Orissa Journal of Commerce
Vol. 45, Issue 4, October-December 2024
ISSN: 0974-8482

URL: www.ojcoca.org
DOI: https://doi.org/10.54063/ojc.2024.v45i04.02

A Study on Feasibility of Rainfall Derivatives to Hedge Rainfall Risk in Coastal Districts of Odisha

Arundhati Mahapatra[1*], Gouri Prava Samal[2]

[1*&2]*Department of Commerce, Rama Devi Women's University, Odisha, India*

[*]*Corresponding Author*

To cite this paper
Mahapatra, A., & Samal, G. P., (2024). A Study on Feasibility of Rainfall Derivatives to Hedge Rainfall Risk in Coastal Districts of Odisha. Orissa Journal of Commerce. 45(4), 11-26.

Keywords
Rainfall Index, Rainfall Derivatives, Asset Class, Volatility, Hedge Effectiveness

JEL Classification
G10, G12, G23, Q54

Abstract: India's monsoon vulnerability exposes its agriculture and industry to significant rainfall risk. The plethora of insurance schemes introduced by the Indian Government to reduce this risk have also failed to deliver. Rainfall derivatives offer a potential hedging solution, as successfully implemented in Western nations. This study investigates the potential of a Rainfall Index (RFI) for trading rainfall derivatives, utilizing daily rainfall data spanning over 15-year period (2008-2022), sourced from four coastal districts of Odisha: Balasore, Ganjam, Puri, and Jagatsinghpur. The analysis focuses on assessing the volatility inherent in the constructed RFI, derived from the observed rainfall patterns. Being a vital input for investment and financial market regulation, the RFI was compared with that of established asset classes – BSE SENSEX, NSE Nifty 50, and Nifty G-Sec, using Pearson's correlation analysis. The results validated that RFI has the potential for being classified as a distinct asset class. Furthermore, the study assesses the hedge effectiveness of rainfall derivatives through a literature-based review, demonstrating their feasibility as a low-cost, adaptable, and sustainable risk management strategy for the Indian economy. By offering a tool to control rainfall-related exposure, these derivatives can enhance planning, minimize volatility, and hedge against losses, thus making them a desirable choice for investors seeking to weather the storms with financial instruments.

1. Introduction

India's 7,500-km of coastline and reliance on the monsoon makes it extremely vulnerable to climate change (Gupta et al., 2022). The monsoon months from June to September bring 3/4th of India's annual rainfall (RBI, 2019). Odisha, one of the states of India (Government of Odisha), has a coastline comprising seven districts- Ganjam, Khordha, Puri, Jagatsinghpur, Kendrapara, Bhadrak and Balasore (Odisha Coastal Zone Management Authority). Coastal Odisha generally receive copious rainfall compared to the rest of the state (Gouda et al., 2017). In coastal regions, the rainfall is ordinarily backed by the low-pressure system during southwest monsoon season (June-September), tropical cyclone in pre-monsoon (March-May) and post-monsoon (October- November) period (Kankara et al., 2018). A large amount of monsoon rainfall over Odisha is mainly contributed by July and August months (Swain et al., 2018). The coastal part of the state is frequently affected by natural disaster like flood and cyclone almost every year (Patnaik et al., 2013). Weather conditions can be extreme and can cause natural disasters. However, the most frequent weather risk is linked to normal, non-catastrophic high-probability weather events (Bartkowiak, 2009). This rainfall risk can be hedged proportionately using rainfall derivatives.

Numerous instruments have been developed and used in the past, whenever risk of some type is to be hedged. For safeguarding against financial loss of some kind, several instruments have been used for hedging. One among them is derivatives. A derivative is defined as a product whose value rests on the

risk factors of one or more assets. These instruments can be used for protection against likely adverse market movements through offsetting exposures or shifting risks. They are predominantly worthwhile during times of volatility. Indian monsoon offers a huge prospect for designing rainfall derivatives for hedging the risk of rainfall. However, hedgers and speculators can take part lawfully in monsoon rainfall trading only when definite amendments have been ratified in the Forward Contract Regulation Act (Kotreshwar, 2014).
The rainfall risk market ecosystem is half-done in the absence of rainfall derivatives markets that would enable hedging rainfall risk by wide-ranging stakeholders. The expansion of such markets necessitates intricate research and regulatory backing. Given the increasing variability in rainfall patterns and the systemic nature of rainfall-related risks, there is a need for innovative financial instruments to hedge such uncertainties. While rainfall derivatives have gained attention globally, their adoption in India remains limited due to challenges in designing effective indices and trading frameworks. This study is significant as it explores the feasibility of introducing rainfall derivatives by constructing a Rainfall Index (RFI) tailored to local rainfall patterns. By doing so, it contributes to the development of a localized risk management tool and provides a foundation for further research and policy formulation in weather-based financial instruments. Considering the great opportunity that these instruments represent, rainfall derivatives can be a pioneering product in the market with significant potential to generate a sustainable rainfall risk hedging market by reforming the widespread speculative tendencies linked to the monsoon.

2. Review of Literature

Bharath & Kotreshwar (2022) implemented a distinctive method of designing the RFI formed on a projected metrics that is Deficit Rainfall Days/Excess Rainfall Days (DRD/ERD) index, which can be exercised as a component for designing rainfall derivatives alike Cooling Degree Days/Heating Degree Days (CDDs/HDDs) implicit in temperature derivatives. DRD/ERD figures were calculated for thirty-six meteorological subdivisions (MSDs) of India. The simple rainfall futures contract structure was clearly described, and it was analyzed in what way they could be useful to hedge the rainfall risk.

Bharath and Kotreshwar (2020) recommended a fresh lot of indices for assessing excess rainfall risk profiles that are designated as ERDs. Empirical figures of ERDs for 50 years of carefully chosen MSDs of India were obtained, and such index values were evaluated in defining the degree of volatility and variability, accompanied by the investigation of the degree of interrelationship between indices of chosen MSDs. The study was formulated on the use of econometric models like the Augmented Dickey Fuller (ADF) test succeeded by the Generalized Auto Regressive Conditional Heteroskedasticity (GARCH) model. The outcomes showed that numerous statistical properties of ERD indices back the impression that these indices can be exercised as a component for designing rainfall derivatives.

Noven et al. (2015) proposed a parsimonious stochastic model for characterizing the temporal and distributional properties of rainfall. The model was centered on a unified Ornstein-Uhlenbeck method activated by Hougaard Levy method. The model was demonstrated by adjusting it to empirical rainfall data on both hourly and daily time span. It was revealed that the model was amply compliant to pick up significant characteristics of the rainfall practice across places and time span. The authors also studied an appeal to setting the price of rainfall derivatives that introduced the market price of risk by the means of Esscher transform.

