the economics of rainfall insurance relies on much less stringent requirements than the conventional models, and can easily be justified through an argument of prudence and sensibility rather than risk aversion and expected utility.

The objectives of this paper are to illustrate the significance of specific event risks as they relate to rainfall insurance, to illustrate how rainfall insurance is priced in practice, and to offer an economic justification for the use of rainfall insurance as a substitute for conventional multiple peril crop insurance, especially for forage crops..

[1] The payoff structure between an exchange traded weather derivative would be the same as an insurance products. In financial markets the two are separated because the regulatory regime for selling an insurance product is quite different than that for OTC derivatives. There are also substantial difference in the accounting principles used for insurance products versus financial derivatives.

Specific Event Risks and the Economics of Certainty

Specific event risk refers to those specific events for which the outcome is known with certainty. The statement "if there is a drought there will be a crop failure" is a simple example of this concept. The specific event 'drought' will, with 100% certainty result in a "crop failure". Consequently, insurance conditioned on specific event risks draws a parallel with cause and effect, with the significant departure from tradition being that the cause is insured, not the effect. Significantly this implies that crop yield damage does not have to be proven in order to receive a benefit from an insured specific event.

The economics of certainty within a framework of specific event risks can be captured by using some classical economic tools. Assume that farm profits are represented by $\Pi(\Omega|\omega)$ where ω is the rainfall event and Ω is the set of resources used in production. Under this specification, $\Pi(\Omega|\omega)$ is determined by the input set but the ultimate measure of profits is conditioned on the specific rainfall events. Profits are determined from revenues $P^*Y(\Omega|\omega)$ and the cost function $C(\Omega|\omega)$. The economic effect of rainfall risk is measured by both. It is assumed that Ω is predetermined so that marginal profits can be measured relative to ω alone.

It is assumed that Y() is concave in ω while C() is convex in ω which implies that as rainfall increases $dY/d\omega > 0$ up to some point at which ω^* is optimal, $dY/d\omega = 0$, and then $dY/d\omega < 0$[2]. This assumption admits that rainfall insurance does not apply to drought conditions alone, but can also be applied to specific events of excessive rain.[3]. The convexity argument in the cost structure is justified by a symmetric argument. There will be some ω^* such that $dC/d\omega = 0$. For $\omega < \omega^*$ costs will be increasing as the costs associated with drought (e.g., labour, capital, and energy costs associated with irrigation) increase and for $\omega > \omega^*$ costs associated with excess rain

[2] Optimal in this context does not imply that the producer chooses the optimal amount of rainfall. Rather, it suggests that there exists a natural optimum amount of rainfall which is exogenous.

[3] I'm making a bit of a generalization here. Naturally there are some crops which do very well under drought conditions and others which do very well with excessive rains. For these cases using $\leq$ or $\geq$ would be totally satisfactory.

(e.g. capital costs of tiling or drainage, down time etc.) are incurred[4].

Marginal profits are then equal to

(1) $\partial\Pi(\Omega|\omega) / \partial\omega = P\, \partial Y(\Omega|\omega) / \partial\omega - \partial C(\Omega|\omega) / \partial\omega$

and will be convex with $\partial\Pi() / \partial\omega > 0$ for $\omega < \omega^*$, $\partial\Pi() / \partial\omega = 0$ for $\omega = \omega^*$ or $\partial\Pi() / \partial\omega < 0$ for $\omega > \omega^*$.

The relationship between rainfall and profits is depicted in figure 1 which shows a possibility frontier, all other things being equal. At point 'c' the marginal impact of rainfall on profits is zero, and for rainfall above and below this point marginal profits decrease at an increasing rate as rainfall becomes too little or too much[5].

From the end users' perspective Π_{min} in figure depicts a critical profit level which needs to be protected. The insured can select a put option which would provide an indemnity if rainfall falls below $\omega_{a,}$ a call option if rainfall exceeds ω_b, or both (a collar). In general the price of these contracts (in the absence of time value) would be

(2) $V_{put} = \int^{\omega a} \Pi'(\omega)\, (\omega_a - \omega) f(\omega) d\,\omega \quad \text{for} \quad \omega < \omega_a$

and

(3) $V_{call} = {}_{\omega b}\int \Pi'(\omega)\, (\omega - \omega_b) f(\omega) d\,\omega \quad \text{for} \quad \omega > \omega_b.$

Equations (2) and (3) rely on several factors to be priced. First, $f(\omega)$ represents the probability distribution function which describes rainfall throughout the growing season; second the insured must have some idea of the specific event to be insured. For the put option in equation (2) the specific event is $\boldsymbol{\omega < \omega_a}$, and for the call option in equation (3) the specific event is given by $\boldsymbol{\omega > \omega_b}$ where $\boldsymbol{\omega_a}$ and $\boldsymbol{\omega_b}$ are strike levels. Finally, the third element is the absolute value of $\boldsymbol{\Pi'(\omega)}$ which will increase as rainfall moves away from the optimum. As written in (2) and (3) the pure-form derivative product would increase compensation at an increasing rate as the option moved further into-the-money.

