Journal of Agricultural Sciences
(Tarim Bilimleri Dergisi)

J Agr Sci-Tarim Bili
e-ISSN: 2148-9297
jas.ankara.edu.tr

The Weather Index Insurance Scheme for Crops: Insights from India

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ARTICLE INFO
Review Article
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Received: 29 September 2024 / Revised: 24 February 2025 / Accepted: 7 March 2025 / Online: 29 July 2025

Cite this article
Luo T L (2025). The Weather Index Insurance Scheme for Crops: Insights from India. *Journal of Agricultural Sciences (Tarim Bilimleri Dergisi),* 31(3):590-611. DOI: 10.15832/ankutbd.1557827

ABSTRACT
Weather index insurance for crops is considered a beneficial supplement or even a replacement for traditional agricultural insurance products due to its advantages in payout efficiency and transaction costs. Among the countries implementing weather index insurance, India is one of the most representative. This paper briefly reviews the positioning and evolution of India's Weather-Based Crop Insurance Scheme (RWBCIS) within its agricultural insurance system, systematically elaborating on the specific measures and implementation experiences related to product design, operational systems, and supervisory mechanisms. The study finds that India positions RWBCIS as an effective supplement to traditional crop yield insurance, leveraging the synergy between the two by considering geographical location, land distribution, and climate types. The orderly implementation of RWBCIS is supported by comprehensive insurance data, a robust and transparent information platform, refined product design, and an extensive meteorological network. Additionally, the establishment of crop insurance calendars and supervisory penalty mechanisms clarifies the allocation of responsibilities and enhances the stability and sustainability of the insurance market. The policy approach of implementing RWBCIS in India, along with its specific arrangements in insurance operation mechanisms, may offer valuable insights for the top-level design of agricultural insurance and product innovation in the world.

Keywords: Agricultural Insurance, PMFBY, RWBCIS, Risk Management

1. Introduction

The development of agriculture and its related sectors is highly dependent on climatic conditions. In the context of frequent global climate disasters, agricultural insurance has become widely used in many countries as a “stabilizer” to disperse risks associated with agricultural production and operations and to ensure supply stability (Astuti 2023). According to industry research, the global agricultural insurance market was valued at approximately $45.7 billion in 2022, and it is projected to reach nearly $65.9 billion by 2029 (Madaki et al. 2023). However, as the agricultural insurance market continues to expand, traditional agricultural insurance products like crop yield insurance have increasingly faced issues such as information asymmetry, complicated compensation processes, and high transaction costs. Consequently, countries worldwide are exploring agricultural insurance models that better suit their national conditions, with crop weather index insurance emerging as a particularly noteworthy innovation (Boyd et al. 2020; Cajucom 2022). The advantage of weather index insurance lies in its basis on the correlation with specific meteorological indices, rather than the actual crop yield or loss conditions. This simplifies and expedites the calculation and payout procedures and can effectively reduce the likelihood of moral hazard and adverse selection caused by information asymmetry (Bucheli et al. 2020; Sun 2022).

In developed Western countries, particularly the United States and Europe, weather index insurance systems have matured and are widely implemented as effective tools for managing climatic risks (Abdi et al. 2022). For instance, in the United States, the agricultural weather insurance system is supported by government programs and a vast network of meteorological data, allowing farmers to receive timely compensation when facing extreme weather events. This system combines advanced climate data and predictive models to provide efficient risk management tools for farmers (Vroege et al. 2019). Similarly, in Europe, countries such as France and Germany have developed comprehensive weather index insurance programs, particularly in response to extreme weather events (Koenig & Brunette 2024). These countries’ experiences demonstrate that integrating meteorological data and modern technologies can significantly enhance insurance coverage and compensation efficiency, particularly when addressing extreme weather conditions (Bucheli et al. 2023).

At present, China is in the process of establishing a “trinity” policy system to ensure income for grain farmers, encompassing pricing, subsidies, and insurance. Among these, agricultural insurance, as a market-oriented tool that does not interfere with the formation of agricultural product prices and better aligns with international regulations, is receiving special attention and high

expectations (Li & Wang 2022; Bhuyian et al. 2022). Since the implementation of agricultural insurance subsidy policies in 2007, China has seen rapid growth in its agricultural insurance market, particularly with the introduction of weather index insurance as a supplementary tool. According to the China Banking and Insurance Regulatory Commission (CBIRC), the premium income of agricultural insurance in China increased from RMB 5.1 billion in 2007 to RMB 81.2 billion in 2020, reflecting a compound annual growth rate (CAGR) of over 20%. Within this growth, weather index insurance has gained significant traction, with pilot programs expanding from a few provinces in the early 2010s to nationwide coverage by 2020 (Sun et al. 2023). For instance, in 2020 alone, weather index insurance accounted for approximately 15% of the total agricultural insurance premium income, covering key crops such as rice, wheat, and corn, as well as livestock and aquaculture sectors (Tang et al. 2021). China's weather index insurance system, supported by national fiscal policies, has gradually improved through technological advancements and the accumulation of data, enhancing product accuracy and claims efficiency.

In Japan and South Korea, the introduction of weather index insurance has focused on product innovation and flexibility to address climate change challenges in agricultural production. Japan's agricultural insurance system integrates weather index insurance with traditional crop insurance to supplement and optimize the limitations of conventional models, providing farmers with more efficient protection in times of extreme weather (Hisamatsu et al. 2020). South Korea has also introduced innovative insurance products to address the shortcomings of traditional systems, offering farmers more convenient coverage (Kim et al. 2021). These countries' experiences demonstrate that with robust economic and policy support, weather index insurance can be rapidly adopted and effectively utilized.

In developing countries, the promotion of weather index insurance faces numerous challenges. While countries such as Mexico, Kenya, and Ethiopia have seen some success in implementing weather index insurance, several barriers still exist. First, many developing countries lack high-quality meteorological data, which hinders the design and implementation of effective weather index insurance. Second, farmers' awareness and participation in weather index insurance programs remain low, limiting the impact of such initiatives (Bhandary et al. 2021). Furthermore, insufficient government fiscal support and weak regulatory frameworks pose significant challenges to the sustainability of weather index insurance in these regions. Despite these issues, weather index insurance has provided some degree of protection in developing countries, particularly in response to climatic events, but its scalability and effectiveness are still constrained by multiple factors.

Among the countries practicing weather index insurance, India stands out as one of the most representative. Due to a combination of geographical location, terrain, and monsoon influences, India exhibits diverse climatic characteristics, making the agricultural sector highly sensitive and dependent on weather conditions. Since 2007, India has implemented early versions of crop weather index insurance (WBCIS) nationwide (Swain 2015), and by 2016, it had developed an agricultural insurance system primarily centered around the Pradhan Mantri Fasal Bima Yojana (PMFBY) for crop yield insurance (Parthiban & Anjugam 2023), with the Restructured Weather Based Crop Insurance Scheme (RWBCIS) serving as a supplementary component. As an integral part of the current agricultural insurance framework, RWBCIS helps to stimulate insurance demand among small-scale farmers, thereby effectively expanding the coverage of agricultural insurance (Sathiyamurthi et al. 2019). Additionally, by reducing transaction costs associated with agricultural insurance, RWBCIS enhances the efficiency of government fiscal expenditures. Compared to the weather index insurance systems of Western and Eastern economic powers, India's experience is particularly relevant for developing countries due to its focus on product innovation, market positioning, and government support aimed at addressing the specific challenges faced by smallholder farmers. India's model provides valuable insights that are more applicable to resource-constrained regions facing significant climate risks.

This study aims to review and analyze India's agricultural insurance policy, particularly the development and implementation of weather index insurance (RWBCIS), and its impact on managing climate change risks in agriculture. India's weather index insurance system, especially in terms of its scalability, flexibility, and cost-effectiveness, offers distinct advantages compared to the systems of Western and Eastern economic powers. Thus, India's experience provides more relevant lessons for other developing countries, particularly those facing significant challenges in agricultural production and climate change. By thoroughly analyzing India's weather index insurance policy, this study not only provides a practical framework for other developing countries to implement weather index insurance but also offers valuable academic insights that can support the improvement and innovation of global agricultural insurance systems.

2. Literature Review

2.1. The evolution of agricultural insurance and the role of weather index insurance

Agricultural insurance has long been a cornerstone of risk management in agriculture, attracting sustained academic and policy interest. Early theoretical models predominantly focused on yield-based insurance schemes, where indemnities were directly tied to observed crop losses (Mruthyunjaya & Kumar 1989). While these traditional models offered a critical safety net for farmers, they were plagued by high administrative costs, adverse selection, and moral hazard—issues that significantly hindered their scalability and efficiency (Kaylen et al. 1989). In response, the latter half of the 20th century saw an increasing emphasis on optimizing subsidy mechanisms and enhancing farmer participation rates to refine conventional insurance frameworks (Meuwissen et al. 2001).

The introduction of Weather Index Insurance (WII) marked a pivotal innovation in agricultural risk management. Unlike yield-based insurance, WII ties payouts to objectively measurable weather indices, such as rainfall or temperature, rather than directly assessing individual losses. This approach effectively reduces transaction costs and mitigates information asymmetry, addressing some of the critical limitations of traditional schemes (Hess 2007). Despite its theoretical promise, early studies highlighted inherent challenges, such as basis risk—the mismatch between index-based payouts and actual losses—which could undermine the utility and equity of the scheme (Collier et al. 2009).

