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Actuarial Pricing of Climate-Linked Agricultural Insurance and Its Impact on Household Poverty Vulnerability (China)

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ABSTRACT
Climate change has intensified the frequency of droughts, floods, and extreme weather in China's rural areas, raising the actuarial challenges of pricing agricultural insurance. This literature review examines how actuarial pricing methods address climate-linked risks in Chinese agriculture and how insurance pricing influences both the uptake of insurance by smallholder farmers and household poverty vulnerability. We detail the evolution of pricing strategies – from traditional premium calculations based on historical loss data to innovative index-based models – and how these are shaped by government interventions such as premium subsidies and regulatory frameworks. Findings from empirical studies indicate that substantial government subsidies (covering ~80% of premiums) have made insurance affordable, significantly increasing farmer participation mdpi.com. Increased insurance uptake, in turn, contributes to income stability and long-term poverty reduction in rural households. However, issues like basis risk, low coverage levels, and regional disparities remain. The review highlights that effective actuarial pricing, supported by targeted subsidies and climate adaptation measures, is critical to enhancing the protective role of agricultural insurance. The paper concludes with policy recommendations on refining pricing models and subsidy schemes to improve insurance effectiveness in reducing poverty vulnerability under climate change.

KEYWORDS
Agricultural insurance; Household poverty; Climate-linked

1 Introduction

Agricultural production in China faces severe climate-related risks, including frequent droughts, floods, and typhoons that threaten crop yields and rural livelihoods. Managing these risks is essential for China's food security and poverty alleviation efforts. Agricultural insurance has emerged as a vital risk transfer tool to safeguard farmers against weather-induced losses. Since the introduction of policy-supported agricultural insurance subsidies in 2007, China's agricultural insurance market has experienced leapfrog growth. By 2024, China's annual agricultural insurance premium income had reached roughly CNY 150 billion, making it the largest agricultural insurance market globally. This expansion, backed by government subsidies often covering 70 – 80% of premiums, has provided risk protection to hundreds of millions of farming householdsmdpi.com.

Despite these strides, key challenges persist. Actuarial pricing of agricultural insurance must account for increasing climate volatility, which complicates the estimation of pure premium rates and catastrophe loads. If insurance premiums are set too high (reflecting heightened climate risk), smallholder farmers may find policies unaffordable, undermining the goal of broad coverage. Conversely, underpricing or heavy subsidization raises questions of fiscal sustainability and potential moral hazard. Importantly, the effectiveness of agricultural insurance is ultimately measured by its impact on farmers' welfare – particularly whether it reduces households' vulnerability to falling into poverty after climate shocks. In the Chinese context, where rural revitalization and poverty reduction remain national priorities, understanding this linkage is crucial.

This paper provides a comprehensive review of: (1) actuarial pricing methods used for climate-linked agricultural insurance in China, (2) how insurance pricing and subsidy policies affect accessibility and uptake among smallholder farmers, and (3) the empirical evidence on agricultural insurance's influence on household poverty vulnerability. The role of government – through premium subsidies, regulations, and climate adaptation initiatives – is discussed as a cross-cutting factor shaping insurance pricing and effectiveness. The review is structured as follows. The Literature Review surveys methodologies for pricing climate risks and findings on insurance uptake and poverty outcomes. The Methodological Framework section presents a conceptual model linking climate risk, pricing, insurance uptake, and poverty vulnerability (Figure 1). The Discussion synthesizes insights and policy implications, and the Conclusion offers closing observations and recommendations.

2 Literature Review

2.1 Actuarial Pricing Methods for Climate-Linked Risks in China

Actuarial pricing of agricultural insurance in China traditionally begins with determining the *pure premium* – the expected annual loss cost – of a given crop insurance policy. This involves analyzing historical loss data (e. g. yield reductions or indemnity payouts) to estimate the probability distribution of losses. For climate-linked risks, where losses

are driven by weather extremes, actuaries increasingly use disaster risk modeling alongside historical data. Recent studies highlight a shift toward *risk-differentiated premium rates* that reflect regional hazard variability. Wu *et al.* (2023) develop an integrated disaster risk index for floods, droughts, and typhoons at the county level and calculate corresponding risk-based premium rates, revealing significant regional differences. Counties in parts of Inner Mongolia, Jilin, and Hunan, for example, were found to require extremely high actuarial rates due to their elevated climate risk exposure. Such work underscores the need to move beyond one-size-fits-all pricing; instead, premiums should incorporate local risk indicators to remain actuarially sound and fair.