[4] As in note 2, setting $dC/d\omega \geq 0$ or $dC/d\omega \leq 0$ instead of $dC/d\omega > 0$ or $dC/d\omega < 0$ for $\omega < \omega^*$ or $\omega > \omega^*$ is entirely acceptable and depends on specific circumstances.

[5] Clearly figure 1 and the accompanying discussion is an abstraction from reality. Most likely there will be a range in rainfall about the optimum for which marginal profits are zero. There, will ultimately be a point at which rainfall deficits and/or accumulations cause diminishing marginal profitability. This point will be crop specific.

While theoretically precise equations (2) and (3) are not very practical since in practice they require the a priori examination of the profit-rainfall response function **$\Pi(\omega)$** and its derivative **$\Pi'(\omega)$**. It is unlikely that producers, insurers, brokers or reinsurers would demand such precision, and the estimation would require significant costs and time.

In practice, **$\Pi'(\omega)$** will be defined by the end user (purchaser of rainfall insurance) as a constant dollar amount, Z, applied to each in-the-money outcome; that is the option would be priced according to

$$\textbf{(4)}\qquad V_{put} = Z \int^{\omega a}(\omega_a - \omega)f(\omega)d\,\omega \quad \text{for} \quad \omega < \omega_a$$

and

$$\textbf{(5)}\qquad V_{call} = Z\ {}_{\omega b}\!\int(\omega - \omega_b)f(\omega)d\,\omega \quad \text{for} \quad \omega > \omega_b\ .$$

In formulations (4) and (5) the integral calculates the expected value of the option when it is in the money, e.g. E[Max(ω_a - ω, 0)] for a put option with units of rainfall (e.g. inches or cm or mm). The value of Z (with units $/inch etc.) is established perhaps as the expected value of **$\Pi'(\omega)$** over the entire range of **ω** when it is in the money. Alternatively, it could also be a measured average cost derived from accounting and production records, or simply as a subjective allocation.

An alternative to the option-like rainfall insurance products described by equations (4) and (5) is the all-or-nothing option. This option is triggered as soon as the rainfall measure becomes in the money. Once this event happens a fixed payout is made. The all-or-nothing option is given by

$$\textbf{(6)}\qquad V_{put} = Z \int^{\omega a}f(\omega)d\,\omega \quad \text{for} \quad \omega < \omega_a$$

and

$$\textbf{(7)}\qquad V_{call} = Z\ {}_{\omega b}\!\int f(\omega)d\,\omega \quad \text{for} \quad \omega > \omega_b$$

where the integral term measures the cumulative probability of the event happening..

There are three requirements to calculating the premium of a rainfall insurance product. The first, as discussed , is a determination of the dollar value placed on the event happening , i.e. Z or **$\Pi'(\omega)$** The second element is to determine the criteria for the event; if the insurance is to insure that no rain occurs over a 14 day period, then the appropriate measure of risk would be the daily record of rainfall; if the derivative is designed to insure that at least 1" of rain falls in a seven day period then the appropriate probability measure would be based on cumulative rainfall. The third element is the definition of the probability distribution or stochastic process which defines the risks and outcomes associated with ω.. It would be atypical at this time to argue or defend the use of Black's option pricing model to price the options since there is no forward market or index with wich to price such a derivative nor can it be argued that the underlying volatility structure complies with geometric Brownian motion. Consequently the most practical approach, and one which is used in practice is to use historical time series to compute probabilities. The most common approach, often referred to as the 'Burn Rate', assumes that history will repeat itself or that there is a form of mean reversion which allows for the use of history to calculate the present with reasonable precision. In the alternative, a normal distribution could be used. With a large number of observations the use of normal curve theory could approximate the burn rate, but it should be understood that the difference between the two approaches is that normal curve theory assumes that history repeats itself over an infinite time horizon whereas the burn rate assumes this repetition only for the period in which data is collected.