Hong and Sohn (2013) conducted a study for introducing weather derivatives for Seoul, Korea. Peer group analysis was used by the authors to introduce the same. Additionally, they used historical weather data from Seoul and its peer cities to offer a straightforward pricing strategy for the weather derivative. They determined ‘Seoul’s Weather Index’. According to the findings, monthly CDD futures, Seasonal CDD strips, monthly HDD futures and Seasonal HDD strips are reasonable to be introduced to Seoul. However, since less than half of the five peer cities utilize them, Seoul shouldn't be exposed to CAT futures and seasonal strips, and Rainfall futures and seasonal strips.

Geyser (2004) evaluated the benefits of rainfall options and proposed an option strategy as a yield risk management tool in order to determine whether rainfall derivatives might be used to manage agricultural output risk in South Africa. The study concluded that farmers might gain significantly from the use of weather derivatives to control production risk in South African agricultural markets.

Paulson et al. (2010) addressed the issue of historical data availability in designing actuarially sound weather-based instruments. Using observed historical data, a Bayesian rainfall model was constructed that makes use of Markov chain Monte Carlo and spatial kriging techniques to estimate rainfall histories. A substantial data set from Iowa was used to verify the applicability of the estimation method. The results from the historical analysis showed that even in Iowa's very homogeneous region, the systemic character of weather risk can change significantly over time.

Goetzmann and Zhu (2005) used a databank of individual investor accounts to study the effects of weather on traders. Their investigation of the trading activity in five chief US cities over a 6-year period found almost no variance in individuals' susceptibility to sell or buy equities on cloudy days in contrast to sunny days. NYSE ranges expand on cloudy days. When this is controlled, the weather effect turns out to be less significant and smaller. The authors interpreted this as proof that the conduct of market makers, in lieu of individual investors, may be accountable for the relationship among returns and weather.

Lennep et al. (2004) found that non-standardized contracts work as a greater efficient risk transfer mechanism than standardized contracts do. The study also revealed that including weather derivatives in a conventional portfolio boosts the performance of the portfolio while maintaining a low standard deviation. It was concluded that, by identifying that incorporating weather derivatives will improve the performance of conventional portfolios, organizations can repackage those non-standardized contracts and offer them as a unique asset class to be contained within a conventional portfolio.

Chiang (2004) developed a model to price weather derivatives for ice wine producers in Ontario and assessed the economic feasibility of offering such a weather derivative product. The study found that weather derivatives are potentially very applicable for ice wine makers. In order to mitigate the risks that agricultural producers face, it can be a helpful financial tool.

Cao et al. (2003) presented a brief survey of the market, described the key products, and illustrated their treatment in risk management. They also discussed the important problems in modeling and valuation. As a final point, considering weather derivatives as a unique asset class, the authors demonstrated their potentiality in asset allocation and portfolio management. It was concluded that as a unique class of financial instrument, weather derivatives can increase the risk return trade off in asset allocation strategies.

From the literature above it is evident that rainfall derivatives are at a very starting stage in this world. Some trading has been started for these products in other parts of the world and some people are doing tedious research in this field, but the trading volume is very less as compared to other derivative products. Western countries like USA, Canada, Europe, Japan, and Australia have depended on rainfall derivatives to hedge rainfall risk (Ritter et al., 2012). There has been a lot of debate going on if rainfall derivative will work in Indian context. Rainfall derivatives can be a very useful tool in case of volatile monsoon conditions. This study can help to boost the market and give necessary recommendations to change the regulatory framework to introduce rainfall derivatives in India. A perception-based study conducted among stakeholders in Odisha reflected encouraging support (Mean = 3.71) on the need to explore the potential of rainfall derivatives as a distinct asset class (Mahapatra & Samal, 2024), underscoring the practical relevance and urgency of such an investigation. This support reflects a strong foundation for advancing discussions on the potential of rainfall derivatives, emphasizing the need for targeted interventions in Odisha to explore their feasibility, which could then be scaled across India.

3. Objectives and Hypothesis of the Study

3.1 Objectives of the Study

1. To discover the potential of the Rainfall Index as a distinct asset class.
2. To examine the effectiveness of using rainfall derivatives for hedging rainfall risk.

3.2 Hypotheses of the Study

These hypotheses are formulated to address the first objective of the study.
H_0: Rainfall Index is not potentially a distinct asset class.
H_1: Rainfall Index is potentially a distinct asset class.

4. Research Methodology

Based on the two objectives of the study, the methodology is also categorized into two parts: one focusing on the potential of the RFI as a distinct asset class, and the other examining the effectiveness of using rainfall derivatives for hedging rainfall risk.

4.1 To Discover the Potential of RFI As a Distinct Asset Class

Sampling frame: Rainfall data (in mm.) of coastal region of Odisha.

Sample Size: Historical daily data of rainfall of south-west monsoon season (June to September) is collected for 4 districts of coastal region of Odisha i.e., Balasore, Ganjam, Puri and Jagatsinghpur. These districts were selected as they are hotspots of rainfall in the coastal region of Odisha, experiencing significant variations in rainfall patterns during the southwest monsoon season.

Data collection Source: Daily rainfall data has been obtained for the past 15 years (2008-2022) from the website of Odisha Weather Monitoring System (OWMS). Existing literature and online resources served as the foundation for this paper. The study is based entirely on secondary data, including government reports, research publications, and credible online sources such as the official websites of NSE and BSE.

Research Tools: Rainfall volatility will be computed by using Standard Deviation (SD) and Coefficient of Variation (CV). Relative risk can be effectively measured using CV. CVs are only reported for complete datasets spanning 15 years or more. Currently, the CV measurements serve as the standard for risk reduction (Skees et al., 2001). This implies that efforts to mitigate risk are guided by an understanding of the variability in the data, as captured by the CV. While CV itself does not directly reduce risk, it plays a critical role in assessing the extent of variability, which is crucial for identifying areas of potential risk and guiding efforts to mitigate those risks effectively. Special care is taken in this study to develop RFI for Coastal Odisha that will reduce relative risk associated with rainfall variability in the region. The formula for calculation of RFI is adapted from a previous study (Singh & Vashisht, 2020). Further, Pearson's Correlation analysis will be carried out to determine the relationship with respect to movement of various indices and RFI figures. The descriptive statistics regarding volatility of indices of diverse asset classes are also calculated.