Globally, the application and evaluation of WII have become prominent research themes. Sub-Saharan Africa has been a focal point for pilot projects, such as Kenya's Kilimo Salama initiative, which successfully integrated WII with mobile payment systems to reduce entry barriers for smallholder farmers (Sibiko et al. 2018). Studies have advanced understanding of the contextual determinants of WII's effectiveness while emphasizing persistent challenges, including farmers' limited awareness of insurance products, data scarcity, and discrepancies between payouts and actual damages (Sibiko et al. 2020). Scholars have also explored the potential of integrating WII into broader risk management strategies, such as coupling it with savings, microfinance, and social protection mechanisms (Martínez Salgueiro 2019; Doherty et al. 2021).

India has emerged as a key case study for WII implementation, providing valuable insights into both its potential and limitations. As an agrarian economy highly vulnerable to climate variability, India's government introduced the Weather-Based Crop Insurance Scheme (WBCIS) to address the dual challenges of moral hazard and adverse selection (Kumar & Babu 2021). While the scheme demonstrated success in expanding insurance coverage, it also raised critical questions regarding the transparency and efficiency of premium subsidies. Some studies argue that the lack of coordination between state governments and insurers exacerbates information asymmetry and delays compensation processes, thereby reducing the scheme's efficacy (Singh & Agrawal 2020). Moreover, Indian scholars have investigated the role of emerging technologies, such as remote sensing and weather forecasting, in enhancing the accuracy of index design, thereby reducing basis risk and improving farmer trust (Shirsath et al. 2019).

While Weather Index Insurance (WII) has garnered significant attention, critiques of its limitations persist. Empirical studies highlight several key challenges. First, WII often struggles to provide adequate coverage for extreme weather events due to the difficulty in accurately modeling low-probability, high-impact risks (Clarke 2016). For instance, a study in China found that WII failed to compensate farmers adequately during severe droughts, as the index thresholds did not align with actual crop losses (Fan et al. 2023). Second, the scientific robustness of index design remains a concern. Research in sub-Saharan Africa revealed that basis risk—the mismatch between index measurements and actual farm-level losses—reduces the effectiveness of WII, with up to 40% of farmers experiencing losses not covered by payouts (Jensen et al. 2018). Third, farmers' understanding of WII products is often inadequate, leading to low uptake and misuse (Rao & Zhang 2020).

Furthermore, the heterogeneity of socioeconomic and institutional contexts poses significant challenges to the scalability of WII. For example, in Sri Lanka, Aheeyar et al. (2019) found that WII programs struggled to account for localized variations in farming practices and weather patterns, limiting their applicability. In low-income countries, WII programs often rely heavily on external support from international organizations and NGOs, raising questions about their long-term sustainability. Akter et al. (2016) documented that in Bangladesh, donor-funded WII initiatives faced difficulties transitioning to self-sustaining models due to high operational costs and limited local institutional capacity. Future research must address these challenges by exploring how WII can be tailored to local contexts, incorporating participatory design processes, and leveraging advances in remote sensing and machine learning to improve index accuracy and inclusivity.

In recent years, technological advancements have ushered in a new era of WII research. Big data analytics, machine learning, and blockchain technology are increasingly explored for their potential to enhance the design and implementation of WII schemes (Singh, 2024). Machine learning algorithms, for instance, can improve the precision of weather forecasts, thereby reducing basis risk, while blockchain technology can enhance transparency and traceability in claim settlements (Chen et al. 2021). Additionally, scholars have emphasized the importance of integrating WII into global climate adaptation strategies, advocating for regional cooperation and knowledge sharing to bolster agricultural resilience in the face of climate change (Lybbert & Sumner 2012).

In sum, the evolution of WII reflects a paradigm shift in agricultural insurance, from traditional indemnity-based approaches to modern, data-driven solutions. Despite its challenges, WII offers a promising framework for addressing the multifaceted risks faced by farmers globally. Future research must continue to explore innovative approaches to design, implementation, and policy integration, ensuring that WII becomes a sustainable and effective tool in agricultural risk management.

2.2. Definition of key terms

To fully understand the mechanisms and challenges of Weather Index Insurance (WII), particularly within India's agricultural insurance system, it is essential to define the key concepts related to this subject. This section will provide formal definitions and academic explanations of terms such as Moral Hazard, Information Asymmetry, Adverse Selection, as well as important

terminology related to India's agricultural insurance schemes, including Weather-Based Crop Insurance Scheme (WBCIS), Restructured Weather-Based Crop Insurance Scheme (RWBCIS), and Pradhan Mantri Fasal Bima Yojana (PMFBY).

i) Moral Hazard

Moral hazard refers to the situation where one party in a transaction may take on higher risks because they do not bear the full consequences of those risks. In the context of insurance, moral hazard occurs when the insured party engages in riskier behavior because they know that the insurer will cover the resulting losses (Arrow 1996). In agricultural insurance, particularly in traditional yield-based crop insurance, farmers might take fewer precautions against crop loss, knowing that the insurance will compensate for the damages. However, Weather Index Insurance (WII) mitigates this by using objective weather parameters (such as rainfall and temperature) for payouts, making it difficult for farmers to influence the payout conditions, thereby effectively reducing the potential for moral hazard (Rao & Zhang 2020).

ii) Information Asymmetry

Information asymmetry refers to a situation where one party has more or better information than the other party, leading to inefficiencies in the market or poor decision-making. In insurance markets, this typically manifests when farmers have more information about the actual condition of their crops than the insurers (Akerlof 1978). This imbalance can result in distorted risk assessments and pricing issues. In Weather Index Insurance, payouts are based on verifiable meteorological data, which helps reduce the information asymmetry problem, as farmers cannot manipulate the weather data used for payout determination (Bokusheva 2018).

iii) Adverse Selection

Adverse selection occurs when individuals with higher risks are more likely to purchase insurance, while those with lower risks opt out, leading to an unbalanced risk pool. This often happens when there is a lack of information about the risk levels of potential policyholders or when individuals self-select into insurance based on their perceived need for it (Jensen et al. 2018). In agricultural insurance, adverse selection may arise if farmers who are more likely to experience extreme weather events or crop failures choose to purchase insurance, thereby increasing the cost for the insurer. Weather Index Insurance mitigates this risk by basing payouts on objective weather parameters, reducing the possibility of adverse selection, as the triggering weather events are external and not controlled by the policyholders.

iv) Risk Management

Risk management refers to the process of identifying, assessing, and prioritizing risks, followed by the coordinated application of resources to minimize, monitor, and control the probability or impact of unfortunate events (Kaplan & Mikes 2016). In agriculture, the core goal of risk management is to help farmers cope with risks posed by natural disasters, climate change, and other uncertainties. Weather Index Insurance is a crucial tool in agricultural risk management, providing a mechanism for farmers to transfer weather-related risks to the insurance market, thereby reducing the financial impact of natural disasters.

v) Weather-Based Crop Insurance Scheme (WBCIS)

The Weather-Based Crop Insurance Scheme (WBCIS) is an insurance plan introduced by the Indian government to address climate-related risks in agricultural production. Unlike traditional yield-based crop insurance, WBCIS triggers payouts based on weather parameters (such as rainfall and temperature). This scheme enhances objectivity and transparency in the compensation process, reducing issues related to information asymmetry and moral hazard (Bhattacharyya et al. 2022). Since its introduction in 2007, WBCIS has become a key component of India's agricultural insurance system, particularly in regions where assessing crop loss on an individual basis is challenging.

vi) Restructured Weather-Based Crop Insurance Scheme (RWBCIS)

The Restructured Weather-Based Crop Insurance Scheme (RWBCIS) is an improved version of WBCIS, aimed at expanding coverage and enhancing effectiveness. Officially launched in 2016, RWBCIS serves as a complement to the Pradhan Mantri Fasal Bima Yojana (PMFBY). RWBCIS has simplified the compensation process, reduced transaction costs, and improved the efficiency of government fiscal expenditures, encouraging greater participation from small-scale farmers (Singh & Agrawal 2020). One of the key advantages of RWBCIS is its incorporation of modern technologies, such as remote sensing and drones, to improve the accuracy of crop yield measurements. It also reduces information asymmetry by using digital platforms to release land ownership and insurance data, enhancing transparency and efficiency in insurance management.

viii) Pradhan Mantri Fasal Bima Yojana (PMFBY)

The Pradhan Mantri Fasal Bima Yojana (PMFBY) is a nationwide crop insurance scheme launched by the Indian government in 2016, aimed at providing yield-based insurance to protect farmers from natural disasters, climate change, and other risks. In contrast to RWBCIS, PMFBY focuses on traditional yield-based insurance and makes insurance more affordable through government subsidies, allowing greater participation from farmers. The program promotes income stabilization for farmers and aims to increase insurance penetration in the agricultural sector (Parthiban & Anjugam 2023). While RWBCIS addresses weather risks using external weather triggers, PMFBY enhances the coverage by integrating both yield and weather considerations, ensuring that farmers receive adequate protection against agricultural risks.

viii) National Crop Insurance Portal (NCIP)

The National Crop Insurance Portal (NCIP) is a digital platform established by the Indian government to enhance transparency and facilitate the management of agricultural insurance. It provides a shared platform for farmers, insurance companies, and government entities to access insurance data and process claims (Pandey et al. 2023). Through NCIP, farmers can check insurance details, including insured amounts and government subsidy percentages. Insurance companies and government departments use the portal to manage premium subsidies and claims processing. The introduction of NCIP has not only increased the efficiency of agricultural insurance operations but also significantly reduced management costs and information asymmetry, laying a solid foundation for the sustainability of India's agricultural insurance system.