Finally, the insureability of rainfall can only be localized. The distribution of rainfall throughout the year is affected by sporadic bursts which impact one locale and not another. Different regions also face different ecological effects from macro weather patterns to lake and other waterway effects. For this reason most rainfall insurance contracts would specify measurement at a specific location over a specific time period. Moreover, it would be unusual for any counterparty to accept a contract which does not provide an authoritative and verifiable measure. For this reason contracts in the U.S.A. would rely exclusively on the measurements from the National Weather Service, and in Canada the authority would be Environment Canada.

Based on this discussion the specific details of an insurance contract (or ticket if an OTC derivative traded product) has at least three elements; 1) The insured event, 2) the duration of the contract, and 3) the location at which the event is measured. The wording is specific as suggested by the following hypothetical contract (which will be discussed below) "The company will insure from June 1, 1999 to July 31, 1999, that accumulated rainfall will not be 100 mm or below at the Environment Canada Weather Station located in Welland Ontario". The contract would then go on to stipulate the indemnity or payoff should the specific event happen. Once the terms have been established the product will either be sold directly at a fixed or negotiated price, or brokered on an over-the-counter exchange on a bid-ask basis.

Data Sources and empirical Measurement of Rainfall Insurance

In this paper a number of different insurance contracts will be specified and valued for three separate locations in Ontario. The number of possibilities for rainfall insurance is limited only by imagination and data, however the examples provided should reasonably represent the most common types and measures of insurance that will emerge for Canadian agriculture.

Data used are daily rainfall measures from 1892 to 1996. Measurement is in mm/day as recorded by Environment Canada. The three locations selected for this paper are Ottawa (Eastern Ontario), Welland (South Central Ontario and Niagra District), and Woodstock (Central Ontario). These three regions have diverse agricultural economies. The Ottawa region is mixed farming but the majority of land would be planted to forages and grain corn. Woodstock represents a diverse cash cropping region which includes forage crops, grains, oilseeds, edible beans, and tobacco. Welland, with its proximity to the Niagra Escarpment represents an area rich in fruit orchards, vineyards, and cash crops. In addition to diversity, these three particular weather stations had daily data as far back as at least 1892[6] [7] .

The analysis and summaries in this study uses daily data from June 1 through to July 31 from 1892 to 1996. Table 1 summarizes some key information for the three locations over this period and Figure 2 Illustrates for Woodstock the variability in total rainfall over this period..

From Table 1 the average rainfall for Ottawa, Welland and Woodstock is 174.1 mm, 145.0 mm and 163.8 mm respectively. The Highest rainfall for each is 325.6 mm (1899), 318.8 (1937) and 308.3 (1892), and the lowest rainfall is 68.9 mm (1991), 44.5 mm (1933) and 40.4 mm (1899). The table reveals that the systematic relationship between the regions cannot be relied

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[6] The Environment Canada data base has many different locations. Most have data to 1996 and many will have data going back as far as 30 or 40 years. Only a small percentage of locations has data prior to 1900.

[7] The fact that data has been recorded as far back as 1890 does not necessarily imply that all of the data is available on each day of each year. The software written specifically for this study eliminated any year which had missing data.

upon. In 1899 Ottawa recorded its highest rainfall ever, while in that same year drought conditions recorded the lowest rainfall in Woodstock. In 1937 Welland recorded its highest rainfall ever, while approximately 120 km away Woodstock recorded rainfall close to the average. In 1991 Eastern Ontario faced a drought while in Central Ontario above average rainfall was recorded. This summary illustrates the importance of using localized weather data , indicates the diversity (and perhaps randomness) of weather patterns across Ontario, and provides an explanation for the differences in the systematic risk of crop production across Ontario that was observed by Turvey (1991).

In the following section a number of contracts will be specified and the premiums compared by location. When specific events are being insured, it will be shown that not only do differences in regions matter for inter year comparisons, but what happens within a year is equally, if not more, important.

Insuring Specific Event Risks

In this section a number of different insurance contracts will be analyzed. The analysis tool is a proprietary computer program written in Visual Basic Applications with Microsoft Excel. Data from Environment Canada are stored in an excel spreadsheet and the VBA organizes the data, checks for missing data, and computes the insurance premiums for the specified rainfall events. Five contracts are evaluated for each of the three locations. These are:

- Option 1: Insurance which pays out $1,000 for each mm of cumulative rainfall below a strike of 125mm calculated using the burn rate method and the normal curve method.
- Option 2: Insurance which pays out $1,000 for each mm of cumulative rainfall below a strike of 100mm calculated using the burn rate method and the normal curve method.
- Option 3: Insurance which pays $10,000 per event where each event is defined as zero rainfall for 14 consecutive days, and the insurance will pay up to four separate and mutually exclusive events.
- Option 4: Insurance which pays $10,000 if the cumulative rainfall between June 1 and July 31 is less than or equal to 100mm.
- Option 5: Insurance which pays $10,000 if the cumulative rainfall between June 1 and July

31 is greater than or equal to 275mm.