4.2 Literature-Based Review for the Hedge Effectiveness of Rainfall Derivatives

To address the second objective regarding the hedge effectiveness of rainfall derivatives, this section presents a literature-based conceptual review. The review synthesizes key insights from scholarly literature to assess how weather derivatives, particularly rainfall-based instruments, have been used or proposed for managing weather-related agricultural risks. It reviews and discusses the effectiveness of weather derivatives in hedging weather risks and introduces them as a novel tool for weather risk management. In order to accomplish this goal, relevant literature was primarily sourced from the Scopus database using targeted keyword searches. Citations are utilized to determine the field structure and the major trends in this field (Niñerola et al., 2019). Our search for an integrated review took into account pertinent research articles that were available in the field because we relaxed the publication year restrictions (Gairola & Dey, 2023). The following primary keywords were used to choose the publications: “weather derivatives,” “rainfall derivatives,” “climate derivatives,” “precipitation derivatives,” “hedging effectiveness,” and “hedging efficiency.” These keywords were combined to extract the papers from the SCOPUS database of Elsevier. The search was limited to English-language journal articles, and excluded other types of documents such as conference proceedings or editorials.

In addition, Google Scholar was used as a supplementary tool to explore broader academic contributions on the topic. However, its use was limited due to the lack of field-specific filtering and quality assurance (Giustini & Maged Boulos, 2013). It searches the full text by default and offers limited control over refining search results by specific metadata fields (Wageningen University & Research). Because of the greater coverage it offers, some of the items are not comparable to those found in other similar databases (Aguillo, 2011). Therefore, to maintain the relevance and quality of the literature reviewed, Scopus was the principal database used for identifying scholarly work related to weather and rainfall derivatives. However, Google Scholar is an effective resource for academic literature (Halevi et al., 2017). Despite its inadequacies, Google Scholar should still be employed in systematic reviews (Mastrangelo et al., 2010). Therefore, this study also cites papers from the same.

This review will help conceptualize rainfall derivatives as a tool for rainfall risk management and provide evidence supporting their feasibility. A summary of the literature on weather derivatives is also given in the paper, but the most significant contribution is the identification of development trends and avenues that can be used to guide future research efforts. The objective is to synthesize the body of written research findings into a user-friendly style so that interested parties may easily comprehend weather derivatives and their effectiveness in mitigating rainfall risk.

5. Data Analysis, Results & Discussion

Although the presence of a RFI is important to support the development of hedging contracts, a key limitation in the Indian context is that RFI-based contracts are not actively traded, despite the existence of commodity trading platforms. Pilot initiatives by the National Commodity & Derivatives Exchange (NCDEX) and the Multi Commodity Exchange (MCX) explored the use of RFIs, but these were not designed for open market trading. Instead, the RFIs functioned primarily as reference indices to determine deviations from normal rainfall and to trigger payouts under weather-based insurance schemes (Shivkumar & Kotreshwar , 2013).

Here an effort is made to advance an overall structure for visualizing RFI-based risk transfer product estimated from the rainfall data of coastal region of Odisha. A standardized approach to rainfall indexation has not yet been developed. To address this gap, the present study employs a methodology for calculating a RFI that has been previously utilized in earlier research (Singh & Vashisht, 2020). The rainfall indexation considered in the study is diverse in outlook of expansion of risk transfer products designed for capital market. It is suggested to identify the index by means of ticker symbol, RFI that will lay the foundation of rainfall derivatives. RFI for a definite location is ascertained as:

$$RFI = \frac{\sum r_{it}}{\sum R_{it}} \times Scale\ Value$$

Where,
r_{it} denotes actual rainfall of ith day of the tth season;
R_{it} denotes cumulative average of daily rainfall of ith day of the tth season;
Scale or multiplier value was assumed 1000 (rainfall is stated equivalent to 1/1000th of a meter, i.e., in millimeter).
RFI specifies how much % of cumulative normal anticipated rainfall is realized. A higher RFI value means that the actual rainfall has exceeded the cumulative average rainfall up to that point (Bharath &

Kotreshwar, 2022). According to Equation (1), RFI values have been calculated for the four coastal districts of Odisha for each of the four monsoon months, as shown in Table 1.

Table 1. RFI for the coastal districts for 15 years (2008-2022) using historical daily rainfall data

Year	June	July	August	September
2008	1296.71	1362.17	903.06	1243.33
2009	1133.40	995.62	1300.00	928.40
2010	2494.46	958.05	779.03	1147.72
2011	1536.03	901.88	1038.17	627.74
2012	1729.03	1016.43	1124.86	709.70
2013	1620.01	1645.02	1147.70	1113.44
2014	1716.76	1144.00	896.36	564.43
2015	1590.02	1597.68	1392.20	953.40
2016	1476.35	972.61	710.10	1052.11
2017	1509.66	1097.75	1056.23	898.99
2018	1706.59	1319.74	996.09	809.15
2019	1324.81	959.67	1009.42	1083.67
2020	1104.99	924.24	1108.77	1317.00
2021	1215.17	1269.46	1530.87	1103.57
2022	1791.39	954.84	973.73	1215.65

Source: Calculated based on secondary data collected from OWMS

Statistical properties of RFI for the 4 coastal districts of Odisha are available in Table 2.

Table 2. Statistics of RFI values for June-Sep for 15 years rainfall data

	June	July	August	September
Mean	1549.69	1141.28	1064.44	984.55
SD	342.99	243.78	218.93	227.45
CV	22.13%	21.36%	20.57%	23.10%

Source: Calculated based on secondary data collected from OWMS

Table 2 shows descriptive statistics such as mean, standard deviation (SD) and coefficient of variance (CV) for RFI values individually for the 4 monsoon months starting 2008 till 2022 of rainfall data intended for the 4 districts of coastal Odisha.

The CV of RFI for all the 4 monsoon months i.e., June, July, August, and September ranges between 20 to 25%. While the CV for September RFI is the highest at 23.10%. It is also clear from the table that volatility decreases from the month June to August but increases in September. A moderate CV suggests that RFI exhibits variability that is sufficient to reflect changes in rainfall patterns without being excessively volatile. This is significant for rainfall derivatives, as extreme fluctuations in variability might deter risk managers and investors who are seeking reliable products to hedge against weather risks. Conversely, low variability might not adequately capture the risk involved, making such a product less useful for weather-based risk management. The moderate CV observed in the data for the coastal region of Odisha strikes a balance, offering predictability while still capturing enough variability to be useful for hedging purposes. This level of variability suggests that RFI could be attractive for rainfall-based financial products, as it offers a stable but sufficiently responsive indicator of rainfall changes. Thus, the moderate CV is considered a pragmatic indicator of RFI's potential as a weather-related financial instrument.

5.1 Potential of RFI As an Asset Class

Volatility is the base for index trading. It is one way of measuring an index's risk (Theron & Vuuren, 2018). Maximum index trades depend greatly on volatility statistics. Volatility plays a crucial role in asset pricing as it leads to alterations in the financial assets risk (Sharma, 2021). Therefore, this study tries to discover the potential of RFI as an asset class as compared to other tradable indices. An investigation of statistical properties of RFI indicates that RFI could be a prospective instrument for speculation as well as hedging. RFI would be an exceptional speculation tool as well. To gain some idea about the statistical properties of diverse asset class indices – equity, fixed income and proposed RFI, an investigation is conducted. For this study, popular equity indices—BSE SENSEX and NSE Nifty 50, and the fixed income security index, Nifty Government Security Index (Nifty G-Sec), have been considered. The analysis for the period of 2008-2022 is carried out taking these indices. Table 3 shows the index values for June, July, August, and September month for 2008-2022.