However, accurate climate risk pricing faces data and modeling challenges. High-quality long-term disaster loss data at granular levels are needed. China's National Disaster Reduction Center has begun providing detailed county-level disaster datasets (2015 – 2021) that improve loss estimations. Actuarial models also grapple with non-stationarity in climate risk – past frequency of extreme weather may not fully predict future risk under climate change. To address catastrophic risk, Chinese insurers and regulators often impose an upper limit on premium rates or use catastrophe loadings and reinsurance. The China Banking and Insurance Regulatory Commission (CBIRC) in 2023 issued trial Regulations on Agricultural Insurance Actuarial Practices emphasizing that comprehensive premium rates should not exceed 20% of the sum insured. This effectively caps premiums for farmers, with the understanding that additional risk costs must be absorbed via government subsidies or reinsurance support. By limiting premium rates, regulators aim to maintain affordability in high-risk regions while still ensuring insurers price policies to cover expected losses.

Index-based insurance products have been piloted as another actuarial innovation to handle climate risks. Instead of indemnifying actual crop loss, index insurance ties payouts to a weather index (e.g. rainfall deficit or area-average yield), which simplifies pricing and reduces administrative costs. Actuarially, the premium for index insurance is based on the probability distribution of the index (such as rainfall levels) and its correlation with losses. While index insurance allows faster payouts and lower costs, basis risk – the risk that the index does not perfectly correlate with an individual farmer's loss – can undermine farmer trust. In China, weather index insurance trials (for example, for drought in northwestern provinces) have shown mixed results: though technically feasible to price using meteorological data, farmers remain wary if payouts occasionally fail when they experience losses. Thus, actuarial pricing methods must balance technical rigor with product designs that are understandable and acceptable to farmers.

In summary, China's approach to pricing climate-linked agricultural insurance is evolving. The literature reflects a movement toward refined, region-specific rate setting grounded in disaster risk assessment. Actuarial models now incorporate climate science inputs and probabilistic simulations (e. g. probable maximum loss estimation) to handle extreme eventsmdpi.com. Still, government oversight ensures that premiums remain capped for the farmer's sake. The next challenge is integrating climate change trends into pricing – a task that demands continual data updates and perhaps scenario-based pricing to ensure long-term solvency of insurance schemes.

2.2 Insurance Pricing, Accessibility, and Uptake among Smallholder Farmers

Insurance uptake by smallholder farmers is highly sensitive to premium pricing. Numerous studies confirm that lowering the effective premium paid by farmers – often through subsidies – substantially increases insurance participation. In China, the central and provincial governments have heavily subsidized crop insurance premiums since 2007, typically covering around 80% of the total premium costmdpi.com. As a result, farmers usually pay no more than 20% of the actuarial premium out-of-pocket, and in some poor regions farmers pay as little as 10%. This massive subsidy effort has directly improved the affordability of insurance, driving the rapid uptake observed over the past decade. By 2018, the planting area insured reached 1.5 billion mu (100 million hectares), about 70% of the country's staple grain crop area. Such breadth of coverage would have been unattainable without pricing policies that deliberately lower farmers' costs.

Government subsidies and pricing regulations thus play a dual role: they make insurance accessible for farmers, but they also shape farmer perceptions. When insurance is offered at a fraction of its true actuarial cost, farmers may question its value or the government's role. Institutional trust becomes vital. A recent survey in Jiangsu province (Jiang *et al.*, 2025) found that trust in government and insurers significantly influenced farmers' decisions to purchase insurance. The credibility imparted by a government-backed subsidy program can alleviate farmers' fears of insurer default or non-payment. Additionally, timely and fair claim payouts help reinforce the perception that insurance is worthwhile. Empirical evidence shows that when farmers observe prompt claim settlements (for example, after a flood or hailstorm), their likelihood of continuing or expanding insurance coverage rises. In contrast, complex claim processes or delayed payments can erode trust, counteracting the positive effect of low premiums.

