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).

Traditionally, small farmers and the rural poor have used various types of mitigation techniques for weather-related risks to their income. These include savings, selling their assets, selling their livestock etc. However, the implied premium on these types of techniques was estimated by Rosenzweig and Biswanger (1993) to be as high as 35%.

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.

The main challenge in managing finances comes from market uncertainties. Large fluctuations in prices of assets are equally harmful to all parties concerned. To hedge against price volatility, different devices have been used in the history of business. Forward contracts, used as a means for fixing the price for future trading, have been in vogue for long. These then, developed into various forms.

The main mechanism lay in both parties agreeing upon rights to ignore physical delivery and accept the settlement of price differentials. Thus, we have contracts which are, in a sense, virtual. The risky asset underlies the contract; in other words, the contract derives its value out of the volatility of the asset.

As a realization of the risk management capacity of derivatives grew, markets for these products developed. Today, they are widely used to promote efficient allocation of capital across economies, so as to increase productivity. This is so in India and other developing countries, as well. Commodity derivatives markets started in India with cotton in 1875, oilseeds in 1900, and jute and jute products in 1912. Forward markets in wheat started at Hapur in 1913 and in bullion at Bombay in 1920 (Kolamkar, 2002). The commodity futures trading in India had a long and healthy existence until all derivatives trading was banned in the 1960s. Section 20 of the Securities Contracts (Regulation) Act, 1956 (SCRA) prohibited all options in securities. In 1969, by a notification under this act, the Government prohibited all forward trading in Securities. So when trading in derivatives was to be introduced, these prohibitions had to be withdrawn. This was done in 1995.

But the market for derivatives could not take-off since there was no regulatory framework in place to govern trading of derivatives. In 1996, the Prof LC Gupta Committee was set-up to develop a regulatory framework for derivatives trading in India. One of the major recommendations was that derivatives should be declared as securities, so that the regulatory framework for securities trading could be used for derivatives trading. This was done in 1999, when the SCRA was amended to include derivatives within the ambit of 'securities'. However, derivatives were defined to include:

a) a security derived from a debt instrument, share, loan, or any other form of security; and
b) a contract which derives its value from the prices, or index of prices, or underlying securities.

Derivatives trading then began in June 2000, initially in index futures, and then in options on indices as well as on individual securities. Trading in stock futures commenced in November 2001.

This was subsequently followed by derivatives trading in commodities, an area which has a direct impact on farmers. For example, future market prices carry signals back to farmers and help them to make sowing decisions. Thus a system of futures markets can help farmers to improve cropping patterns and production patterns based on market prices (Thomas, 2002).

1.1 Weather derivatives

Controlling weather is not something we can do very much about – however, controlling the risks to a business due to the effect of weather is possible through the use of weather derivative products.

Weather derivatives are a newer form of derivatives. The first of such contracts was signed in 1997 in the United States of America.

A financial weather contract can be defined as a “weather contingent contract whose payoff will be in an amount of cash determined by future weather events” (Dischel and Barre, 2002). The settlement value of these weather events is determined from a weather index, expressed as values of a weather variable measured at a stated location.

Across many countries there have been contracts in the form of “weather insurances” and in the form of “weather derivatives”. While weather insurance is basically a type of weather derivative – since it also derives its payoff value based on an underlying weather index, there are essential regulatory issues which differentiate the two.

From other financial derivatives, however, weather derivatives do have some major differences. The most important of these is that while the financial derivatives are used to hedge an underlying asset, weather derivatives are used in an indirect way, being used to hedge the risks associated with the underlying asset and not the asset itself. This is because weather cannot be priced. Gold derivatives could be used to hedge against fluctuations in the price of gold. But
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this can be done because gold itself is traded and has a price – and so the price of the gold derivative could be derived from the price of gold. However, since weather is not priced and is not a tradeable quantity, weather derivatives are used in an indirect way, to hedge against the risks associated with weather. However, this then leads to the difficulty in pricing weather derivatives.

The impact of weather on business activities is enormous and, obviously, varies with the business, the location and with climate change. As an example, the air-conditioning industry would be affected by a cooler-than-normal summer, in which sales would come down. Similarly geyser manufacturers would have an upswing in sales if a winter was colder than normal. Weather could affect many industries in many different ways:

- agricultural produce would be affected by the lack of rainfall
- ice-cream companies would have less sales when the summer is less severe
- air-coolers and air conditioners would sell less in a milder summer
- a construction company would have a lower availability of labour when the winter is severe / rainfall is very high

In the agricultural sector, the amount of rainfall could make a significant difference to the yield patterns. This would be even more prominent in developing countries like India, where about 60% of the agricultural produce is dependent on the rainfall.