The first two put option-like insurance policies or derivatives are drought insurance contracts calculated using Equation 3, where Z is fixed rather than using marginal profits as defined by equation 1. The distributional assumption is that the empirical rainfall distribution is not necessarily normal. Hence, the ‘Burn Rate’ is calculated using the empirical distribution, and this is compared to a normal distribution assumption. For the first option the specific event which triggers a payout, or puts the policy in-the-money, is when cumulative rainfall is less than 125 mm on July 31, and for the second option the strike is at 100 mm on July 31.

The third option is a specific event rainfall policy which insures 2-week drought. This policy will pay $10,000 to the insured for each non-overlapping 14 day period in which no rain is recorded. The policy would expire out-of-the-money if even 1mm or rainfall fell at least once every 14 days. Up to four separate events will be covered under this policy which means that the possibility of a payoff increases with extended drought.

The fourth option is a specific event drought contract which pays $10,000 if cumulative rainfall is less than 100mm on July 31. The option expires out-of-the-money if rainfall in excess of 100mm is recorded. This policy differs from the first two in that it is a single-event, single-payout policy. The payout of $10,000 is fixed and is paid out regardless of whether rainfall is 0mm or 100mm. In the first two cases the amount by which rainfall is below 100mm determines the payoff.

The fifth option is a specific event call option. Policies of this type could be referred to as flood insurance, but in general an end user of this policy will have crops which are sensitive to excessive rainfall. The call option pays a fixed rate of $10,000 if cumulative rainfall is greater than or equal to 275mm on July 31.

The results from these policies are presented in Table 2. With the exception of the first two options, It would be incorrect to compare and contrast all of the policies because the underlying probability structure differs between them. However it is possible to compare the three locations since it is the nature and design of probabilities which distinguishes them. For the first option, there is a substantial difference between the cost of insurance in Ottawa, Welland, and Woodstock. At a 125mm strike the value of the option is equal to $4,142 in Ottawa and $12,819 in Welland. The maximum payoff that would have been made since 1892 is 84,600 for Woodstock, $80,500 for Welland, and $56,100 for Ottawa. The results illustrate the significance of how events are distributed. For example, even though Woodstock would have recorded the largest payoff, the insurance costs is still lower than Welland.

If a normal distribution is assumed the calculated premiums are lower at 3,906 for Ottawa, and $10,701 in Welland and $6,901 in Woodstock. From a historical perspective there is a bias associated with the normal distributional assumption at the 125mm strike level. In contrast, at the 100mm strike the normal distribution overprices relative to the empirical distribution, which is to say that it assigns probabilities to large in-the-money events which have not occurred in over 100 years. However, the nearer the strike is to the mean the closer the normal distributional assumption will echo the premium calculation of the empirical distribution.

The zero rainfall 14-day event option is priced at $952, $2,039, and $1,810 for Ottawa, Welland, and Woodstock respectively. There is a 91.4% chance that no event will occur in Ottawa, while an 81.6% chance of no event is recorded for Welland. There is nearly a 2% chance of 2 events occurring in Welland, a 3% chance of two events in Woodstock, and a 1% chance of two events in Ottawa. In general, significant drought is a rare event which occurs about once a decade only. However, depending on location, the frequency and distribution of these rare events can vary significantly.

The fourth option is a less extreme drought policy than that above, but its structure is different as well. As at July 31, the chance of having less than 100mm of accumulated rainfall is very rare in Ottawa where the premium would only be $571. Welland is most drought prone with a cost of $2,621, and the cost of the policy in Woodstock would be $1,714.

Finally, the fifth option illustrates how insurance can be used to protect against excessive rainfall. With a premium of $571, Woodstock appears to have the greatest likelihood of excessive rain, with Welland and Ottawa facing costs of only $388 and $381 respectively. In contrast to the fifth option there is a much greater likelihood of too little rain than too much rain.