Overall, academic discussions on agricultural insurance and weather index insurance reflect significant progress in addressing the challenges of agricultural risk management. These studies highlight the importance of customized insurance products, technology integration and stakeholder synergies in ensuring the sustainability and effectiveness of agricultural insurance. A comprehensive analysis of the Indian case is presented below, manually organized by systematically reviewing government documents, publicly available data, and previous studies related to weather insurance in India, and relying on the literature analysis tool MAXQDA to create appropriate charts and graphs in order to demonstrate the academic value of the Indian case in a more intuitive manner.

3. The Development of Weather Index Insurance in India's Agricultural Insurance System

3.1. The construction and evolution of India's agricultural insurance system

As a major agricultural producer frequently impacted by natural disasters, India began experimenting with agricultural insurance plans at an early stage. In 1985, India launched the Comprehensive Crop Insurance Scheme (CCIS) nationwide, which was based on compensating for losses according to the affected area. This scheme operated until 1999, after which it was replaced by the National Agricultural Insurance Scheme (NAIS), which provides compensation based on regional yield insurance. Following the implementation of NAIS, India made several adjustments to optimize its operational mechanisms, including refining insurance zones, actuarial premium rates, trigger points, and compensation methods. Over the years, these continuous adjustments have contributed to the ongoing development of the NAIS (Punia et al. 2021; Singh & Agrawal 2020).

However, given that small and marginal farmers account for as much as 85% of the agricultural population in India, with an average landholding of less than 2 hectares per person, traditional yield-based insurance plans gradually exposed some inherent shortcomings during their implementation (Kaur et al. 2021). These issues include complicated compensation processes, high transaction costs, and frequent occurrences of moral hazard and adverse selection. In this context, starting in 2007, the Indian government introduced the Weather-Based Crop Insurance Scheme (WBCIS) as a supplementary measure to traditional crop yield insurance and officially launched it in the Indian agricultural insurance market. Unlike traditional yield-based crop insurance, weather index insurance uses meteorological indices as the trigger mechanism for payouts, significantly enhancing the timeliness and efficiency of compensation. Moreover, because the indices triggering compensation are objective, WBCIS is believed to reduce the likelihood of moral hazard (Poddar 2020). However, despite the introduction of WBCIS, India's agricultural insurance system continues to face several challenges in terms of institutional design. These include issues such as unreasonable premium and sum insured determinations, delayed compensation payments leading to low insurance penetration, and incomplete basic land and insurance data (Singh & Agrawal 2020).

In response to the aforementioned issues, the Indian government once again reviewed and adjusted the NAIS and WBCIS, revising premium rates, insured amounts, and insurance payout regulations. In 2016, the government officially launched the current agricultural insurance system, which is primarily centered around the PMFBY and supplemented by the RWBCIS. Table 1 presents the main differences in the operational mechanisms between the current agricultural insurance system and the earlier NAIS.

Compared to NAIS, PMFBY and RWBCIS have reduced insurance premium rates, redefined the insured amounts based on the actual cost of crop production, increased the government's premium subsidy ratio, and further standardized the distribution of these subsidies. Additionally, the current agricultural insurance system places greater emphasis on using emerging technologies to enhance the service levels of agricultural insurance. On the one hand, the use of drones and remote sensing

technology has improved the accuracy of crop yield measurements and the timeliness of payouts. On the other hand, the development of a crop insurance website platform to publish land title information and basic insurance data has reduced information asymmetry, providing foundational data support for the regulation and service of agricultural insurance.

Table 1- Comparison of Major Insurance Schemes in India

Category	***NAIS (1999-2016)***	***PMFBY***	***RWBCIS***
Applicable Period	1999–2016	2016 to present	2016 to present
Eligibility	All farmers (including self-cultivators and tenant farmers)	Must submit land ownership documents, crop sowing records, and evidence of actual agricultural activity	Same as PMFBY
Risk Coverage	General coverage for "all risks"	All risks during sowing, growing, and harvesting periods	Risks related to weather disasters
Covered Crops	Food crops, oil-bearing crop, and horticultural crops (economic crops)	Same as NAIS	Same as NAIS
Land Tenure Information	Self-reported by individual states	Uniform electronic land tenure data	Same as PMFBY
Insurance Zones	Determined by individual regions	Village-level units	Based on meteorological station locations
Sum Insured	For loaned farmers: loan amount; for non-loaned farmers: ≤150% of average yield	Determined by crop production cost or government budget	Same as PMFBY
Premium Rate	Approximately 10%	Spring crops: ≤2%, Autumn crops: ≤1.5%, economic crops: 5%	Spring crops: ≤3.5%, Autumn crops: ≤2%, economic crops: 5%
Premium Subsidy	10% (only for smallholders)	60% for rainfed areas, 50% for irrigated areas	Same as PMFBY
Payout Trigger	Yield	Yield	Weather parameters
Premium Disbursement	No specific provision	Disbursed in installments	Same as PMFBY
Yield Estimation Method	Traditional crop-cutting experiments	Crop-cutting experiments using drones and remote sensing	Same as PMFBY
Payout Timeframe	6-12 months	Within two weeks after data verification	Same as PMFBY

Source: Gulati et al. 2018; Punia et al. 2021; Singh & Agrawal 2020; Kaur et al. 2021; National portal of India 2024
Note: In India, areas with more than 50% of total irrigated land are classified as irrigated zones, while those with less than 50% are classified as rainfed zones.

3.2. Exploration and practice of the weather-based crop insurance scheme in India

Before the Indian government officially introduced the early version of the Weather-Based Crop Insurance Scheme (WBCIS) into the agricultural insurance system in 2007, several insurance companies had already undertaken beneficial experiments. One of the earliest attempts was by ICICI Lombard General Insurance in 2003, which launched a pilot weather index insurance scheme for cotton and castor growers (Shirsath et al. 2019). Subsequently, in 2005, Agriculture Insurance Company of India (AICI) introduced a more comprehensive pilot project based on a seasonal total rainfall index. However, this rainfall index insurance had a significant drawback: the design only considered the total rainfall during the growing season as the trigger value, without differentiating between the various growth stages of the crops. This led to an extended measurement period for rainfall, reducing the objectivity of the rainfall index (Kumar & Babu 2021).

To address the design flaws of earlier weather index insurance products, IFFCO-Tokyo General Insurance launched a weighted rainfall insurance pilot program during 2004-2005 in Andhra Pradesh, Karnataka, and Gujarat. This program took into account the varying rainfall requirements at different growth stages of crops (Giné et al. 2010). Specifically, the plan roughly divided the crop growth stages by month and applied weighted trigger values for rainfall at different stages to improve the accuracy of the weather parameter triggers. Meanwhile, to solve the problem of extended rainfall measurement periods, AICI

introduced a multi-stage weather index, which segmented the measurement periods according to the different growth stages of the crops. Each period had distinct weather parameter triggers corresponding to the specific needs of the crops during that stage.

Building on the beneficial exploratory practices of earlier years, the Indian government officially launched the Weather-Based Crop Insurance Scheme (WBCIS) nationwide in 2007, based on preliminary pilot programs. However, the initial weather index products at that time overlooked the continuous impact of rainfall on crop yields across different growth stages. Specifically, excess or insufficient rainfall in one growth stage could affect the crop's water requirements in subsequent stages, meaning that the trigger values for each stage could not be set independently.

To address this issue, the Agriculture Insurance Company of India (AICI), participating in WBCIS, introduced an updated multi-stage and carry-forward rainfall index in 2009. This index included a precondition for two crop growth stages, where if the rainfall during a specific stage exceeded twice the trigger value, the surplus would carry forward to the next stage. In addition to determining trigger values based on rainfall, AICI also developed an index for the maximum consecutive dry days within a specific period. The compensation amount under this index was structured as a piecewise linear function of the number of dry days.

After these attempts and improvements, India officially launched the Restructured Weather Based Crop Insurance Scheme (RWBCIS) in 2016, positioning it as an effective supplement to the Pradhan Mantri Fasal Bima Yojana (PMFBY) within the Indian agricultural insurance market.

Since India began implementing weather index insurance pilots, the scheme has rapidly developed and has become the largest weather index insurance market globally. This has significantly increased the coverage of agricultural insurance among small-scale farmers, with the number of insured households exceeding 14 million in 2013 and premium income reaching $300 million. Since the implementation of the current agricultural insurance system in 2016, RWBCIS, as a valuable supplement to PMFBY, has worked in synergy with it to promote the healthy and orderly development of India's agricultural insurance market, with both schemes expanding in scale. By 2020, the total number of insured farmers in India exceeded 60 million, the insured area surpassed 49 million hectares, and total premium income exceeded $4 billion.

4. Operational Mechanisms of India's RWBCIS

RWBCIS is a specialized form of agricultural insurance implemented by the Indian government, designed to provide farmers facing uncontrollable weather risks with a broader range of insurance options. The Indian government has played an active role not only in the design of the Weather-Based Crop Insurance Scheme (WBCIS) but also in providing financial support through subsidies. Before officially launching this agricultural insurance program, the Indian government spent several years on preparatory work, including the digitization of land records, conducting Crop Cutting Experiments (CCE), and using historical weather data to simulate and determine trigger thresholds. Additionally, small-scale pilots of weather index insurance were conducted, and related policies and legal frameworks were adjusted.

Overall, the Indian government has made relatively comprehensive and clear arrangements for the operational mechanisms of RWBCIS. These arrangements have taken into account the unique climatic conditions of India, the availability of data, the need for timely payouts, and strategies to mitigate moral hazard and adverse selection.