Pricing structure also affects uptake in more nuanced ways. Some studies suggest that even a short delay in premium payment can improve adoption – for instance, allowing farmers to pay the premium after harvest rather than at planting time can increase participation rates. This highlights that liquidity constraints and timing are as important as the premium amount itself for cash-constrained smallholders. Moreover, the literature on *inclusive insurance* indicates that reaching the poorest farmers may require not just subsidies but also simplified products and enrollment processes. In China's targeted

poverty alleviation programs, complementary measures such as premium waivers for registered poor households and bundling insurance with agricultural loans have been tried to encourage the most vulnerable farmers to enroll. These interventions recognize that even a 20% share of the premium can be a barrier for extremely low-income families. Indeed, inclusive agricultural insurance programs have been found to raise rural household consumption by stabilizing income, though their positive effect is notably weaker in areas with very high climate risk (where uninsured losses may still occur or basis risk is an issue).

Table 1 summarizes key studies on insurance pricing and farmer uptake in China. Across diverse contexts, a common finding is that reducing the cost burden on farmers – whether via direct subsidies, innovative payment schedules, or community-based schemes – leads to higher insurance take-up. However, it is also evident that non-price factors (education, risk awareness, social norms) influence participation. For example, Jiang *et al.* (2025) identified psychological factors (risk perception, attitudes, and subjective norms) as significant determinants of purchase intention, beyond the objective price of insurance. This suggests that while actuarial pricing and subsidies create the necessary economic conditions for high uptake, they must be complemented by farmer education and trust-building to achieve widespread adoption of agricultural insurance.

Table 1 Key studies on agricultural insurance pricing, uptake, and impacts in China

Study (Year)	Data & Methodology	Key Findings
Wu *et al.* (2023)	County-level disaster loss data (2015–21); actuarial modeling of risk-index-based premiums.	Developed integrated flood/drought/typhoon risk index for each county to set risk-differentiated premiums. Identified 63 counties with extremely high indicated premium rates, reflecting spatial concentration of climate risk. Highlighted need for regionalized pricing to improve rate accuracy and fairness.
Hu *et al.* (2024) mdpi.com	Field survey of 7 grain-producing counties; welfare model of subsidies (Jiangsu province).	Found an inverted U-shaped relationship between subsidy rate and farmers' welfare. Current ~80% subsidy maximizes net welfare gains; increasing subsidy to 90% yields diminishing returns and deadweight loss. Implies that China's ~80% premium subsidy is near-optimal for balancing farmer benefit and fiscal cost.
Jiang *et al.* (2025)	608 farmer questionnaires (Jiangsu); structural equation modeling (TPB & PMT frameworks).	Insurance uptake is driven by risk perception (threat appraisal) and cost–benefit assessment. High premium or "response cost" deters purchase. Institutional trust (in government/insurers) significantly boosts willingness to enroll and converts intention into actual uptake. Recommends strengthening farmer education and trust to complement subsidy-driven affordability.
Wang & Zhong (2025)	Panel data (2004–21) for 31 provinces; fixed-effects and mediation models.	Every 1-unit increase in agricultural insurance "contribution" (premium density) led to ~ 8.99% growth in agricultural GDP, evidencing insurance's protective role in the agri-economy. Insurance impact was stronger in eastern, non-major grain regions and in years with lower disaster incidence. Suggests insurance promotes investment and productivity, thereby indirectly reducing poverty.
Zheng *et al.* (2025)	National panel data (2011–2020) on rural consumption and insurance; threshold regression.	Inclusive agricultural insurance significantly increased rural household consumption (via income stabilization), but the positive effect was weaker in provinces with very high climate risk. Indicates diminishing marginal impact of insurance where climate shocks are extremely frequent or severe, possibly due to remaining uninsured losses or basis risk.
Zhang & Wang (2025)	Game-theoretic model (government–farmer–insurer) comparing subsidy schemes.	Under "subsidize farmers" (premium subsidy) versus "subsidize insurers" (cost subsidy) scenarios, found that solely subsidizing farmers can prompt insurers to raise premiums or limit coverage to remain profitable. A shift to subsidizing insurers' operating costs ensures insurers can offer new or higher-risk crop insurance without charging farmers more. Recommends balancing subsidy to sustain insurer participation in underserved markets (e.g., specialty crops).