Table 3. Indices of various asset classes for 15 years (2008-2022)

Year	Nifty GS	Nifty 50	Sensex	RFI
2008	848.89	4303.05	14344.6	1201.31
2009	981.40	4552.47	15292.70	1089.36
2010	979.83	5454.06	18169.33	1344.81
2011	1013.33	5290.39	17606.91	1025.96
2012	1097.85	5277.80	17414.13	1145.00
2013	1177.11	5749.81	19276.91	1381.55
2014	1202.10	7765.12	25979.69	1080.39
2015	1348.07	8199.99	27061.43	1383.32
2016	1496.14	8530.14	27735.15	1052.79
2017	1652.97	9834.04	31670.91	1140.66
2018	1598.19	11132.41	36817.64	1207.89
2019	1831.21	11365.73	38220.69	1094.39
2020	1988.54	10917.36	37004.77	1113.75
2021	2054.00	16373.96	54778.10	1279.76
2022	2010.72	16839.03	56499.41	1233.90

Source: Calculated based on secondary data collected from NSE, BSE and OWMS

Table 4. Statistics of indices of various asset classes for the period (2008-2022)

	Nifty GS	Nifty 50	Sensex	RFI
Mean	1418.69	8772.36	29191.49	1184.99
SD	416.46	4004.86	13444.47	118.13
CV	29.36%	45.65%	46.06%	9.97%

Source: Calculated based on secondary data collected from NSE, BSE and OWMS

In Table 4, the mean, standard deviation, and CV (%) of all the indices has been calculated for June, July, August, and September month for the period 2008-2022. As compared to other indices, the CV (%) of RFI is lower and indicates lower volatility of this index. Low volatility is when an asset does not fluctuate dramatically, but changes at a steady pace over a period (Jones). One of the significant parameters to estimate an index is volatility. Volatility mechanism works both ways. When volatility is low, it marks an index safer and lower on risk scale. But it also proportionally shrinks the chances for creating profits. The past achievements of diverse asset classes in the long run are certainly stable with the criterion that higher risk generates higher rewards. On the other hand, many academic studies along with historic back tests of low volatility indices specify that portfolios contained entirely of low volatility indices have a habit to outdo portfolios of high volatility indices in the long run (Joshipura & Joshipura, 2019). This circumstance is generally inferred to indicate that low volatility stocks have higher returns, on average (Banner, 2012). Hence, though RFI has comparatively low volatility, it does have the potential to be traded.

The variation in volatility of these indices gives chances to portfolio diversification to reduce this volatility. To check the chances of portfolio diversification, the correlation analysis among these indices is conducted.

5.1.1. Pearson's Correlation Analysis

Table 5. Pearson's Correlation analysis of various asset classes with RFI for years 2008-2022

		Nifty GS	Nifty 50	Sensex	RFI
Nifty GS	Pearson Correlation	1	.939**	.938**	-.007
	Sig. (2-tailed)		.000	.000	.982
	N	15	15	15	15
Nifty 50	Pearson Correlation	.939**	1	.999**	.099
	Sig. (2-tailed)	.000		.000	.725
	N	15	15	15	15
Sensex	Pearson Correlation	.938**	.999**	1	.101
	Sig. (2-tailed)	.000	.000		.720
	N	15	15	15	15
RFI	Pearson Correlation	-.007	.099	.101	1
	Sig. (2-tailed)	.982	.725	.720	
	N	15	15	15	15
**. Correlation is significant at the 0.01 level (2-tailed).					

Source: Secondary data collected from NSE, BSE and OWMS

The Pearson's Correlation analysis in Table 5 reveals a strong positive co-movement between Nifty GS, Nifty 50, and Sensex, all statistically significant at the 0.01 level. However, RFI exhibits a very weak and statistically insignificant correlation with these three indices. This distinct behavior implies that RFI could indeed represent a distinct and unique asset class, potentially driven by its own specific underlying factors and market dynamics. As a result of this, RFI can be introduced on an exchange as it has the potential to be a tradable asset class. Furthermore, in line with earlier research, our work has shown potential for introducing RFI-based weather derivatives. The outcomes further validate the potential of RFI as a new asset class to be included in a portfolio for risk hedging (Shivkumar & Kotreshwar , 2013). This suggests that RFI will be an innovative and useful tool for risk hedging. It will appeal to both hedgers and speculators to trade RFI futures and options.

Therefore, the null hypothesis (H_0) i.e., *Rainfall Index is not potentially a distinct asset class* is rejected and the alternative hypothesis (H_1) i.e., *Rainfall Index is potentially a distinct asset class* is accepted.

5.2 Hedge Effectiveness of Rainfall Derivatives: A Literature-Based Review

This section addresses the second objective of the study. The review draws upon published research to understand how weather derivatives—particularly rainfall-based ones, perform as risk-hedging instruments. A comprehensive analysis of the literatures on hedge effectiveness of weather derivatives indicates that there is still a dearth of information, especially in this field. Another name for a financial weather derivative contract is a weather contingent contract, with a cash payout reliant on future weather events. A weather index, which is represented as values of a weather variable measured at a specific location, is used to calculate the settlement value of various weather events (Dischel & Barrieu, 2002). Weather derivatives are regarded as a more effective, affordable, and long-term alternative risk management approach. Because of its many benefits, weather derivative contracts are used in several developing nations in addition to industrialized ones. There are several different levels of initiatives underway on the state of weather derivative contracts in India. On March 1, 2024, the Department of Economic Affairs through Union Ministry of Finance published a notification to add weather to the list of commodities (Securities and Exchange Board of India (SEBI), 2024). This inclusion was noted in the Union Budget 2024–25 speech by Finance Minister Nirmala Sitharaman. The recognition of weather as a commodity is seen as a significant step towards enabling such financial instruments. While NCDEX has already finalized plans for such instruments, their launch awaits final government clearance. Since present restrictions prohibit trading in instruments that cannot be delivered in physical form, certain revisions to the Securities Contract Regulation Act and the Forward Contract Regulation Act are necessary (Sharma & Vashishtha, 2007). Remarking on the efficacy of these items as a risk-hedging strategy would be premature, given they are still in the early stages of development and adoption. Nevertheless, there is ample empirical proof that weather derivatives are successfully used across the world.