4.1. Provisions on policyholder

1. Policyholder eligibility

Before each crop season begins, the Indian government determines the crop planting area through the Crop Cutting Experiment (CCE). In theory, all farmers (including owner-cultivators and tenant farmers) who plant the specified crops within the CCE areas are eligible to participate in RWBCIS. However, they must also meet the following conditions:

Farmers must submit necessary land documents, including the Record of Rights (RoR), Land Possession Certificate (LPC), and relevant lease agreements related to land transactions.

Farmers must ensure they have insurable interest during the insurance season and must submit the identification numbers of the crops already sown or planned for sowing.

Submitting land documents and proof of sowing or planned sowing serves two purposes. First, it ensures that actual agricultural production is taking place, verifying the authenticity of the farmers insurance and helping to prevent moral hazards such as fraudulent insurance claims. Second, it assists the government in reasonably guiding farmers to choose suitable insurance plans.

2. The regulations on bundling sales to debtor farmers

The Indian government mandates that farmers applying for crop loans or using the Kisan Credit Card (KCC) for agricultural production are automatically enrolled in RWBCIS. This means that the government operates under a loan-and-insurance bundling model. If a debtor farmer wishes to opt out of the plan, they must submit a declaration to the lending bank at least 7 days before the registration deadline for crop insurance for that season. If no declaration is submitted, the farmer is automatically included in the plan. By bundling crop loan applications with registration in RWBCIS, the policy not only helps farmers mitigate agricultural production risks but also assists lending financial institutions in reducing the risk of loan defaults due to adverse weather conditions.

4.2. Regulations regarding the insurance season

India primarily experiences a tropical monsoon climate, which divides agricultural production into two seasons: Kharif (April to October) and Rabi (October to the following March). The Rabi season is mainly affected by droughts, floods, and heatwaves, while the Kharif season is primarily impacted by high temperatures and frost.

RWBCIS adjusts its insurance coverage and regulations based on the crop season. During the Rabi season, the insurance primarily covers weather indices related to excessive or insufficient rainfall. Conversely, in the Kharif season, the insurance focuses on weather indices related to low temperatures, high temperatures, and frost. This seasonal arrangement helps tailor insurance policies to the specific climate characteristics and crop growth stages of each season, thereby enhancing the applicability and effectiveness of the insurance products.

4.3. Provisions on the scope of application

1. The coverage of meteorological risks

Weather index insurance uses weather parameters as the measure for triggering payouts. The covered meteorological risks must meet the following conditions: first, they can be directly or indirectly caused by measurable changes in weather parameters; second, losses caused by adverse weather events must be quantifiable; third, it must be demonstrated that these risks are related to quantifiable crop yield losses.

Specifically, weather disasters during the autumn planting season are mainly related to precipitation, including insufficient rainfall, excessive rainfall, unseasonal rainfall, rainy days, and drought. For the spring planting season, weather disasters are primarily related to temperature, while also including humidity, wind speed, and hail.

2. The coverage of crops

The crops covered under India's RWBCIS typically have the following characteristics: first, they are crops of significant importance to India's economy and agriculture; second, they are high-risk crops that are highly susceptible to meteorological factors, especially drought and flood; third, they are crops grown in regions where meteorological data is available.

The covered crops specifically include food crops (grains, millets, and pulses), oilseeds, and horticultural economic crops. Additionally, coverage varies according to the cropping season: during the autumn planting season, weather index insurance covers crops such as rice, sorghum, pearl millet, groundnut, soybean, sunflower, and cotton; during the spring planting season, it primarily covers wheat, mustard, chickpea, potato, cumin, and coriander.

4.4. Provisions on the sum insured, premium rates, subsidies, and payouts

1. Provisions on the sum insured and premium rates

The sum insured for an individual farmer is calculated as the product of the unit insured amount and the cultivated area of the crop. Since the input costs vary across different growth stages of the crop, the unit insured amount is primarily determined based on the estimated cumulative production costs for each growth stage. Additionally, as the government provides premium subsidies, the local government's financial capacity is also considered when determining the unit insured amount. For example, in the case of wheat, the sum insured is determined by first dividing the growth stages into four phases: emergence to jointing, booting to heading, flowering to grain filling, and maturity. The insurance amount is then set according to the costs incurred at each stage. Premium rates vary depending on the crop season and crop type (Table 2), and the rate is determined based on the lower value between the government-specified rate and the actuarial rate.

Table 2- Premium Regulations for India's Weather Index Insurance Scheme

No. and Seasons	*Crop*	*Maximum Premium Payable by Farmers*
Autumn Planting Season		
1	Wheat	1.5% or actuarial rate, whichever is lower
2	Other crops (including cereals, millets, pulses, and oilseeds)	2.0% or actuarial rate, whichever is lower
Spring Planting Season		
1	Oilseeds	3.5% or actuarial rate, whichever is lower
2	Other crops (including cereals, millets, pulses)	2.5% or actuarial rate, whichever is lower
Spring and Autumn Planting Seasons		
1	Annual/Perennial horticultural and other economic crops	5% or actuarial rate, whichever is lower

Source: Singh, 2024; Singh & Agrawal, 2020; Kaur et al. 2021; National portal of India, 2024

2. Provisions on premium subsidies

Many countries that implement agricultural insurance schemes typically provide direct premium subsidies or indirect policy incentives to encourage farmers to participate, aiming to promote risk-sharing in agricultural insurance. Similarly, the Indian government provides premium subsidies to all registered farmers participating in RWBCIS. Specifically, India classifies land into rainfed and irrigated areas based on irrigation coverage, with the central government setting subsidy caps of 25% and 30% of the premium for rainfed and irrigated areas, respectively.

In addition, the Indian government employs a cost-sharing model for premium subsidies. Except for the northeastern region of India, the central and state governments each cover 50% of the subsidy. In the northeastern region, the central and state governments cover 90% and 10% of the premium subsidy, respectively, meaning that state governments must match the central government's contribution accordingly. Generally, the combined premium subsidy provided by the central and state governments accounts for up to 60% of the agricultural premium, while the farmers bear 40%.

It is also worth noting that the central government encourages state governments to provide additional subsidies based on local conditions and financial capacity. However, this extra subsidy must be fully borne by the state government, without any contribution from the central government.

The Indian government disburses premium subsidies in installments (Figure 1). The first installment is released before farmers purchase insurance; the second installment is disbursed after verifying basic agricultural insurance data; and the final installment is issued upon approval of the financial data of the insurance business. This phased disbursement model reflects the Indian government's balanced approach of providing early incentives to insurance companies while maintaining oversight in the later stages.

Specifically, to encourage and ensure that insurance companies can quickly and timely distribute payouts when farmers face natural disasters, the central and state governments can disburse the first premium subsidy installment before farmers purchase insurance, based on 50% to 80% of their respective subsidy shares from the previous season. After farmers complete the insurance purchase, the insurance companies can apply for the second subsidy installment. The relevant government levels then verify the basic information of the insurance policies, and once confirmed, they release the second premium subsidy.

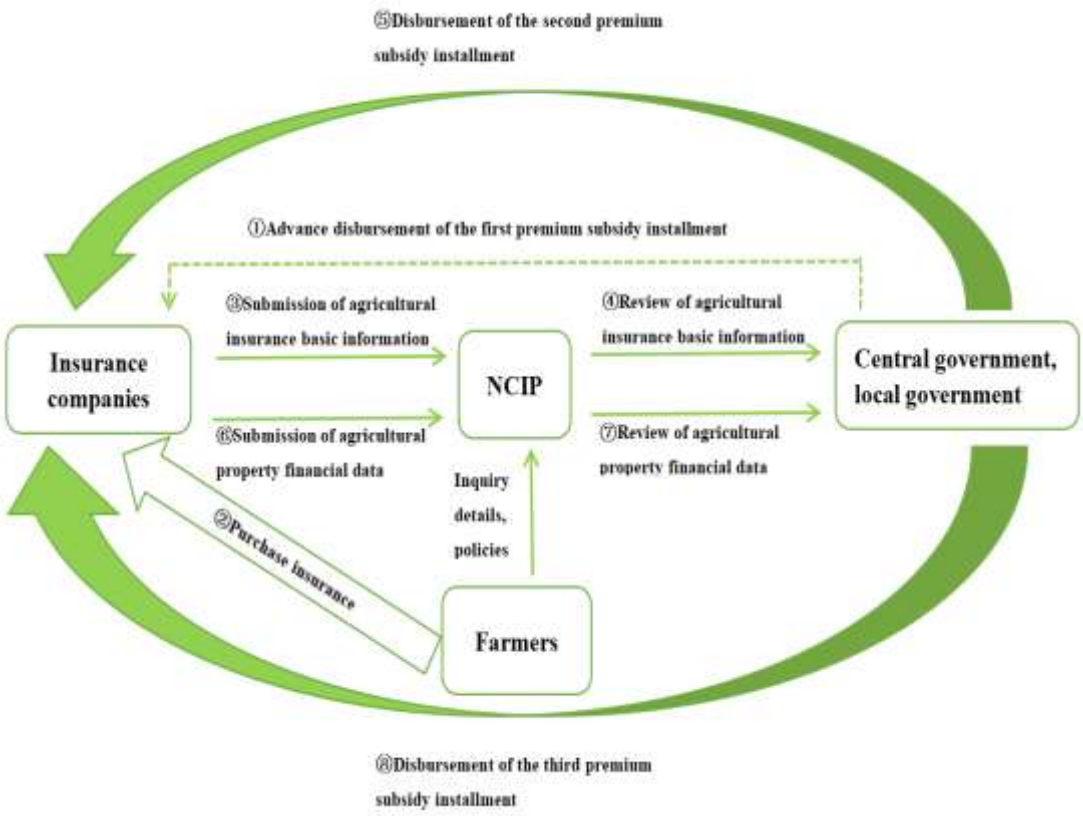


Figure 1- Premium Subsidy Arrangement for India's RWBCIS Source: Produced by the author

It is worth noting that the implementation of agricultural insurance in India is supported by the National Crop Insurance Portal (NCIP) under the Ministry of Agriculture and Farmers' Welfare. The platform is accessible to farmers, insurance companies, and government entities, ensuring transparent and shared data. Through the establishment of a digital platform, direct information channels have been created between farmers and insurance companies, insurance companies and state governments, and state governments and the central government. Premium subsidies are strictly disbursed through NCIP's Management Information System (MIS) and the linked Public Financial Management System (PFMS). Farmers can use the platform to check detailed insurance information, including the sum insured and the premium shares borne by various government levels. Correspondingly, the central and state governments only release the final premium subsidy to insurance companies after completing approval and reconciliation on the platform.

