

Parametric Insurance in Arid Regions: International Experience and Prospects for Implementation in Uzbekistan

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Abstract—Climate change, increasing drought frequency and duration, water scarcity and high dependence of agricultural production on irrigation are fundamentally transforming agricultural risk profiles in arid and semi-arid economies. Traditional indemnity-based agricultural insurance, which requires individual loss assessment, is associated with high transaction costs, delayed claims settlement and limited accessibility for smallholder farmers. Parametric insurance provides an alternative by linking payouts to objectively measurable indices such as precipitation, temperature, soil moisture, vegetation health, river runoff or combinations thereof rather than to individually assessed losses. This study aims to systematize international experience in parametric and index-based insurance for climate risks and assess the prospects for adapting such instruments to Uzbekistan. The methodology combines a structured literature review, comparative institutional analysis of international insurance schemes, analysis of Uzbekistan's emerging agricultural insurance framework, and conceptual modelling of a drought insurance product suitable for irrigated and rain-fed agricultural systems. The findings indicate that a hybrid index combining meteorological, hydrological and satellite-derived indicators is potentially more appropriate for Uzbekistan than a simple rainfall index. The proposed model should account for precipitation deficits, dry-spell duration, temperature stress, vegetation conditions and irrigation-water availability while incorporating crop-specific phenological stages. A three-level architecture is proposed: micro-level insurance for individual producers, portfolio-level coverage for agricultural clusters and producer organizations, and sovereign or quasi-sovereign coverage against catastrophic drought events. The study demonstrates that parametric insurance should not be regarded as a substitute for climate adaptation. Its effectiveness is enhanced when combined with water-saving technologies, agricultural advisory systems, digital financial infrastructure, agricultural lending and reinsurance. Uzbekistan's recently established agricultural insurance framework creates a significant institutional opportunity for introducing parametric mechanisms as part of a broader climate-risk financing strategy.

Index Terms—parametric insurance, index insurance, agricultural insurance, drought, climate risk, basis risk, remote sensing, NDVI, water scarcity, Uzbekistan, climate adaptation, reinsurance.

1. Introduction

Drought is one of the most difficult climate-related risks

facing agriculture because its effects develop gradually, extend over large areas, and can affect crop production, livestock, water supply, and rural incomes at the same time. Unlike a localized natural disaster, drought can last for several months, with its economic consequences extending across several agricultural seasons.

The issue is particularly important in Central Asia because of the region's arid climate, the transboundary nature of its water resources, the heavy reliance of agriculture on irrigation, and increasing variability in water flows. Uzbekistan's official climate policy documents distinguish several interconnected forms of drought, including hydrological, meteorological, and soil drought. Agriculture is among the sectors of the economy most vulnerable to these risks.

Recent climate projections make the issue even more pressing. The Asian Development Bank notes that the Amu Darya basin is expected to face rising temperatures, more frequent and severe droughts, and declining water availability. These changes could make agricultural production increasingly difficult to predict and manage.

The economic challenge is not limited to the occurrence of drought itself. It also concerns farmers' limited ability to finance recovery after a climate shock. Crop losses reduce income, make it harder to service loans, limit the purchase of seeds, fertilizers, and fuel, and may lead to lower investment in the next production cycle.

Under traditional agricultural insurance, compensation is generally paid after the actual loss has been established. The insurer must inspect the insured property, determine whether the loss was caused by the insured event, assess the amount of damage, and only then make the payment. For a large number of small and geographically dispersed farms, this process can be costly.

Parametric insurance takes a different approach. A payout is triggered when a predefined threshold of an objectively measurable index is reached. For example, if cumulative rainfall during a critical stage of crop development falls below a specified threshold, the insurance payment can be made automatically in accordance with the terms of the policy.

Index insurance emerged in response to the high costs

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associated with traditional insurance. Research has shown that index-based products can reduce transaction costs and moral hazard because policyholders cannot directly influence the external indicator used to determine the payout. At the same time, the main limitation remains basis risk, the possibility that the index will not accurately reflect the actual loss suffered by an individual policyholder.

The issue is particularly relevant to Uzbekistan as the country reforms its agricultural insurance system. In April 2025, Uzbekistan adopted Law No. ZRU-1056, “On Agricultural Risk Insurance,” which establishes the institutional framework for agricultural insurance, including the creation of the Agricultural Insurance Fund, reinsurance arrangements, and government subsidies covering part of insurance premiums.

This raises a central research question: What type of parametric insurance architecture is best suited to Uzbekistan’s climatic, agricultural, institutional, and data conditions?