2.3 Agricultural Insurance and Household Poverty Vulnerability

A central question in the literature is whether agricultural insurance actually reduces households ' vulnerability to poverty. In theory, by providing compensation after shocks and encouraging investment, insurance should prevent farmers from falling into poverty due to adverse events. The empirical evidence from China largely supports this protective role. Studies consistently find that participation in agricultural insurance correlates with higher and more stable incomes, consumption smoothing, and improved livelihood outcomes among rural households. For instance, a recent provincial panel analysis concluded that agricultural insurance has a "significant poverty reduction and income-increasing effect," contributing to long-term poverty alleviation and rural economic growth. Similarly, a study on rural

household consumption found that insurance payouts help households maintain spending on food and essentials even after crop losses, thereby reducing the risk of transient poverty.

China's agricultural insurance expansion since 2007 coincided with a historic national poverty reduction campaign. Many researchers attribute part of the poverty alleviation success to risk management tools like insurance acting as a safety net. By 2020, extreme rural poverty was declared eliminated in China, and policy-based crop insurance is credited with playing a supporting role by safeguarding farmers' productive assets and income. Insurance encourages farmers to adopt higher-return (but riskier) farming practices, knowing that potential losses are covered. This can increase productivity and income over time, helping lift households above the poverty line. Additionally, insurance payouts post-disaster prevent households from resorting to drastic coping strategies (selling land, livestock, or pulling children from school), which can have long-term impoverishing effects.

However, the literature also points out conditions and limitations of the insurance-poverty linkage. One important consideration is the level of coverage. If insurance only covers a small fraction of the loss (due to low sum insured or high deductibles), its ability to shield households from poverty is limited. In early years, China's agricultural insurance was criticized for "wide coverage, low protection" – many farmers had insurance, but compensation levels were insufficient to fully restore losses. Recognizing this, the government launched pilots for full-cost insurance and income insurance in recent years, which insure a larger portion of farmers' input costs or even guarantee a target income. These products, though costlier, are aimed at providing deeper protection and thus greater poverty impact. Initial evidence from full-cost insurance pilots shows enhanced resilience: participating farmers recovered faster after disasters and did not fall behind on loan repayments or consumption needs.

Another factor is the timeliness and reliability of payouts, as noted earlier. If insurance fails to pay promptly, the household may still descend into poverty in the interim. Ensuring efficient claims processes – through measures like digital claims assessment (using remote sensing to speed up loss verification) – has been part of China's strategy to improve insurance effectiveness. Moreover, some research raises the issue of moral hazard and dependency: could generous insurance subsidies reduce farmers' incentives to adapt to climate change (e.g. by investing in irrigation or resilient crop varieties)? There is an ongoing debate. Some scholars argue that overly high subsidy rates (90% or above) might create inefficiencies and even encourage riskier behavior. In China's case, the prevailing subsidy (~80%) has been found to strike a reasonable balance, yielding net welfare gainsmdpi.com. Yet, calls have been made for *diversified subsidy schemes* that adjust support based on farm size or risk level – for example, providing higher subsidy for smallholders who are more vulnerable, and encouraging larger commercial farms to adopt more risk mitigation practices alongside insurance.

Overall, the evidence strongly suggests that agricultural insurance reduces the vulnerability of rural households to impoverishment by climate and disaster shocks. In China's context, insurance is considered a "safety net" and "springboard" – it not only catches families when disasters strike, but also gives them confidence to invest and improve their livelihood, contributing to poverty alleviation. As multiple studies affirm, the poverty reduction effect of insurance is generally positive and significant. The magnitude of this effect, however, depends on program design details: coverage level, premium burden on farmers, and integration with other rural development initiatives. The next section will further discuss the interplay of these elements, using a conceptual framework to illustrate how actuarial pricing, government policy, farmer uptake, and household outcomes are interlinked.

3 Methodological Framework

To synthesize the relationships discussed above, Figure 1 presents a conceptual framework linking climate risk, actuarial pricing, insurance uptake, and household poverty vulnerability in the Chinese context. Climate change and extreme weather increase the underlying risk in agriculture, which, in an actuarially fair scenario, *raises* the pure premium rates for insurance. Higher premiums, if passed directly to farmers, would normally *reduce* insurance uptake due to affordability constraints. However, government interventions – notably premium subsidies and pricing regulations – *reduce* the effective premium paid by farmers, thereby *improving access* and encouraging greater insurance uptake. In China, this mechanism is evident in practice: subsidies have kept farmer-paid premiums low, supporting high participation ratesmdpi.com.