This phased disbursement of premium subsidies allows government oversight to be integrated throughout the entire operation of the insurance scheme, enabling timely identification of issues at each stage and improving the efficiency of claim settlements. Additionally, the disbursement of the first subsidy installment before farmers purchase insurance helps alleviate the financial pressure on insurance companies and serves as an incentive for their operations.

3. Provisions on insurance payouts

India's RWBCIS payouts vary depending on the cropping season. Insurance companies typically sell bundled policies. According to sample policies from India's NCIP, autumn season policies bundle excess rainfall and deficient rainfall indices. Simply put, farmers who purchase this insurance for the autumn season and experience extreme weather events like droughts or floods in their region that meet the specified weather parameter thresholds are eligible for payouts from the insurance company. The payout criteria for excess rainfall insurance are straightforward and solely based on rainfall amount. However, the payout criteria for deficient rainfall insurance involve two measures: rainfall amount and consecutive days of drought. As long as either condition is met, the payout is triggered. Below, the payout regulations for India's crop weather index insurance will be explained using the autumn season weather index insurance as an example.

Regulations on Meteorological Data Acquisition: The meteorological indicators involved in the payout process for weather index insurance primarily include rainfall, temperature, and humidity, with data sourced from ground-based weather stations in the risk areas. The availability and quality of ground-based weather data are generally regarded as key factors for the effective implementation of weather index insurance. As a result, India's relevant technical departments have set strict regulations on how meteorological data are obtained for RWBCIS. Based on the concept of a "regional approach" and considering India's actual

distribution of farmland and weather conditions, farmers' fields are divided into different unit risk areas. Each risk area is linked to a fixed ground-based weather station that records, compiles, and provides weather parameter data exclusively for payouts in that area, thereby establishing a weather network for weather index insurance payouts. It is reported that over 5,000 ground-based weather stations are associated with India's RWBCIS, offering extensive coverage that generally meets the weather data requirements for weather index insurance in major cultivated areas.

In addition, the Indian government has special provisions for obtaining meteorological data in areas where ground-based weather stations do not provide adequate coverage. In some remote and scattered farmlands, collecting weather data is challenging. The government allows the use of virtual weather stations to obtain data in these regions. Virtual weather stations combine local geographic and climatic characteristics using data from the Indian Meteorological Department, state government ground-based weather stations, and satellite observations to generate simulated weather data through technical analysis. These simulated data can be used under specific conditions to calculate RWBCIS payouts in place of actual weather data. While the use of virtual weather stations expands the coverage of RWBCIS, providing weather parameters necessary for insurance payouts in areas lacking ground-based data, there is still some uncertainty compared to the data from ground-based stations. Therefore, the government requires that simulated data be adjusted and validated before use to enhance reliability and applicability.

Regulations on Trigger Conditions: Weather index insurance typically sets one or more meteorological factors as trigger conditions. When actual meteorological indicators reach the trigger threshold, the insurance company pays out according to the specified payout criteria, regardless of whether the insured farmer has suffered a loss. Taking the autumn season weather index insurance as an example, the trigger standards for India's weather index insurance can be explained as follows. The autumn season weather index insurance covers both excess rainfall and deficient rainfall indices. Since the basic principles for both are similar, the trigger standards for deficient rainfall insurance will be used to detail the payout regulations.

Specifically:

First, relevant state government departments classify the key growth stages of each crop based on the crop's growth cycle, historical data, and local soil type, usually aligning the growth cycle with the crop stages defined in agronomy.

Second, after assessing the climatic conditions of the crop growing area and the required range of rainfall for each growth stage, stage-specific linear payout trigger values are established for rainfall amounts at each growth stage.

Third, based on the observed meteorological indicator values from ground-based weather stations, corresponding to different intervals of trigger values, the final payout amount is calculated using a payout formula.

For example, the typical three key growth stages of a crop are the sowing stage, flowering stage, and maturity stage. Table 3 presents the crop's key growth stages, the corresponding crop calendar, weather trigger values, and the associated payout amounts. Here, Trigger Value 1 refers to the highest rainfall amount that meets the triggering condition, meaning that payouts begin when the actual rainfall is below this value. The Exit Value is the lowest rainfall amount that triggers the full payout of the insured amount. Trigger Value 2 lies between these two values and represents a secondary payout condition. Payout Value 1 corresponds to the payout amount when rainfall falls between Trigger Value 1 and Trigger Value 2. Payout Value 2 applies when rainfall is below Trigger Value 2 but still above the Exit Value. The highest payout is made when rainfall drops below the Exit Value.

Table 3- Payout Regulations for Deficient Rainfall Index (in USD)

Growth Stage	***Crop Calendar***	***Trigger Value 1 (mm)***	***Trigger Value 2 (mm)***	***Exit Value (mm)***	***Payout Value 1 (USD/ Hectare)***	***Payout Value 2 (USD/ Hectare)***	***Maximum Payout (USD/ Hectare)***
Sowing Stage	July 15-August 31	200	150	100	0.61	0.98	79.27
Flowering Stage	September 1 - September 30	475	270	25	0.29	0.49	179.27
Maturity Stage	October 1 - October 31	200	95	10	0.85	1.37	204.88

Source: Gulati et al. 2018; Bjerge & Trifkovic, 2018; Dileep & Kotreshwar, 2023; National portal of India, 2024.
Note: The trigger values and payout amounts are only examples. Actual values are not fixed and can vary depending on the crop type and weather conditions.

Thus, when an area experiences insufficient rainfall or even consecutive drought conditions, the first step is to determine whether the average rainfall over a certain period is below Trigger Value 1. If it is, the next step is to identify the specific trigger

range in which this value falls. Finally, the payout amount is calculated in stages by substituting the rainfall value into formulas (1) to (4) based on the specific trigger range it falls into. The formulas are expressed as follows:

$$Y = (m_1 - x) \times n_1 \qquad If: m_2 < x \leq m_1 \tag{1}$$

$$Y = (m_1 - m_2) \times n_1 + (m_2 - x) \times n_2 \qquad If: m_3 < x \leq m_1 \tag{2}$$

$$Y = n_3 \qquad If: x \leq m_3 \tag{3}$$

$$Y_1 = Y \times h \tag{4}$$

Where; Y, represents the unit payout amount; x is the observed rainfall value; m_1, m_2, and m_3 correspond to Trigger Value 1, Trigger Value 2, and the Exit Value, respectively; n_1, n_2, and n_3 represent Payout Value 1, Payout Value 2, and the Maximum Payout, respectively. h indicates the insured area, and Y_1 is the total payout amount.

For example, if a crop's insured area is 2 hectares and the observed rainfall during the sowing stage is 120 mm—below the maximum trigger value of 200 mm—it falls within the range between Trigger Value 2 (150 mm) and the Exit Value (100 mm). The unit payout amount can be calculated using formulas (2) and (4) as follows:

Unit Payout Amount= (200−150)×50+(150−120)×80=4900 INR
Total Payout Amount= 4900×2=9800 INR
Converting this into USD (assuming 1 USD = 82 INR):
Unit Payout Amount: 4900÷82≈59.76 USD
Total Payout Amount: 9800÷82≈119.51 USD
So, the unit payout amount is approximately 59.76 USD, and the total payout amount for 2 hectares is approximately 119.51 USD.

The payout calculation for the excess rainfall index is similar to that for the deficient rainfall index, with the primary difference being the observation period. For the excess rainfall index, the trigger is met when the cumulative rainfall over any two days reaches the threshold, whereas the deficient rainfall index uses the cumulative rainfall over a period of 30 to 50 days. Additionally, the drought index insurance (CDD), which uses consecutive drought days as the trigger, operates on the same principles as rainfall-based index insurance. The difference lies in using the number of drought days as the trigger, while the rest of the calculation follows the same method as the deficient rainfall index.

India's weather index insurance integrates weather parameters designed with a staged linear trigger mechanism that accounts for the varying growth characteristics of crops, different stages of development, meteorological risks, and seasonal variations. This approach allows for more accurate measurement and distribution of weather risks, while also improving the precision and practicality of insurance payouts.

4.5 Management system arrangements

1. Operational system

The operational system of India's RWBCIS is shown in Figure 2. Insurance companies are the core implementing entities of the scheme. Generally, agricultural insurance implementation can be categorized into two types: one is the direct operation model, represented by countries like China and the U.S., where insurance companies directly manage operations; the other is the cooperative or agency model, represented by Japan, where mutual aid organizations or agencies manage and operate on behalf of the government. India's agricultural insurance model is more aligned with the China-U.S. model, where insurance companies are the direct operators.