In general, almost all businesses are either adversely or favourably affected by the weather (Figure 1.1).

![Figure 1.1. Some of the sectors/industries affected by weather.](image-url)
In the United States of America, it is estimated that about one-seventh of the economy is sensitive to weather risk (Gakos, 1999). In India, where there is a high dependence on agriculture, a significant portion of the economy would be sensitive to weather risk.

Whilst the weather poses a lot of challenges it, at the same time, throws up a lot of opportunities. Trading on the weather could help in hedging risks. Besides this, it could be an innovative product in portfolio management.

Many market makers have been entering the weather markets, and many more who are in the risk management market would be able to find value in the dynamics of the weather market. Besides swapping risks in different geographical locations in the world, holding of weather derivative contracts creates a diversity in portfolios, which most risk managers would look for. Cross trading of weather and commodities is another arena. For example, sellers of rainfall derivatives may buy futures in commodities where the lack of rainfall could result in shortages and so drive up prices. The combination of weather and related commodity risks adds depth and breadth to the weather market and is the source of innovative products in the risk management arena (Sattiah and Gunaranjan, 2005).

Upfront, it is understood that weather derivatives are essentially for hedging volume risk and not for price risk — Energy companies hedge the volume of energy demand, winter clothing manufacturers hedge the volume of woollens sold, farmers can hedge the volume of yield. Pricing and payouts therefore will necessarily have to be developed from expectations on the price based on historical data or projected data.

In the conventional form, weather derivatives contracts would have attributes, which would be similar to those for other derivatives, albeit with some modifications. There would have to be an index, which for example, could be the average rainfall over a specified period, a clearly defined contract period, a weather station, which would be used as a reference, a tick rate and a pre-decided premium. In addition, in order to restrict the maximum gain or loss, weather derivatives contracts usually have a specified upper limit.
The risk that is covered by weather derivatives includes the potential adverse impact of the weather on expected costs, revenues and cash flows. In India, most importantly, crop produce could be hedged against weather through weather derivatives.

Although initial weather derivative contracts in the US and Europe involved energy companies, slowly other businesses have started realizing the advantages of these contracts. As thought is being given to weather contingent risks, it is also being realized that cost of weather risk, if removed, can help in lowering prices and increasing sales.

One such example was the strategy adopted by Bombardier, a snow mobile manufacturer in Canada (Ladbury, 2000). In the winter of 1998, the company offered a huge rebate to its customers if a pre-decided amount of snow did not fall in the season. This guarantee was made by the company by buying weather derivatives with a snowfall index. As it happened, the snowfall that year was above the strike level decided and so the company did not receive any payout from the weather derivative. However, it more than made up for the cost of the derivative through the increased sales it had on its snowmobiles.

Some examples, which can easily be foreseen in India, would be:
(i) Winter clothing manufacturers would have a lowered sales figure if a winter season is less cold than normal.
(ii) Appu-Ghar, and similar theme parks would have a lower number of visitors and merry-makers on rainy days, or on winter days when the sun does not come out.
(iii) Builders and construction companies might have over-runs of timelines in their projects when less labourers report for work because of rain or because of excessively low temperatures in winter.
(iv) Agricultural produce in many crops, especially in un-irrigated areas, would be affected by lack of, or at times, excessive rainfall.
(v) Revenues from a cricket match would be considerably affected if rain washes out play.

The origin of weather derivatives lies in the contracts initiated by Enron in 1997, and were structured as protection against warmer or cooler than average weather. From the energy sector, this new market spread to other industrial sectors and to countries other than the US.
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The market grew rapidly and soon spread from the energy industry to other industries and from the USA to Europe and Japan. The weather derivatives market has steadily grown and now there are many companies, which have groups dedicated purely to the business of trading in weather derivatives. The Weather Risk Management Association (WRMA) has reported that weather derivatives trade in 2006 accounted for a notional value of over $45 billion. Initially the trading was over-the-counter, but slowly it spread to the Chicago Mercantile Exchange (CME), the London International Financial Futures and Options Exchange (LIFFE) and other exchanges. Today, noticeably increased volumes of trading are apparent, and these are helping in market liquidity and price discovery (Chockalingam, 2003).

Besides energy companies, the entry of banks provided a fillip to the growing demand for weather derivative contracts. From 1997, when the first recorded contract was signed, to March 2002, the total national value of all written transactions reached US$ 11.8 billion (WRMA 2002). But these were mainly concentrated in the US energy industry. ENRON, in particular had set up a weather desk, and this was instrumental in starting a weather trading market and creating liquidity (Stoppa and Hess, 2003). At one time, more than 40% of the outstanding notional value was held by ENRON. Luckily for the weather market, the collapse of ENRON did not affect the liquidity in the market. Other market players picked up the ENRON deals and it was obvious then, that the weather market had reached a critical mass, where the exit of a dominant player did not matter.