Weather derivatives are more advantageous than regular insurances, although the market for these products is still quite small. A growing body of literature explores the potential benefits of weather derivatives as a tool for risk management. Hedge effectiveness may increase if the hedger is able to use temperature and rainfall derivatives together (Woodard & Garcia, 2008). The hedging effectiveness of weather index-based insurance can be improved by combining various weather factors (Vedenov & Barnett, 2004). When minimizing variance is the goal, there is no discernible difference in the hedge effectiveness of call, put, and futures. On the other hand, put options perform significantly better when the hedger's goal is to minimize semi-variance because the hedger receives a risk premium when it sells the put option for hedging. (Zhou et al., 2016). Conventional risk-hedging methods and instruments have not only proven expensive and ineffective in India, but they have also become a burden on the nation's finances. They primarily provide a hedge against price risk alone. Being more severe and heavily dependent on the weather, the volume-related risk is still essentially uninsured. Within an economy such as India, controlling the volume-related weather risk may be more flexible, cost-effective, and long-term if a suitable weather-based derivative contract structure is in place. A versatile management approach for the non-catastrophic weather risk is offered by weather derivatives (Stulec et al., 2016).

Hedging against income fluctuations caused by weather-related events is the goal of employing weather derivatives. The degree of income stabilization is also known as risk reduction potential or hedging effectiveness (Pelka & Musshoff, 2013). The contract design which includes the tick size, strike level, and index controls the hedging effectiveness (Musshoff et al., 2011). The benefits to costs ratio determine the prospective demand for a weather derivative. Simple index-based derivatives with poor efficacy resulted in a decreased willingness to pay. Nevertheless, they can also be offered at a lesser cost due to their reduced transaction costs. Therefore, we cannot automatically draw the conclusion that weather derivatives with a low hedging effectiveness are 'inapplicable' or that they lack trading potential (Musshoff et al., 2011). Hence, weather derivatives have a lot of potential to develop into a new asset class that allows investors to diversify their portfolios, much like other contracts with exotic underlying (Brockett et al., 2005).

Table 6. Summary of Literature Review on Hedging Effectiveness of Weather Derivatives

Author (Year of study)	**Market under study**	**Symbols**	**Sample Period**	**Methodology**	**Hedging effectiveness**
Stoppa & Hess (2003)	Morocco	Rainfall index derivative	1978- 2001	Optimization process	Risk associated with agricultural production can be effectively managed with weather derivatives.
Brockett, Wang & Yang (2005)	U.S.	HDDs and CDD	1979-2002	Simulation	When it comes to achieving the goal of risk minimization, linear basis hedging outperforms nonlinear basis hedging by a wide margin. Additionally, basis hedging typically works better in the winter than in the summer.
Woodard & Garcia (2008)	U.S.	Temperature & precipitation derivatives	1971-2005	Sensitivity analysis	Temperature contracts are more effective than precipitation derivatives. Higher levels of spatial aggregation proved to be more

					successful for weather hedges, suggesting that re/insurers rather than individual producers will be the most likely end-users.
Yang & Brockett & Wen (2009)	U.S.	HDD & CDD indexed standardized weather derivatives	1.1.1979-30.4.2002	Regression models	The standardized weather derivatives written on the Risk Management Solutions (RMS), or Chicago Mercantile Exchange (CME) indexes provide a very effective hedge.
Musshoff, Odening, & Xu (2011)	North-east Germany	Rainfall options	1993-2006	Stochastic simulation	The hedging effectiveness of rainfall options as a hedge is highly influenced by the basis risk.
Pelka & Musshoff (2013)	Central Germany	Temperature & precipitation-based weather derivatives	1995 - 2009	Bootstrapping method, t-test	In comparison to a mixed index, where the weather variables are measured at different weather stations, the hedging effectiveness of using several weather derivatives at the same time based on a basic index of only one weather variable is substantially higher.
Pelka & Musshoff (2014)	China	Precipitation index-based insurance	1980-2009	Burn Analysis, Regression Analysis, Standard Deviation (SD) Value at Risk	In certain provinces in China, precipitation index-based insurances can make a significant contribution to the stabilization of agricultural income.
Zhou, Li & Pai (2016)	U.S.	Temperature derivatives	1.1.1970-31.12.2007	Stochastic temperature model, Crop yield model, Risk-neutral pricing method, profit optimization procedure	Higher hedging effectiveness is achieved by reducing idiosyncratic risk through the large-scale spatial aggregation of corn yields.
Salgueiro & Tarrazon-Rodon (2019)	Spain	Temperature and rainfall-based options	1971-2011	Index value Simulation & Daily Simulation Techniques, Root mean square error	As a way to reduce basis risk exposure, the results obtained highlight the significant hedging potential and the appropriateness of taking into account a mix of options targeted to adjacent stations.
Raucci, Lanna, Silveira & Capitani (2019)	Brazil	European put options with rainfall index	1992-2016	Index modeling method, Monte Carlo simulations	The producers' income volatility was significantly decreased by the adoption of weather-based derivatives.

Source: Authors' compilation

According to the review, rainfall-based indices were most commonly used in the context of weather derivatives, and could be found in four different forms: average, cumulative, surplus, and deficit. Amongst this cumulative rainfall was the most common (Abdi et al., 2022). RFI-based derivatives must be launched to complete the rainfall risk market and properly hedge rainfall risk (Dileep, 2022). The evidence from multiple empirical studies demonstrating the effectiveness of weather derivatives only serves to support their implementation in any nation, especially one where the weather is extremely irregular and unpredictable (Sharma & Vashishtha, 2007). It is possible that not all nations have the same prerequisites for the weather derivative market to succeed. Regarding the Indian economy, however, it seems to be a generally quite good fit for the implementation of weather derivatives. Furthermore, it is reasonable to anticipate that the current trend of the Indian financial sector's integration with the international market will help the derivatives market succeed in terms of attracting foreign players and boosting competition. Due to their affordability, adaptability, and sustainability, weather derivatives are drawing more and more attention from risk managers worldwide (Choksi, 2012). It is worthy of being tried in India as well.

However, having understood how hedge effectiveness measures the reduction in risk, it is crucial to examine the factors that can limit this effectiveness. One of the most significant factors is basis risk.

5.1.2. Basis Risk

Under these kinds of contracts, one significant constraint relates to what is called as basis risk. This is dependent upon the degree of positive correlation between the insured's losses and the index. If the insured suffers a loss and is not compensated by the insurer for the loss or if a payment larger than the loss is made available, basis risk may arise. This is the result of the contract's indemnities being triggered by the weather event rather than by actual producer yields (Spaulding et al., 2010). The moral hazard and adverse selection issues underlying traditional insurance are intended to be resolved with rainfall derivatives. However, one problem with a rainfall derivative is that it has basis risk. When there is a discrepancy between the spot price and the futures price in financial derivatives, basis risk typically appears. However, three situations lead to basis risk in rainfall derivatives.