Insurance uptake among farmers, in turn, *reduces* household poverty vulnerability by providing financial protection. When farmers are insured, they are less likely to experience catastrophic income shocks from climate disasters, which means they are less likely to fall into poverty or chronic destitution after such events. There is also a feedback loop: widespread insurance adoption can incentivize better risk management and potentially stabilize rural economies, further reducing vulnerability over time.

It is important to note that the dashed arrow in Figure 1 indicates that climate risks, if not managed by insurance or adaptation, *increase* poverty vulnerability – this highlights why insurance is needed in the first place. The framework also shows that the government's role (through subsidies and policies) is pivotal in counterbalancing the effect of rising

climate risk on insurance pricing. Without subsidies, actuarial premiums reflecting high climate risk could price out smallholders, leading to low uptake and greater vulnerability. Thus, effective actuarial pricing in a climate change era cannot be separated from policy context: in China's case, the state functions as a reinsurer and financier of last resort to ensure premiums remain within farmers' reach.

In methodological terms, this conceptual model aligns with findings from both quantitative studies (e.g. econometric analyses of subsidy effects on insurance demandmdpi. com) and qualitative insights from policy evaluations. It underscores a systems perspective: the impact of agricultural insurance on poverty is mediated by pricing and uptake, which are themselves influenced by climate factors and policy choices. Future research can use this framework as a basis for modeling the dynamic interactions – for example, simulating how changes in subsidy levels or climate risk would ultimately affect poverty outcomes in rural China.

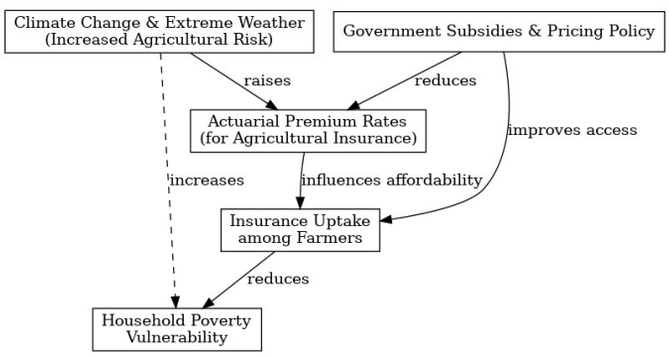

Figure 1

4 Discussion

The reviewed literature paints a comprehensive picture of how actuarial pricing, policy intervention, and climate risk intersect to determine the success of agricultural insurance in China. One key insight is the delicate balance between financial sustainability and social equity in insurance pricing. Actuaries must price premiums high enough to cover increasing climate-induced losses, yet if those premiums are unaffordable for small farmers, the social goal of protecting vulnerable households is defeated. China's approach has been to heavily subsidize premiums to resolve this tensionmdpi. com. While this has clearly achieved broad coverage and poverty mitigation, questions arise about long-term sustainability. The government's insurance subsidy bill has grown alongside premiums – reaching nearly 80% of CNY 150 billion in 2024mdpi.com. Policymakers are now exploring ways to optimize subsidies, such as scaling support by farm size or risk level (diversified subsidies) to improve efficiency. The evolutionary game analysis by Zhang and Wang (2025) even suggests redirecting some subsidies to insurance institutions (for operating costs) rather than directly to farmers, to encourage insurers to develop products for currently underserved markets (like specialty crops) without raising premiums for farmers. Such innovative strategies could ensure insurers remain engaged and solvent while expanding coverage to new risks.

Another discussion point is the integration of agricultural insurance with climate adaptation efforts. Insurance should not work in isolation; ideally, it complements measures like improved irrigation, drought-resistant crop varieties, and early warning systems. If premiums are adjusted (via discounts or surcharges) to account for farmers' adaptation actions, it could incentivize risk reduction on the ground. In practice, this concept is still emerging in China. Some local programs offer premium discounts for farmers who implement certain risk mitigation practices (for example, building typhoon-resilient greenhouses), but these are not yet widespread. The National Strategy for Climate Change Adaptation 2035 explicitly calls for strengthening financial services like insurance as part of climate adaptation. Over time, we may see a more explicit linkage where actuarial pricing incorporates an adaptation credit: farmers who adopt adaptive practices might effectively face lower risk profiles and thus lower premiums. This would align economic signals with climate resilience goals.