Slowly banks started entering the fray. Société Générale, Crédit Lyonnais, Deutsche Bank and ABN AMRO entered fairly early. Another fillip was given when reinsurers like Swiss RE entered the market. In time, the World Bank Group discovered the potential of the markets to absorb weather risks in emerging markets, and the first known emerging market transactions took place in South Africa and Mexico (Stoppa and Hess, 2003).

One of the first indexes developed was the Heating Degree Day (HDD) index which was used by energy producers. The HDD index could be used to hedge fluctuations in revenue based on the demand for heating. It basically is an indicator of how many days had temperatures below a baseline temperature,
and how many degrees below. In the US, the baseline temperature was taken as 65°F since this was the generally accepted temperature below which most people would require heating and so there would be an accompanying increase in demand for energy. On a particular day, the number of degrees that the average temperature of the day is below the baseline temperature determines the number of HDDs on that day.

1.2 The importance of agriculture in India

Whilst there has been a decline in the percentage of Agricultural GDP in the total GDP of India over the last three decades (Figure 1.2), there has been a substantial growth in the absolute GDP of agriculture (Figure 1.3). Agriculture is still the largest economic sector and plays a significant role in the socio-economic development of the country.
India is, today, the third largest producer of food in the world. However, inspite of the 'green revolution', agriculture witnessed a very modest 2.1% average annual growth rate during the ninth five year plan while total GDP grew at an average of 5.4% per annum (Chandrashekhar, 2004). Indian agriculture was given a fillip through the National Agricultural Policy, 2000.

The process of planned economic development in India began with the launching of the first five year plan in April 1951 (Prasad, 2006). Successive five year plans have aimed at improving inputs used by farmers including seeds, fertilizers, machinery etc. As a result, there has been a considerable increase in yield, not only of major foodgrains (Figure 1.4), but also of horticultural crops.

![Figure 1.4 Yield per hectare of wheat (all India)](Data from Ministry of Agriculture, Government of India, Indian Agriculture Statistics, 2006)

The agricultural sector occupies a key position in the Indian economy. It provides employment to about 65 percent of the working population of India (Prasad, 2006).

But of significant importance is the fact that the monsoons still play a critical role in determining whether a harvest will be good or bad – and this, in turn, determines the fate of a large number of Indian farmers whose livelihood depends on the income from their lands. Rain-fed agriculture continues to play a
major role in India even today. Even though the percentage of irrigated area vis-à-vis total sown area has increased over the years, even today, almost 60% of sown area is not irrigated and relies on rain (Figure 1.5).

Coupled with this is the fact that the productivity in India is very low as compared to the average yield in the world. This could be attributed to:

(i) Illiteracy and lack of awareness of modern techniques.
(ii) Inadequate and inefficient finance for agricultural produce.
(iii) Low level of land holdings.
(iv) Inadequate irrigation facilities.

In the last few decades, several farmers have committed suicide in various states of India. These have mostly been attributed to large debts run-up by the farmers in the face of repeated crop failures.

Amongst states, there is a significant variation in not only yield, but also in the area which is irrigated. Punjab, for example, produces 60% of India’s wheat and 40% of India’s rice. Haryana is the second largest producer of foodgrains in India.

1.3 Weather risk mitigation measures in India

Weather risk mitigation measures in India began quite some years back with the government of India offering crop insurance through the Comprehensive Crop
Insurance Scheme starting 1985. Subsequently, the CCIS was replaced by the National Agriculture Insurance Scheme which was implemented from the Rabi season of 1999-2000. However, both these schemes did not meet with much success. One of the main reasons was the primary need in the insurance to be able to prove a loss. A farmer taking an insurance had to be able to show that he had suffered a loss which could be directly attributed to the effect of weather. There was then, the accompanying paper-work and other formalities, which deterred people from going in for insurance policies. Again, such contracts cannot be used to hedge profits, which might be affected by weather-related aspects, since a ‘loss of profit’ cannot be construed as a ‘loss’ in insurance parlance.

The CCIS was offered to farmers at arbitrarily set premiums of around 1-2% while claims made were approximately 9% of the sum insured. This led to a loss of 184,446 lakhs, exclusive of administrative costs (Ifft J., 2001). As we moved on to the NAIS, the premiums were raised to around 1.5 – 3.5%. Whilst the NAIS is an improvement in many ways over the CCIS, it was once again plagued with a plethora of problems. Losses continued to be high, with claim amounts vastly overshadowing the premium collected (Figure 1.6).