1. It happens when the recorded rainfall and the actual rainfall in a particular location do not perfectly correlate.
2. The absence of rain gauge places registered in the exchange gives rise to basis risk in over-the-counter trading.
3. It happens where recorded rainfall in a particular location differs slightly from the underlying rainfall value used as the basis for the RFI-based futures contract.

A higher level of basis risk emerges if there is a significant difference between the actual and recorded rainfall. Therefore, when hedging the rainfall risk, the hedger needs to be mindful of basis risk. To reduce the basis risk, more and more rain gauge stations can be constructed to collect rainfall data. The effectiveness of rainfall derivatives as a hedge is increased by lower basis risk (Dileep & Kotreshwar, 2023).

When employing standardized contracts for hedging, basis risk is a significant consideration. Hedgers that use standardized weather derivatives for hedging are exposed to basis risk as well as the risk arising from a weather contract drafted in a location other than the area they want to cover. Participants who want to control their weather exposures in places not listed by exchanges are exposed to basis risk (Considine, 2000). The existence of risk premiums can considerably reduce the hedging effectiveness of weather hedges. Furthermore, geographic basis risk becomes less of a barrier to effective hedging as the level of spatial aggregation rises. It has been discovered that precipitation hedges increase product basis risk. Hedgers must assume both the basis risk and the credit risk when trading over the counter in standardized weather contracts (Brockett et al., 2005). The creation of weather derivatives based on rainfall indices requires careful consideration of the basis risk. This is because the area under consideration has a variety of edaphoclimatic formations (Raucci et al., 2019).

Thus far, basis risk in weather derivatives has been overlooked a lot. Nonetheless, the argument made in this research is that the market for weather derivatives accepts weather derivatives more widely when basis risk is considered. In this regard, it is crucial for all market participants to accurately evaluate the basis risk for a weather hedge. When using exchange-traded instruments as a hedge for a local business risk, basis risk might escalate to a critical point. Conversely, reinsurance treaties may be replaced with exchange-based instruments (Rohrer, 2004). Therefore, a transparent information policy regarding the basis risk of weather derivatives is critical to the continued viability of these products.

6. Conclusion

Rainfall derivatives are financial instruments which an investor uses to hedge risks associated with rainfall fluctuation (Berhane et al., 2020). The use of rainfall derivatives in the Indian setting has been the subject of a protracted discussion. The design of RFI-based derivatives and other essential concerns for trading rainfall derivatives were not the main focus in previous studies. Thus, this work fills this research gap. This study computed the RFI based on rainfall data collected and maintained by the OWMS. The index mirrors the amount of rainfall received in comparison to the long-term average for a definite area and timespan. The study takes into consideration the four aforementioned coastal districts of Odisha due to the different rainfall patterns prevailing there. To bring up rainfall derivatives in the Indian market we require an appropriate RFI that can be categorized as a distinct asset class. Hence, in this study RFI was calculated at the state level for coastal districts of Odisha using the formula from earlier researches, and the results have proved that RFI can be a distinct asset class and it can be considered as a useful index for trading rainfall derivatives. This is consistent with earlier research that claims rainfall derivatives have the potential to be a separate asset class and, as such, provide investors with an added arsenal to enhance their portfolios (Bharath & Kotreshwar, 2022). Numerous studies have looked into the feasibility of creating insurance based on weather indexes, despite the fact that weather risk is primarily systemic in nature. (Skees et al., 2001) investigated the creation of drought insurance based on a RFI in Morocco and it was discovered that the product would be feasible and Moroccan farmers would greatly benefit from the product. Weather derivatives can effectively manage weather-related risks in Sri Lankan paddy farming by providing risk-protection against yield shortfalls (Dayasekara, 2015). Therefore, prior research indicates that rainfall derivatives contracts are feasible hedging instruments for mitigating rainfall risk (Dileep, 2022). The study also assessed the hedging effectiveness of weather derivatives through a literature-based review. The results of the studies supported the notion that weather derivatives are a trustworthy and effective risk management tool that is required to protect stakeholders from the dangers of weather uncertainty (Musshoff et al., 2011). It lessens or eliminates the drawbacks of standard insurance by linking the payoffs to a fairly quantified weather index, such as temperature, rainfall, humidity, and sunshine (Gyamerah et al., 2019).

This study has implications for researchers and practitioners. First, scholars can possess a deep understanding of the parametric weather risk financial products' intricacies and nuances associated with these instruments. They will be able to design models that accurately capture the relationship between weather events and financial outcomes. Second, it can assist the exchanges in creating a strong weather index that is tailored to the season, geographic areas, and landscape, along with suitable actuarial risk premia and strike levels. This way, the loss resulting from systemic risk should be covered by the index-triggered pay-out (Gairola & Dey, 2023). Ultimately, rainfall derivatives could offer a promising solution to manage climate-related risks in India.

7. Scope for Further Research

Future research should concentrate on assessing the impact of three or more meteorological factors on the hedging effectiveness of weather derivatives. From an agronomic perspective, it could also be advisable to incorporate not only the rainfall but also the temperature, the wind etc. in the index. The valuation of weather derivatives is a further research task that was omitted in this study. To encourage the development of the weather derivatives market, more effort is required to create a consistent and widely accepted valuation model.

Acknowledgement: This research was supported by the Odisha University Research and Innovation Incentivization Plan (OURIIP) fellowship, provided by the Odisha State Higher Education Council (OSHEC), Higher Education Department, Government of Odisha.

References

Abdi, M. J., Raffar, N., Zulkafli, Z., Nurulhuda, K., Rehan, B. M., Muharam, F. M., Khosim, N. A., & Tangang, F. (2022). Index-based insurance and hydroclimatic risk management in agriculture: A systematic review of index selection and yield-index modelling methods. *International Journal of Disaster Risk Reduction*, *67*, 102653. https://doi.org/10.1016/j.ijdrr.2021.102653

Aguillo, I. F. (2011). Is Google Scholar useful for bibliometrics? A webometric analysis. *Scientometrics*, *91*(2), 343-351. https://doi.org/10.1007/s11192-011-0582-8

Banner, A. (2012). *Enjoying the benefits of the low-volatility anomaly*. Institutional Investor. Retrieved from https://www.institutionalinvestor.com/article/2bsvoatvxvy8pwqwefjsw/portfolio/enjoying-the-benefits-of-the-low-volatility-anomaly

Bartkowiak, M. (2009). Weather derivatives. *Mathematics in Economics*, 5-17.

Berhane, T., Shibabaw, N., Awgichew, G., & Kebede, T. (2020). Option pricing of weather derivatives based on a stochastic daily rainfall model with Analogue Year component. *National Library of Medicine*, *6*(1). https://doi.org/https://doi.org/10.1016%2Fj.heliyon.2020.e03212

Bharath V. (2022). Conceptual Study on Securitizing Weather-related Risk in India. *ymerdigital*, *21* (7), 154-172. Retrieved from https://ymerdigital.com/uploads/YMER210708.pdf

Bharath, V., & Kotreshwar, G. (2020). Evaluating rainfall risk profile of Indian subcontinent based on index metrics. *Indian Journal of Finance and Banking*, *4*(2), 38-50.