The important observation from exploring this limited number of insurance products is the verification that a uniform rainfall insurance policy will not be successful, at least on an actuarial basis. The risks by location are significantly different as one would expect in an area where different and varied macro and micro climatic conditions prevail. Of the three locations illustrated above, Welland is the most drought prone, and therefore insurance or derivative products targeted towards this region would be higher than the other two regions. Ottawa is the least likely area to suffer extreme drought conditions. It is also important to recognize that different climatic conditions can affect different locations at the same time. Recall from Table 1 the observation that in 1899 Ottawa recorded its wettest season on record, Woodstock its driest, and in that same year Welland was near average. The obvious caveat is that even though some weather conditions can be highly correlated amongst locations this is not a rule that can be relied on with any actuarial precision[8].

Discussion and Conclusions

the purpose of this paper was to provide some insights into the economics of rainfall and its relationship to specific event risks which cause economic damage . It was argued that a paradigm for understanding rainfall insurance starts with the definition of a profit function, and how profits vary with rainfall. In a classical economic framework, insurance would be calculated according to changes in the direct and indirect marginal profits of the business. Because measuring changes to marginal profits can be costly and impractical the approach was not pursued in this study. Rather, a fixed payoff associated with a specific event was assumed in all cases.

Drought insurance relies on the strike value (elected coverage level) of rainfall and its relationship with the underlying probability distribution or stochastic process wich determines the frequency of specific rainfall events. Using daily rainfall data compiled by Environment Canada, and having found three locations across Ontario which had daily data from 1892, this paper examined only five such policies . Depending on which policy was used the range of prices truly

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[8] One can imagine many situations where incomplete data at one location may require regression or correlation analysis with a second location in order to extrapolate rainfall. If , under these circumstances, systematic risk is low and the extrapolation is used to calculate premiums, it may be prudent to use Monte Carlo or other simulation techniques to estimate the premiums.

reflected the underlying weather risks. The premiums for drought insurance ranged from $12,819 to $571, and it was shown that these differences are location specific.

The emergence of primary and secondary markets for weather based risk management products will result in many new products coming to the market. For forage crop insurance this is timely since the largest problem with forage insurance is measuring actual yields. Note that at no point in this paper was crop yield measurement or proven losses an issues. Rainfall insurance can provide a simple and intuitive approach to managing production risks which can be delivered in a cost effective and unambiguous manner. This paper provided some insights into the theoretical justification for these products, illustrated how rainfall insurance/derivative premiums can be computed, and raised some practical issues relating to the recognition of risks. However, it is understood that as the market does grow these techniques will become more refined, and the market for weather insurance and derivative models will become much more sophisticated.

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Table 1: Data Summary 1892-1996, Cumulative Rainfall (mm) June 1 to July 31			
Location	**Ottawa**	**Welland**	**Woodstock**
Average	173.3	144.0	162.8
Standard Deviation	51.7	54.1	56.9
High	325.6	318.8	308.0
Low	68.9	40.4	44.5
Min and Max Years			
1892	228.9	305.6	308.3
1899	325.6	138.4	40.4
1933	123.2	44.5	72.2
1937	194.7	318.8	141.6
1991	68.9	94.2	153.0

Table 2: Estimated Premium and Payoff results for Insured Events; June 1 - July 31			
Description	**Ottawa**	**Welland**	**Woodstock**
Drought Insurance Put Option@$1,000/mm; Strike = 125mm			
Burn Rate Model Premium	$4,142	$12,819	$9,100
Normal Curve Model Premium	$3,906	$10,701	$6,901
Maximum Payout (1892-1996)	$56,100	$80,500	$84,600
Drought Insurance Put Option@$1,000/mm; Strike = 100mm			
Burn Rate Model Premium	$968	$4,372	$3,524
Normal Curve Model Premium	$1,464	$5,101	$3,103
Maximum Payout (1892-1996)	$31,100	$55,500	$59,600
Drought Insurance; Insure specific event of 0mm/day for 14 days; Maximum 4 events;$10,000/event			
Premium	$952	$2,039	$1,810
Standard deviation of Payout	$3,259	$4,506	$4,553
Maximum payout	$20,000	$20,000	$20,000
Chance of 0 events	.914	.816	.848
Chance of 1 events	.076	.165	.124
Chance of 2 events	.010	.019	.029
Chance of 3 events	.00	.00	.00
Chance of 4 events	.00	.00	.00
Drought Insurance; Insure specific event of <=100mm cumulative rainfall; Payout=$10,000			
Premium	$571	$2,621	$1,714
Maximum Payout	$10,000	$10,000	$10,000
Flood Insurance; Insure specific event of >=275mm cumulative rainfall; Payout=$10,000			
Premium	$381	$388	$571
Maximum Payout	$10,000	$10,000	$10,000