The main problems of the NAIS could be summarized as:
(i) Target of achieving financial sustainability within five years of the commencement of the scheme was a daunting task.
(ii) Arbitrary premiums were fixed, which did not equal the risk levels.
NAIS has not proved to be very popular. In 2005-06, the all-India figure of farmers opting for NAIS stood at 19%, with statewise figures being as low as 1% for Uttarakhand and even lower for the North-Eastern states (www.indiastat.com).

Some satisfaction can be drawn from the fact that government crop insurance has been a failure in almost all the countries where it has been tried. On the other hand, private programmes have had better success rates. Skees,(2000) points out that one of the main reasons for the slow growth of private crop insurance is the government subsidized schemes, which tend to stifle innovation. Examples of private crop insurance schemes can be seen in the United States and South Africa in particular.

After lessons learnt from the NAIS, the Agricultural Insurance Corporation of India has, in 2004, introduced a rainfall index scheme called "Varsha Bima" – or Rainfall Insurance. In the year 2006 it was implemented across 16 states in India.

1.4 Need for a study of the prospects and challenges for weather derivatives in India

Weather derivatives are in a nascent stage the world over; no standardisation of contracts has been achieved and very few pricing mechanisms have been developed. Although some trades have been done and some thinking has gone into the rigours involved, volumes are nowhere near being comparable with other derivative products.

There has been a prolonged debate and a few experiments with these in the Indian conditions. Weather derivatives could be an effective hedge against the vagaries of weather, which could result in a lower-than-expected agricultural output. And this would be true both, at an individual farmer level, or collectively at a larger level. Once again, the same argument would hold true for many other sectors where sales and revenues earned would be weather-dependant.

An interesting and required area of research is the potential need for weather derivative products. In the initial stages, for the market to grow, there would be need for a large number of market players. Taking the agricultural sector in India as the one which could benefit the most, this could be a good starting point for research. Research into the demand for weather derivatives and willingness
to invest in such products would give an insight into the potential market and
the manner in which they could be structured. Such a study has not been done in
India, and this could possibly boost the market, while simultaneously be a feed
into regulatory and policy issues which would have to be in place as the market
takes off.

The weather derivatives market will have to understand the complex
relationships between various weather events e.g. high/low temperature,
excess/deficient rainfall or a combination of these, with losses. This could give
an insight into the appropriate time period of contracts while structuring
weather derivative products.

As the weather derivative market in India grows, there would be many players.
There would thus be a need for clear regulatory and policy directives, so as to
avoid a possible market crisis or illegal dealings, which might, in turn have
negative fall-outs on investors in these derivatives. This is another interesting
area of research.

1.4.1 Need for an empirical study of willingness to pay

India has experimented with the crop insurance programme for many years.
Whilst most of the schemes have been government programmes, a few private
players have ventured into the field. However, the primary question has been of
not just what an Indian farmer is able to pay, but also of what he is willing to
pay. Unfortunately, most debates start with an assumption that a farmer would
not be able to pay for hedging his yield, and so the government would
necessarily have to subsidise any scheme that is floated.

An empirical study into farmers’ willingness to pay for a weather derivative
would give the required insight into the structuring of such products, whether
such products can be introduced without any government subsidy, as has been
the case with all crop insurance thus-far, and the viability of private players
coming up with innovative hedging products for farmers.

1.5 Outline of the thesis

The thesis is organised in 11 chapters. After a study of existing literature in
Chapter 2, the research methodology and the objectives of the study are brought
out in Chapter 3. Chapter 4 brings out a theoretical analysis of farmers’
willingness to pay based on his expected utility. The theoretical model is used
along with historical data, to derive a theoretical willingness to pay in the case of farmers growing soyabean in Jhalawar district of Rajasthan. This sets the pace for the survey which was carried out in two districts of Rajasthan – Jhalawar and Tonk. An important aspect of 'basis risk' necessarily plays a role in hedging through weather derivatives. A clear understanding of the intensity of this factor is brought out in Chapter 5, through a study of rainfall data from two nearby weather stations. Chapter 6 elucidates the scope of the survey, which was carried out, and the methodology adopted for the study. An analysis of the data and the results obtained are given in Chapter 7 of this thesis. We move on to a study of the regulatory issues relevant to the introduction of weather derivatives in India, in Chapter 8. The valuation and pricing of weather derivatives warrants attention. The modalities for a naïve pricing method are brought out in Chapter 9. A summary of the findings and the recommendations of the research are given in Chapter 10. The final chapter lists the bibliography for the thesis.

A detailed study of the relevant literature is given in the ensuing chapter.