Bharath, V.,, & Kotreshwar, G. (2022). Modeling and Designing of Rainfall Derivative Contract in India. *Parikalpana - KIIT Journal of Management*, *18*(1), https://www.google.com/search?q=https://doi.org/10.23862/kiit-parikalpana/2022/v18/i1/212343

Brockett, P. L., Wang, M., & Yang, C. (2005). Weather Derivatives and Weather Risk Management. *Risk Management and Insurance Review*, *8*(1), 127-140.

Cao, M., Li, A., & Wei, J. Z. (2003). Weather derivatives: A new class of financial instruments. *Available at SSRN 1016123*.

Care, R., & Weber, O. (2023). How much finance is in climate finance? A bibliometric review, critiques, and future research directions. *Research in International Business and Finance*, *64*. https://doi.org/10.1016/j.ribaf.2023.101886

Chiang, S. H. C. (2004). *The feasibility of a weather derivative for Ontario ice wine producers* (Doctoral dissertation, University of Guelph).

Choksi, A. (2012, May). Emergence Of Weather Derivatives-Feasibility in Indian Context. *Zenith International Journal of Business Economics & Management Research*, *2*(5).

Considine, G. (2000). Introduction to weather derivatives. *Weather derivatives group, Aquila energy*, 1-10.

Dayasekara. (2015). Feasibility of Weather Derivatives for Agriculture Risk Reduction. *Proceedings of 12th International Conference on Business Management.* Colombo, Sri Lanka.

Dileep, N. (2022). Comparison of Rainfall and GDP: A Feasibility Study on Introducing Rainfall Derivatives in the Indian Weather Risk Market. *Indian Journal of Economics and Finance (IJEF)*, *2*(2), 39-44. https://doi.org/http://doi.org/10.54105/ijef.B2530.112222

Dileep, N., & Kotreshwar, G. (2023). Rainfall Index Based Futures: A Tool for Absorbing Systemic Monsoon Risk. *International Journal of Finance, Insurance and Risk Management*, *XIII*(1), 79-87.

Dischel, R. S., & Barrieu, P. (2002). Financial weather contracts and their application in risk management. In *Climate Risk and the Weather Market: Financial Risk Management With Weather Hedges* (pp. 25-42). London, UK: Risk Waters Group Ltd. Retrieved from http://eprints.lse.ac.uk/id/eprint/10362

Gairola, G., & Dey, K. (2023). Moderators of pricing and willingness to pay for parametric weather risk mitigants in agriculture: An integrative review, conceptual framework, and research agenda. *Cogent Economics & Finance*, *11*(2). https://doi.org/10.1080/23322039.2023.2254579

Geyser, J. M. (2004). Weather Derivatives: Concept and application for their use in South Africa. *Agrekon*, *43*(4), 444–464. https://doi.org/10.1080/03031853.2004.9523660

Giustini, D., & M. N. (2013). Google Scholar is not enough to be used alone for systematic reviews. *National Library of Medicine*, *5*(2), 214. https://doi.org/https://doi.org/10.5210%2Fojphi.v5i2.4623

Goetzmann, W. N., & Zhu, N. (2005). Rain or shine: where is the weather effect?. *European Financial Management*, *11*(5), 559-578.

Gouda, K., Sahoo, S. K., Samantray, P., & Shivappa, H. (2017). Comparative Study of Monsoon Rainfall Variability over India and the Odisha State. *Climate*, *5*(4), 79. https://doi.org/https://doi.org/10.3390/cli5040079

Government of Odisha. (n.d.). *Topography*. Retrieved April 23, 2025, from https://odisha.gov.in/odisha-profile/topography

Gupta, L., Maurya, S., & Saxena, A. (2022). Climate Change Risk and Climate Finance in India: A Critical Analysis and Policy Recommendations. *Orissa Journal of Commerce*, *43*(3), 9-28. https://doi.org/https://doi.org/10.54063/ojc.2022.v43i03.02

Gyamerah, S. A., Ngare, P., & Ikpe, D. (2019). Hedging Crop Yields Against Weather Uncertainties—A Weather Derivative Perspective. *Mathematical and Computational Applications*, *24*(3), 71. https://doi.org/https://doi.org/10.3390/mca24030071

Halevi, G., Moed, H. F., & Ilan, J. B. (2017). Suitability of Google Scholar as a source of scientific information and as a source of data for scientific evaluation—Review of the Literature. *Journal of Informetrics*, *11*(3), 823-834. https://doi.org/http://dx.doi.org/10.1016/j.joi.2017.06.005

Hong, S. J., & Sohn, S. Y. (2013). Peer group analysis for introducing weather derivatives for a city. *Expert systems with applications*, *40*(14), 5680-5687.

Jones, E. (n.d.). *Are these the 8 best volatility indicators traders should know?* IG International Limited. Retrieved from IG International: https://www.ig.com/en/trading-strategies/are-these-the-8-best-volatility-indicators-traders-should-know--230124

Joshipura, N., & Joshipura, M. (2019, August). The Volatility Effect: Recent Evidence from Indian Markets. *Theoretical Economics Letters*, *9*(6). https://doi.org/https://doi.org/10.4236/tel.2019.96136

Kankara, R. S., Ramana Murthy, M. V., & Rajeevan, M. (2018). *National assessment of shoreline changes along Indian Coast - A status report for 26 years 1990-2016* (NCCR Publication, 2018). National Centre for Coastal Research. Retrieved from https://www.nccr.gov.in/sites/default/files/schangenew.pdf

Kotreshwar, G. (2014, July 17). *Why not hedge on the monsoon?* Retrieved from The hindu businessline: https://www.thehindubusinessline.com/opinion/why-not-hedge-on-the-monsoon/article64597714.ece

Mahapatra, A., & Samal, G. P. (2024). Harnessing Rainfall Derivatives for Agriculture Risk Hedging: A Study on Stakeholder Perceptions and Regulatory Framework in Odisha. *IUP Journal of Financial Risk Management*, *21*(4), 5-32. Retrieved from https://iupindia.in/ViewArticleDetails.asp?ArticleID=7534

Martínez Salgueiro, A., & Tarrazon-Rodon, M.-A. (2019). Weather derivatives to mitigate meteorological risks in tourism management: An empirical application to celebrations of Comunidad Valenciana (Spain). *Tourism Economics*, *27*(4), 591-613. https://doi.org/10.1177/1354816619890751

Mastrangelo, G., Fadda, E., Rossi, C. R., Zamprogno, E., & Buja, A. (2010). Literature search on risk factors for sarcoma: PubMed and Google Scholar may be complementary sources. *BMC Res Notes*, *3*(131). https://doi.org/https://doi.org/10.1186/1756-0500-3-131

Musshoff, O., Odening, M., & Xu, W. (2011). Management of climate risks in agriculture – will weather derivatives permeate? *Applied Economics*, *43*, 1067–1077. https://doi.org/10.1080/00036840802600210

Niñerola, A., Sánchez-Rebull, M.-V., & Hernández-Lara, A. (2019). Tourism Research on Sustainability: A Bibliometric Analysis. *Sustainability* , *11*(5). https://doi.org/https://doi.org/10.3390/su11051377

Noven, R. C., Veraart, A. E., & Gandy, A. (2015). A lévy-driven rainfall model with applications to futures pricing. *AStA Advances in Statistical Analysis*, *99*(4), 403-432.