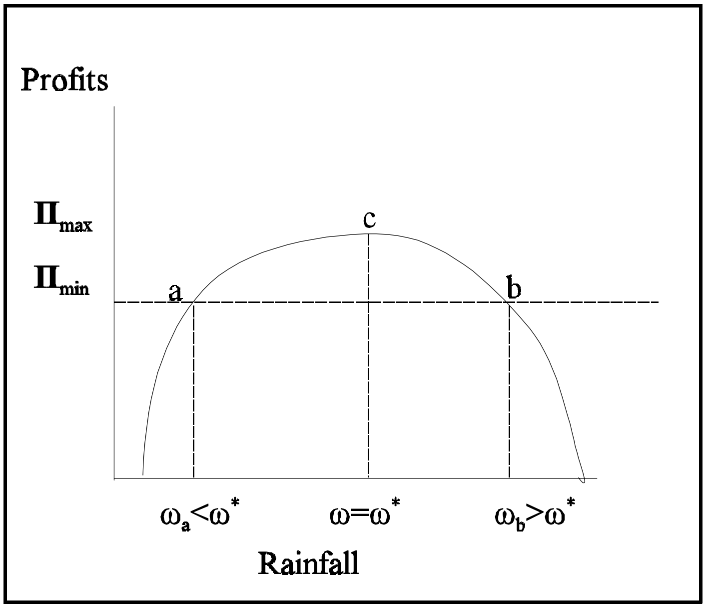

Figure 1: Business profits are a concave function of rainfall.

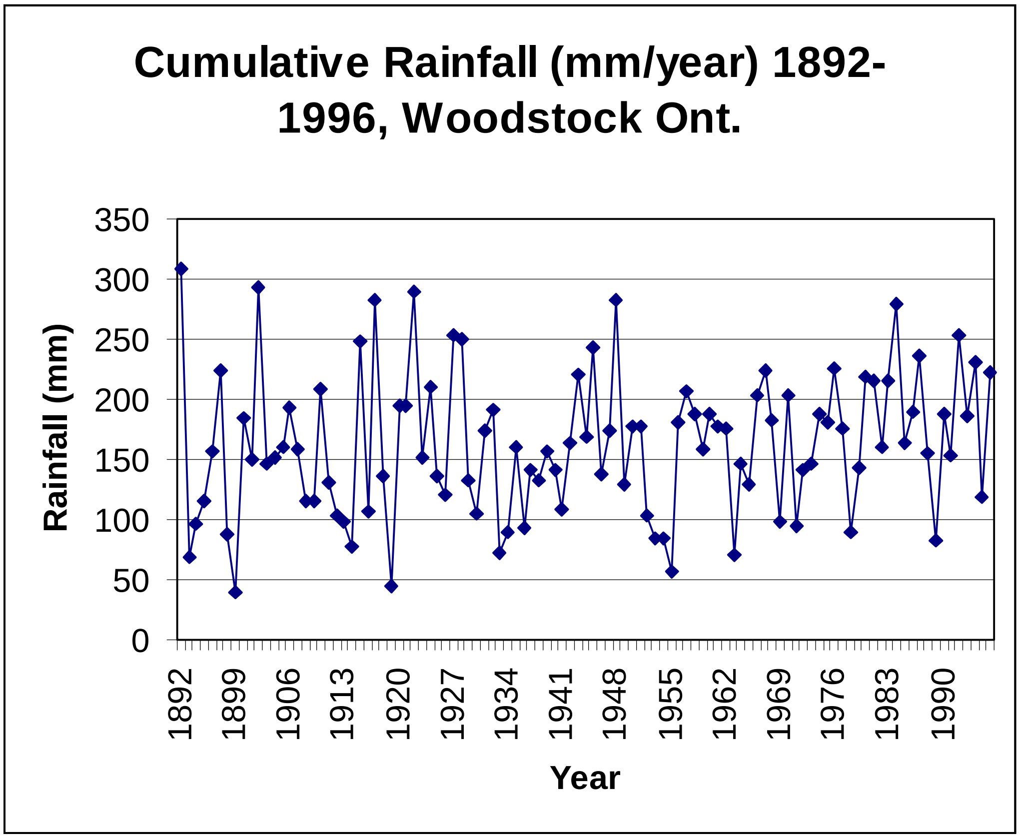

Figure 2 Cumulative rainfall for Woodstock Ontario from June 1 through to July 31: 1892-1996