The literature on poverty vulnerability suggests that agricultural insurance's impact is significant but not a panacea. Insurance addresses the symptoms (financial loss from shocks) but not the root causes of rural poverty. Therefore, insurance works best as one component of a broader rural development toolkit. In China's rural revitalization framework, insurance is paired with interventions like improved market access, education, and infrastructure to holistically reduce poverty. Notably, there is evidence of a threshold effect: insurance has diminishing returns in extremely high-risk or underdeveloped settings unless those other factors are in place. For example, in remote mountainous regions, farmers may remain highly vulnerable due to isolation and lack of alternative livelihoods, even if they have insurance for their crops. Thus, the policy implication is to continue coupling insurance with other poverty reduction and climate adaptation strategies.

Lastly, the review highlights ongoing challenges and research gaps. One challenge is ensuring that insurance products keep pace with evolving needs. As mentioned, coverage for newer risks (like specialty agriculture, horticulture, or livestock diseases exacerbated by climate change) is still limited. Developing actuarial models for these emerging risks will be important. There is also room for improving data analytics – for instance, using big data and AI to refine risk assessment and pricing, which Chinese insurers have begun exploring to enhance precision in underwriting climate risks. On the research front, while many studies have quantified insurance's impact on income and consumption, fewer have explicitly measured *vulnerability* (the probability of falling into poverty). Future research could use panel household data to calculate vulnerability indices with and without insurance, offering a more direct gauge of insurance's protective effect. Moreover, as climate extremes intensify, studying worst-case scenarios – can the insurance system handle catastrophic years, and what are the poverty outcomes in those cases – will be vital for stress-testing the current insurance framework.

5 Conclusion

Climate-linked agricultural insurance in China stands at the intersection of actuarial science, public policy, and rural development. This review has shown that actuarial pricing methods are adapting to the challenges of more frequent and severe weather events through sophisticated risk modeling and region-specific rate setting. Yet, without substantial government support, the actuarially indicated premiums in high-risk regions would be beyond the reach of most small farmers. China's extensive use of premium subsidies and regulatory caps has been a linchpin in making agricultural insurance accessible and thus effective as a risk management tool. These pricing and subsidy strategies have paid dividends in terms of insurance uptake: today, a majority of Chinese farmers, including smallholders, carry some form of crop insurance coverage.

The literature confirms that agricultural insurance, by stabilizing incomes and enabling investment, contributes to reducing poverty vulnerability among rural households. Families with insurance are better cushioned against falling into poverty when disasters strike, which supports China's broader poverty alleviation and rural revitalization goals. However, insurance is not a silver bullet. Ensuring its long-term impact on poverty requires continuous refinement of both pricing mechanisms and policy support. The Chinese government's recent moves to introduce higher coverage products (full-cost and income insurance) and to refine subsidy allocation are steps in the right direction. These efforts aim to enhance the depth of protection while managing fiscal costs and encouraging insurers' participation in underserved segments.

In conclusion, actuarial pricing of climate-linked risks in agricultural insurance must be viewed through a multi-dimensional lens. It involves not only calculating risk-based rates but also designing a supportive ecosystem of subsidies, regulations, and complementary adaptation measures. China's experience offers valuable lessons: broad-based premium support can jump-start an inclusive insurance market and yield social benefits like poverty reduction, but it must evolve towards more targeted, efficient models as the market matures. For policymakers, the priority should be to maintain farmers' incentives for risk reduction (to avoid over-reliance on subsidies) while safeguarding the affordability of insurance. For actuaries and insurers, improving data analytics for climate risks and innovating products for diverse agricultural sectors will be crucial. Ultimately, the success of climate-linked agricultural insurance will be measured by its dual impact: the financial sustainability of insurance providers and the economic resilience of farm households. Achieving both is challenging, but as this review indicates, it is attainable with sound pricing practices and robust public-private collaboration.

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