Odisha Coastal Zone Management Authority. (n.d.). Retrieved from https://www.sczmaodisha.org/

Patnaik, U., Das, P. K., & Bahinipati, C. S. (2013). Analyzing Vulnerability to Climatic Variability and Extremes in the Coastal Districts of Odisha, India. *Review of Development & Change* , *XVIII*(2), 173-189. https://doi.org/https://doi.org/10.1177/0972266120130206

Paulson, N. D., Hart, C. E., & Hayes, D. (2010, May 11). A spatial Bayesian approach to weather derivatives. *Agricultural Finance Review*, *70*(1), 79-96. https://doi.org/https://doi.org/10.1108/00021461011042657

Pelka, N., & Musshoff, O. (2013). Hedging effectiveness of weather derivatives in arable farming – is there a need for mixed indices? *Agricultural Finance Review*, *73*(2), 358 - 372. https://doi.org/http://dx.doi.org/10.1108/AFR-10-2012-0055

Rainfall data. (n.d.). Retrieved from SRC Odisha: https://srcodisha.nic.in/rain_fall.php & Odisha Weather Monitoring System (OWMS).

Raucci, G. L., Lanna, R., Silveira, F. d., & Capitani, D. H. (2019). Development of weather derivatives: evidence from the Brazilian soybean market. *Italian Review of Agricultural Economics*, *74*(2), 17-28. https://doi.org/10.13128/rea-10850

RBI. (2019). *Will the Weather Gods Smile or Frown? Evaluating Monsoon Forecasts*. Retrieved from Reserve Bank of India: https://rbi.org.in/scripts/BS_ViewBulletin.aspx?Id=18289

Ritter, M., Mußhoff, O., & Odening, M. (2012). Minimizing geographical basis risk of weather derivatives using a multi-site rainfall model. *AgEcon Search.* Dublin: AgEcon Search.

Rohrer, M. B. (2004). The relevance of basis risk in the weather derivatives market . (M. Costantino, & C. A. Brebbia, Eds.) *Computational Finance and its Applications*. Retrieved from https://www.witpress.com/Secure/elibrary/papers/CF04/CF04007FU.pdf

Securities and Exchange Board of India (SEBI). (2024). *Notification for List of Commodities Under SCRA, 1956 dated March 01, 2024.* Retrieved from SEBI: https:// www.sebi.gov.in/legal/gazette-notification/mar-2024/notification-for-list-ofcommodities-under-scra-1956-dated-march-01-2024_82030.html

Sharma, A. K., & Vashishtha, A. (2007). Weather derivatives: risk-hedging prospects for agriculture and power sectors in India. *The Journal of Risk Finance, 8*(2), 112 - 132. https://doi.org/10.1108/15265940710732323

Sharma, P. C. (2021). Impact of Investors' Sentiments on Selected Sectoral Indices Return Volatility: Special Reference to NSE. *Orissa Journal of Commerce, 42*(1), 44-58. https://doi.org/https://doi.org/10.54063/ojc.2021.v42i01.04

Shivkumar , D., & Kotreshwar , G. (2013, November). Trading in weather risk transfer products – Reengineering rainfall indexation. *International Journal of Business and Management Invention, 2*(11), 33-41.

Singh, H., & Vashisht, A. (2020). Use of rainfall derivative to hedge rainfall risk in agriculture sector in India. *Journal of Xi'an University of Architecture & Technology,12*(5),2280-2289. https://xajzkjdx.cn/volume-xii-issue-5-may-2020/

Skees, J., Gober, S., Varangis, P., Lester, R., & Kalavakonda, V. (2001). *Developing Rainfall-Based Index Insurance in Morocco*. (Policy Research Working Paper No. 2577). World Bank. http://hdl.handle.net/10986/19674

Spaulding, A., Kanakasabai, M., Hao, J., & Skees, J. (2010). Can Weather Derivative Contracts Help Mitigating Agricultural Risk? Microeconomic Policy Implications for Romania. Retrieved from https://econpapers.repec.org/paper/ekd003307/330700139.htm

Stoppa , A., & Hess, U. (2003). *Design and Use of Weather Derivatives in Agricultural Policies:the Case of Rainfall Index Insurance in Morocco*. Paper presented at *"Agricultural Policy Reform and the WTO: Where are we heading"*. Capri, Italy.

Stulec, I., Petljak, K., & Bakovic, T. (2016). Effectiveness of weather derivatives as a hedge against the weather risk in agriculture. *Agric. Econ. – Czech, 62*(8), 356–362. https://doi.org/10.17221/188/2015-AGRICECON

Swain, M., Pattanayak, S., & Mohanty, U. (2018). Characteristics of occurrence of heavy rainfall events over Odisha during summer monsoon season. *Dynamics of Atmospheres and Oceans, 82*(17). https://doi.org/http://dx.doi.org/10.1016/j.dynatmoce.2018.05.004

Theron, L., & Vuuren, G. V. (2018). The maximum diversification investment strategy: A portfolio performance comparison. *Cogent Economics and Finance, 6*(1).

Vedenov, D. V., & Barnett, B. J. (2004). Efficiency of weather derivatives as primary crop insurance instruments. *Journal of Agricultural and Resource Economics, 29*(13), 387-403.

Wageningen University & Research. (n.d.). *How to use Google Scholar*. Retrieved from https://www.wur.nl/en/article/how-to-use-google-scholar.htm

Woodard, J. D., & Garcia, P. (2008). Basis risk and weather hedging effectiveness. *Agricultural Finance Review, 68*(1), 99 - 117. https://doi.org/10.1108/00214660880001221

Yang, C.C., Brockett, P.L. & Wen, M. (2009), Basis risk and hedging efficiency of weather derivatives, *Journal of Risk Finance*, Vol. 10 No. 5, pp. 517-536. https://doi.org/10.1108/15265940911001411

Zhou, R., Li, J. S.-H., & Pai, J. (2016). Hedging crop yield with exchange-traded weather derivatives. *Agricultural Finance Review, 76*(1).