In India, six insurance companies participate in the weather index insurance scheme. Among them, AICI is the only state-owned insurance company, while the remaining five are private commercial insurance companies. The responsibilities of these insurance companies span multiple aspects of the agricultural insurance process, including promotion, underwriting, claims settlement, reinsurance, and public announcements. In addition, to further expand the coverage of the agricultural insurance scheme, insurance companies are also tasked with enhancing necessary infrastructure, such as building shared agricultural insurance databases that include crop yield and meteorological data.

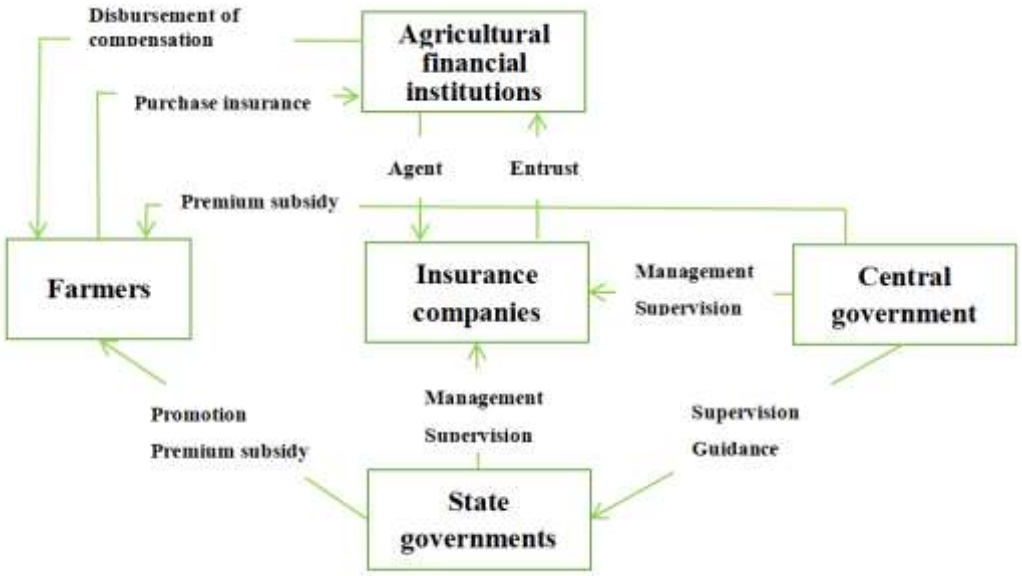


Figure 2- Operational System of India's RWBCIS

The agricultural insurance and credit risk management departments under India's central and state governments primarily play roles in providing guidance, support, and regulatory oversight. The central government's agricultural insurance and credit risk management department is mainly responsible for formulating and supervising the implementation of agricultural insurance schemes. This includes disbursing central government financial subsidies, conducting CCE experiments according to the crop calendar and uploading the data for automatic claims calculation, coordinating with the Indian Meteorological Department to provide weather data to insurance companies in a timely manner, establishing a national-level oversight committee to ensure that state governments disburse premium subsidies on time, and evaluating the business performance of insurance companies while implementing corresponding penalty mechanisms.

The functions of the relevant state government departments primarily include timely disbursement of subsidies to insurance companies, directly guiding and supervising the activities of insurance companies, promoting agricultural insurance products to farmers, and raising awareness of the importance of insurance in stabilizing agricultural production.

In the operation of agricultural insurance in India, banks and other agricultural financial institutions directly involved in the sale of insurance products play a key role. These institutions have an agent-principal relationship with the insurance companies. In each state, local banks leverage their extensive and precise network channels spread across county, district, town, and village administrative units to sell crop insurance on behalf of AICI. Meanwhile, small private financial institutions and cooperatives typically act as agents for private commercial insurance companies in offering agricultural insurance products.

Overall, the primary responsibility of banks and financial institutions is to provide sales channels for agricultural insurance, create digital records for each insured farmer using detailed information from the National Crop Insurance Portal, and disburse compensation to affected farmers strictly according to the crop calendar timeline.

As described above, in India's crop weather index insurance operational system, insurance companies, the central government, state governments, and agricultural financial institutions each have distinct roles and work in coordination. This multi-stakeholder mechanism helps distribute risk, enhancing the sustainability and stability of agricultural insurance. Additionally, the collaborative oversight mechanism balances the interests of all parties, improving the operational efficiency and fairness of agricultural insurance.

2. Regulations on supervision and constraints

First, the insurance process time constraint mechanism. Before the start of each crop season, India's agricultural insurance and credit risk management departments collaboratively prepare the main crop calendar, taking into account historical crop planting experiences, weather conditions in cultivated areas, data from on-field experiments, and previous insurance processes. The goal is to standardize the insurance operation process. During the formulation, relevant technical departments within agricultural insurance and credit risk management not only consider general agricultural climate conditions, rainfall distribution, irrigation

and water availability for farmland, appropriate sowing methods, and crop varieties, but also impose time constraints on agricultural production activities. These constraints aim to minimize adverse selection and moral hazard as much as possible. The crop calendar is also published on India's National Crop Insurance Portal.

As shown in Table 4, the crop calendar provides detailed regulations on a series of processes for implementing the crop weather index insurance plan, specifying the timeline for each process and the responsible agencies. The crop calendar primarily includes the timeline for drafting bid documents, the start and end dates for farmer enrollment, mandatory deadlines for phased disbursement of premium subsidies by various government levels, and the procedures and timelines for Crop Cutting Experiments (CCE). For each crop, the enrollment deadline should be based on the previous crop calendars of the region. Typically, for spring (Kharif) crops, the deadline is no later than July 15, and for autumn (Rabi) crops, no later than December 15.

By establishing the crop insurance calendar, two key objectives are achieved: first, it clarifies the responsibilities and obligations of all stakeholders involved in advancing the crop weather index insurance plan; second, it imposes time constraints on critical processes. This structured approach helps prevent stakeholders from shifting responsibility or prolonging timelines, which could reduce the window for farmer compensation. Consequently, the timeliness of insurance payouts is improved to a certain extent.

Second, the supervision and penalty mechanism. To ensure that insurance procedures are strictly followed and to improve the timeliness of insurance payouts, the central government of India has established supervisory constraints on key time points in the insurance process. If any state government extends the deadline for the relevant procedures, the central government will not provide the central share of the premium subsidy for that region. In other words, if there is a delay in any stage of the insurance process, the respective state government must bear the full responsibility for the premium subsidy as well as any additional costs incurred due to the delay. If the state government takes more than 30 days to submit the relevant data to the insurance company, causing the company to be unable to pay the insurance claims to the farmers within the stipulated time, the state government must pay a punitive interest of 12%.

Table 4- Key Processes of India's Crop Weather Index Insurance Plan

No.	*Key Process*	*Spring Season (Kharif)*	*Autumn Season (Rabi)*	*Participating Agencies*
1	CCE (Crop Cutting Experiment)	September 15 (previous year)	March 15 (current year)	Government agencies, insurance companies
2	Release of notification for crops, regions, premium amounts, etc.	November 5 (previous year)	June 1 (current year)	Government agencies
3	Disbursement of the first premium subsidy installment	March 15 (current year)	September 15 (current year)	Government agencies
4	Enrollment for insurance	April 1 (current year)	October 1 (current year)	All participating entities
5	Generation of basic insurance data	July 31 (current year)	December 31 (current year)	Insurance companies
6	Disbursement of the second premium subsidy installment	Within 15 days after approval of business data and receipt of the insurance company's application	Same as Kharif	Government agencies, insurance companies
7	Payout timeframe	Within two weeks after approval or automatic authorization of payouts	Same as Kharif	Insurance companies
8	Disbursement of the final premium subsidy installment	After approval and reconciliation on the website	Same as Kharif	Government agencies

Source: Raju et al. 2016; Singh, 2024; Singh & Agrawal, 2020; National portal of India, 2024.

In addition to using fines to ensure that relevant institutions advance the claims process on time, the Indian government employs a phased disbursement of premium subsidies as a supervisory measure. The government's premium subsidy is

distributed in three phases: aside from the first installment, which is disbursed before the insurance purchase, the second and third installments are only released after the final verification of agricultural insurance data by various levels of government and after the approval and reconciliation on the NCIP website are completed. This supervisory and penalty mechanism not only encourages insurance companies to process claims promptly, ensuring the timeliness of payouts but also significantly reduces the likelihood of moral hazard among the implementing entities.

Third, the automatic claim approval mechanism. The Indian government imposes strict time limits on various stages of the insurance process, and if certain key processes are not completed within the specified time, they will enter an automatic approval procedure. This is particularly relevant for the data and preliminary preparations required for claims; if any implementing entity delays the claims process, the automatic approval mechanism can effectively ensure the timeliness of claims. The "Guidelines for the Crop Weather Index Insurance Scheme" explicitly reference the specific implementation details of PMFBY in this regard. According to the automatic claim approval mechanism under PMFBY, if a state government fails to submit yield data to the agricultural committee within a month after the harvest of a specific crop, the insurance company will use technologically synthesized yield data to calculate the payout amount and subsequently pay eligible farmers. In the context of weather index insurance, the data required from the government by the insurance companies includes meteorological data and pre-cultivation crop survey data, among others. If the submitted crop survey data is not approved within the specified time, it will be automatically approved and directly used for claim calculation.

4.6 Performance analysis

India's Weather Index Insurance has demonstrated significant achievements in areas such as coverage, claims settlement timeliness, farmer satisfaction, and sustainability, while also revealing certain areas needing improvement.

In terms of coverage, the number of insured farmers rose from 150 million in 2016 to 250 million in 2022, increasing the proportion of insured agricultural households from 20% to 33%. As shown in Figure 3, although the overall number of participants has grown steadily, there are notable regional disparities. High-coverage regions such as Punjab and Haryana boast insurance rates exceeding 50%, whereas the northeastern and remote rural areas report coverage rates below 20%. This disparity highlights the need for enhanced policy support and targeted awareness campaigns in underserved regions to address the imbalance.

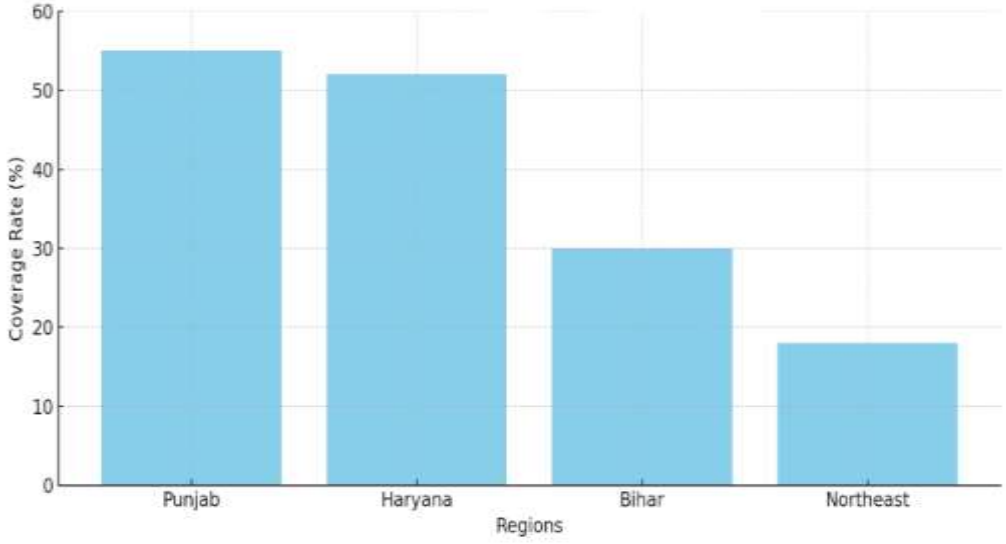


Figure 3- Coverage Rate by Region
Source: Murthy et al. 2024; Singh, 2024; National Portal of India, 2024

The timeliness of claims settlement serves as a critical indicator of the insurance mechanism's operational efficiency. Figure 4 illustrates that between 2020 and 2022, the rate of timely claim settlements improved from 75% to 85%, with the average delay in payouts decreasing from 30 days to 20 days. This improvement is largely attributable to the introduction of automated approval mechanisms, particularly in the crucial stages of weather data collection and analysis. Nevertheless, challenges persist, with delayed claims still occurring due to bottlenecks in data submission and verification processes in certain regions. This underscores the importance of optimizing data collection and transmission workflows, alongside strengthening infrastructure, as key steps to further improve settlement efficiency.

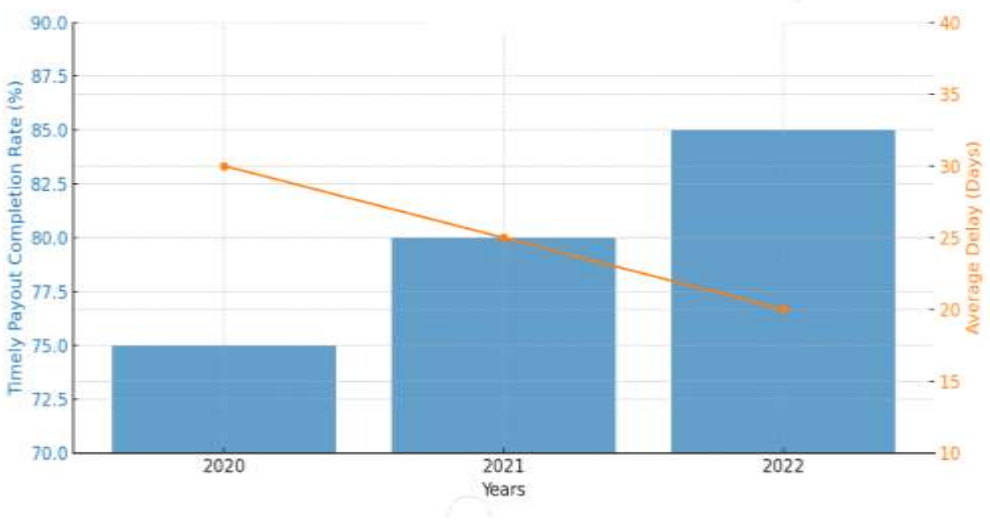


Figure 4- Timely Payout Completion Rate and Average Delay
Source: Lawrence et al. 2023; Singh 2024; National Portal of India 2024

Despite the consideration of farmers' needs in the design of weather index insurance policies, satisfaction levels with its implementation vary widely. Many farmers report discrepancies between meteorological data and actual losses, leading to inadequate compensation that falls short of covering real damages. This gap arises from the inherent limitations of weather index models, which, while effective at capturing broad trends, may fail to account for localized weather anomalies or microclimatic variations. Additionally, insurance companies often struggle to communicate the intricacies of these products to farmers in an accessible manner. Insufficient explanations about coverage terms, claims processes, and payout calculations leave many farmers confused and frustrated. This lack of transparency has undermined trust in the insurance system, with some farmers viewing it as unreliable or even exploitative.

From an economic efficiency perspective, weather index insurance has demonstrated its value in reducing risk exposure for both the government and farmers. By transferring weather-related risks to the insurance sector, farmers can stabilize their incomes, allowing them to invest more confidently in agricultural inputs and innovation. Meanwhile, the profitability of insurance companies has improved, incentivizing greater private sector participation in agricultural insurance. The inflow of private capital has contributed to the expansion and diversification of the insurance market, fostering innovation in product design and delivery mechanisms.

However, the sustainability of this system remains a pressing concern. Government subsidies play a pivotal role in ensuring affordability for farmers, but their scale raises questions about long-term viability. In 2022, government contributions accounted for over 60% of the total premium pool, creating a dependency that obscures underlying market risks. Furthermore, the increasing frequency and severity of extreme weather events driven by climate change present a formidable challenge. These events not only escalate the cost of claims but also heighten the uncertainty faced by insurers, straining the financial stability of the insurance fund. In the absence of comprehensive risk mitigation measures and enhanced reinsurance mechanisms, the system's capacity to cope with future shocks could be severely tested.

Addressing these issues requires a multifaceted approach. Bridging the gap between meteorological indices and actual damages calls for more localized and granular data collection, coupled with advanced modeling techniques. Efforts to build farmers' trust in the system should focus on improving the clarity and accessibility of insurance products, leveraging local networks and communication channels to engage with rural communities effectively. To enhance sustainability, transitioning toward a more balanced risk-sharing framework that gradually reduces dependence on government subsidies is essential. Additionally, integrating climate resilience strategies into the insurance framework—such as investing in disaster risk reduction and adaptation measures—can mitigate the escalating risks posed by climate change, ensuring the long-term stability and effectiveness of weather index insurance in India.

Overall, India's weather index insurance has proven to be an important policy tool aimed at mitigating agricultural risks and stabilizing farmers' incomes, achieving notable success in expanding coverage, improving claims efficiency, and enhancing economic benefits. Through the collaborative efforts of the government, insurance companies, and financial institutions, the system has established an effective operational model driven by precise data and automated approval mechanisms. However, challenges remain, including regional disparities in coverage, the disconnect between compensation amounts and actual losses, insufficient farmer trust, and the long-term sustainability risks posed by climate change. India's case presents significant research

value and offers valuable insights for global application, particularly for developing countries seeking to address agricultural vulnerabilities and climate-related risks.

5. Discussion and Implications for Global WII Development

India's successful implementation of Weather Index Insurance (WII) offers valuable insights for the global development of WII, particularly through its integration with traditional crop yield insurance. By combining multiple insurance products tailored to the specific climatic and agricultural conditions of different regions, India has created a multi-layered, complementary agricultural insurance system (Parthiban & Anjugam 2023). This model demonstrates that a single type of insurance often fails to address the diverse needs of farmers, especially in regions with significant climate variability (Singh 2024). Other countries can adopt similar approaches to diversify their insurance products, providing more customized coverage for farmers in different agricultural zones.

A critical component of India's success is the establishment of robust data platforms and transparent information systems, exemplified by the National Crop Insurance Portal. This platform enables real-time data sharing among farmers, insurance companies, and government agencies, ensuring the efficiency and transparency of the insurance process (Singh & Agrawal 2020). Developing countries, particularly those lacking comprehensive data infrastructure, can learn from India's example and invest in building transparent, shared data platforms to enhance the accessibility and effectiveness of WII. Such platforms also promote trust and confidence in the insurance system, which is crucial for widespread adoption.

Furthermore, India's continuous innovation in product design, particularly through the development of flexible payout mechanisms, has been instrumental in reducing basis risk. By incorporating region-specific climate characteristics and crop growth stages, India has been able to provide more accurate and timely payouts (Dileep & Kotreshwar 2023). This approach is essential for ensuring fairness and efficiency in weather index insurance, and other countries can benefit from adopting similar strategies. Additionally, India's emphasis on smallholder farmers and regions prone to climate-related disasters highlights the importance of targeting vulnerable populations, ensuring that WII provides protection to those most in need. Through these lessons, other nations can effectively adapt WII to their local contexts, improving agricultural resilience and risk management.

5.1 Implications for developing countries

India's on-going in WII experience highlights the critical importance of adapting insurance policies to the diverse agricultural and climatic environments of developing countries. Unlike conventional yield-based insurance, WII provides a simplified and cost-effective model based on predefined weather triggers (Punia et al. 2021; Singh & Agrawal 2020). However, its success hinges on the alignment of insurance products with the local realities of farming practices, socio-economic conditions, and regional climate profiles. In this regard, India's phased approach to product development and contextual customization has demonstrated how insurance can effectively address the specific needs of diverse agro-climatic zones, making it a model worth emulating.

A key lesson from India lies in its innovative use of segmented payout mechanisms to address the pervasive issue of basis risk. By incorporating multiple weather triggers corresponding to different growth stages of crops, India's WII reduces discrepancies between payouts and actual losses (Dileep & Kotreshwar 2023). Developing countries with varied cropping systems and irregular weather patterns can adopt similar mechanisms to enhance payout accuracy and credibility. Moreover, integrating localized climate data and crop calendars into insurance frameworks further ensures that insurance products resonate with farmers' realities and mitigate potential misalignments between weather parameters and actual losses.

Public-private partnerships (PPPs) have been instrumental in the success of India's WII program, offering a blueprint for developing countries seeking to expand insurance coverage. The government's role in providing subsidies, regulatory oversight, and infrastructure has complemented private insurers' expertise in operational efficiency and product innovation. Such collaboration has allowed India to balance public welfare objectives with market-driven efficiency (Agarwal et al. 2023). For other countries, fostering PPPs can unlock the full potential of WII by leveraging public resources to de-risk private investments while ensuring that products remain accessible and affordable for smallholder farmers.

The integration of digital platforms and data transparency has been a cornerstone of India's WII implementation, highlighting the transformative potential of technology in overcoming operational challenges. Centralized databases for meteorological and agricultural data have not only streamlined claims processing but also built trust among stakeholders by ensuring transparency (Patwari et al. 2024). Developing countries can benefit from investing in similar digital platforms, which can serve as both operational tools and educational resources. By providing farmers with clear, real-time information about insurance processes and benefits, these platforms can significantly enhance enrollment rates and satisfaction.

Accurate meteorological data is indispensable for the effective operation of WII, and India's focus on improving its weather monitoring infrastructure offers valuable insights. Developing countries often face challenges in this area due to the lack of

sufficient weather stations and inconsistent data collection. Addressing these gaps through targeted investments in meteorological networks, including the installation of automated weather stations and the integration of satellite-based data systems, is critical. Strengthening meteorological capabilities not only improves the precision of WII products but also lays the foundation for broader climate resilience initiatives.

Lastly, the success of WII in developing countries will depend on fostering financial inclusivity and promoting farmer education. Many smallholder farmers lack access to financial services and often face barriers to understanding insurance products. India's efforts to combine subsidized premiums with targeted outreach programs have demonstrated how financial and informational barriers can be mitigated. For developing countries, prioritizing financial literacy campaigns and simplifying insurance procedures can ensure that WII becomes a viable and trusted tool for rural communities.

India's case underscores the transformative potential of WII in addressing agricultural risks in developing countries. However, successful adoption requires a holistic approach that incorporates context-specific design, robust partnerships, technological advancements, and inclusive policies. By learning from India's innovations and addressing the unique challenges of their agricultural sectors, developing countries can leverage WII to enhance agricultural resilience and contribute to the broader goal of food security in an era of increasing climate uncertainties.

5.2 Implications for challenges of WII development

While India's experience has greater generalizability, a critical discussion of the potential problems in its development process is essential for adapting to the challenges facing the development of WII worldwide. India has achieved significant success in promoting WII, however, its experience also reveals potential limitations and challenges that may arise in other countries and regions, particularly those with different agricultural environments and climate conditions.

Basis risk remains a major challenge for the global promotion of WII. Although India has improved payout accuracy by introducing a multi-stage payout mechanism and region-specific climate characteristics, this approach still cannot completely eliminate basis risk, particularly with the intensification of climate change and the increasing frequency of extreme weather events (Dileep & Kotreshwar 2023). The vast differences in climate characteristics and agricultural production systems across regions make it difficult to design a universally applicable WII product. Global WII promotion must adopt more personalized designs tailored to different climates and agricultural environments, implementing flexible adjustment mechanisms to cope with the uncertainties in climate and agricultural production (Singh 2024).

Data infrastructure is another critical issue in the global development of WII. Despite India's success in establishing robust data platforms and meteorological monitoring systems, many developing countries still face significant barriers due to insufficient weather stations and inconsistent data collection. The quality and coverage of meteorological data directly affect the accuracy and fairness of WII products. A lack of precise weather data may lead to significant discrepancies between payout standards and actual losses (Dileep & Kotreshwar 2023). To address this issue, global WII projects need to strengthen meteorological data collection and analysis, particularly in regions with weaker meteorological monitoring facilities. Moreover, the high costs associated with acquiring and processing weather data may make it challenging for low-income countries to bear these investments.

The participation of smallholder farmers and vulnerable areas must be prioritized in the global context. Although India's WII program has made progress in assisting smallholder farmers and rural areas, barriers such as limited insurance awareness and payment capacity continue to pose significant challenges. In regions with information asymmetry and a lack of financial education, the effective promotion of WII faces considerable difficulties (Agarwal et al. 2023). To enhance participation, global WII initiatives should focus on financial education and transparency, simplifying insurance products to make them more accessible and understandable for low-income farmers. Additionally, while India's subsidy policies have improved participation in the short term, long-term reliance on government subsidies may not ensure the sustainability of the insurance system.

Finally, collaboration between the government and the private sector plays a crucial role in the sustainable development of WII. India's success demonstrates that public-private partnerships (PPPs) can effectively combine government policy support with private sector market operations, improving coverage and efficiency in WII projects (Patwari et al. 2024). However, in many countries, governments may face fiscal constraints and may not be able to provide sufficient subsidies or infrastructure support, while private companies may hesitate to invest due to high costs or market risks. As such, global WII promotion may require more innovative cooperation models, particularly in resource-poor countries and regions, to develop flexible financial products and support mechanisms to ensure the widespread and sustainable adoption of weather index insurance.

In conclusion, while India's WII practices offer valuable lessons for global development, there are several challenges in its widespread adoption. Issues such as basis risk, data infrastructure, participation, and public-private collaboration may limit the global application of WII. Therefore, the global promotion of WII should focus on context-specific design, flexible policy

support, precise data infrastructure, and financial inclusivity to ensure that this tool can effectively contribute to agricultural risk management worldwide.

6. Conclusions

India's experience with Weather Index Insurance (WII) offers valuable insights for global agricultural risk management, particularly in its integration with traditional crop yield insurance, forming a multi-layered and complementary agricultural insurance system. India's experience indicates that a single type of insurance is often insufficient to address the diverse needs of farmers in different regions, especially in areas with significant climate change impacts and agricultural diversity. Therefore, other countries can learn from India's approach by offering diversified insurance products that provide more targeted protection.

However, despite the significant achievements of India's WII system in expanding coverage, improving claim efficiency, and enhancing farmers' economic benefits, several challenges remain. First, weather-indexed insurance products still face basis risk, especially as extreme weather events become more frequent. How to further improve the accuracy of payouts and reduce the gap between weather indices and actual losses remains a critical issue (Tiwari et al. 2020). Additionally, although the Indian government has improved transparency through digital platforms and information systems, the lack of data infrastructure in remote areas continues to be a significant constraint on the widespread adoption of WII (Patwari et al. 2024).

Moreover, while India's model emphasizes smallholder farmers and regions severely affected by climate change, the participation and awareness of these groups in the insurance system still need further enhancement. To overcome this barrier, India's policy design needs to pay more attention to demand-side considerations, rather than solely relying on supply-side drivers (Tiwari et al. 2020). In this context, promoting farmer education and improving information transparency, particularly in terms of how modern technologies can enhance understanding and participation in insurance, is particularly crucial.

This study also highlights some limitations within India's WII system, particularly regarding payout timeliness and farmers' trust. Despite improvements, delays in payout still occur in some regions. This issue suggests that the future development of WII requires further optimization of data collection and processing workflows to enhance the efficiency and reliability of the entire system.

From an application perspective, efforts should be made to enhance farmer education and promotion to improve awareness and demand for weather index insurance, especially among smallholder farmers in remote areas. Secondly, India's experience shows that relying solely on a supply-side driven insurance model does not ensure broad coverage; therefore, a greater emphasis should be placed on demand-side drivers through agricultural extension services to boost farmer participation. By collaborating with local agricultural cooperatives and industry bodies, insurance products can be promoted at the grassroots level.

Additionally, future research should further explore the integration of WII with other risk management tools, such as savings, microfinance, or social protection mechanisms, to provide more comprehensive protection for farmers (Martínez Salgueiro, 2019; Doherty et al. 2021). Technological advancements, particularly the integration of artificial intelligence, blockchain, and satellite data, will help improve the accuracy of climate data and the transparency of payouts, which is crucial for increasing farmers' trust.

Overall, India's WII model provides valuable lessons for other developing countries, particularly in how to integrate climate change risk management into agricultural insurance systems. However, WII products must be flexible and customized to local conditions, taking into account specific climatic, agricultural, and socio-economic characteristics, to effectively address the challenges posed by global climate change.

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