2. Research Objective and Tasks

The aim of this study is to develop a sound framework for adapting parametric drought insurance to the conditions of Uzbekistan, drawing on international experience and recent advances in climate-monitoring technologies.

To achieve this aim, the study addresses the following objectives:

1. To examine the economic rationale and underlying principles of parametric insurance;
2. To identify and classify the main types of indices used in drought insurance;
3. To examine international experience in India, Kenya, Ethiopia, other African countries, and other drought-prone regions;
4. To assess the main advantages and limitations of parametric insurance;
5. To examine the problem of basis risk;
6. To assess the potential use of satellite data and NDVI;
7. To identify the institutional conditions required for introducing parametric insurance in Uzbekistan;
8. To develop a conceptual insurance product for agricultural producers in Uzbekistan;
9. To formulate recommendations on government subsidies, reinsurance, and the digitalization of the insurance system.

3. Research Methodology

This study takes a conceptual and analytical approach and combines four complementary methods.

A. Structured Literature Review

The study reviews academic research on index insurance, weather indices, drought insurance, satellite monitoring, basis risk, and climate-risk modelling.

Recent systematic reviews of the literature on weather index insurance show that precipitation and temperature indices remain the most widely used. Drought, vegetation, and soil-moisture indices are used less frequently, although they may provide a more direct representation of agricultural losses.

A separate part of the analysis focuses on the use of satellite data. A systematic quantitative review of 89 studies found a growing use of satellite datasets in index insurance. NDVI was the most commonly used indicator, while several studies found that higher spatial resolution was associated with lower basis risk.

B. Comparative Institutional Analysis

The study examines the following approaches:

- weather index insurance in India;
- livestock risk insurance in Kenya and Ethiopia;
- sovereign parametric insurance through African Risk Capacity (ARC);
- digital agricultural insurance models in African countries;
- emerging hybrid models that incorporate satellite data.

C. Institutional Analysis of Uzbekistan

The study analyses the Republic of Uzbekistan’s Law “On Agricultural Risk Insurance,” which establishes the framework for government coordination, the Agricultural Insurance Fund, an agricultural insurance information system, reinsurance, and insurance premium subsidies.

D. Conceptual Modelling

Drawing on international experience, the study proposes a parametric insurance architecture in which the payout is determined by a function combining several climate and agro-environmental indicators.

4. Parametric Insurance versus Traditional Agricultural Insurance

Under traditional agricultural insurance, the claims process generally follows this sequence:

insurance contract → occurrence of a climate-related event → assessment of actual loss → claims assessment → calculation of the payout → payment.

In other words, the insurer first determines the actual loss suffered by the policyholder and only then calculates the amount of compensation.

Parametric insurance works differently. The actual loss is not assessed. Instead, the policy is linked to a predefined insurance index, such as precipitation, temperature, or another objectively measurable indicator.

The process can therefore be represented as:

insurance contract → monitoring of the index → trigger reached → automatic calculation of the payout → payment.

Let:

I — actual value of the insurance index during the insured period;

I_t — trigger level, at which the insurance payout begins;

I_m — index level at which the maximum payout applies;

L — insurance limit, i.e. the maximum amount payable under the policy;

P — actual insurance payout.

For a deficit index, where a decline in the index leads to an increase in the payout, the payout is calculated as follows:

If $I \geq I_t$:

$P = 0$

No insurance payout is made.

If $I_m < I < I_t$:

$P = L \times (I_t - I) / (I_t - I_m)$

In this range, the payout increases proportionally as the index declines.

If $I \leq I_m$:

$P = L$

The maximum insurance payout is made.

Thus, the relationship between the index and the payout can be summarized as:

Index value	Insurance payout
$I \geq I_t$	0
$I_m < I < I_t$	$L \times (I_t - I) / (I_t - I_m)$
$I \leq I_m$	L

Example:

Suppose the insurance index is cumulative precipitation expressed as a percentage of the historical norm.

Let:

$I_t = 80\%$ — the level at which the payout begins;

$I_m = 40\%$ — the level at which the maximum payout applies;

$L = \text{USD } 100,000$ — the insurance limit.

The payout is then calculated as follows.

At 80% of normal precipitation:

$P = 100,000 \times (80 - 80) / (80 - 40)$

$P = \text{USD } 0$

At 70% of normal precipitation:

$P = 100,000 \times (80 - 70) / (80 - 40)$

$P = \text{USD } 25,000$

At 60% of normal precipitation:

$P = 100,000 \times (80 - 60) / (80 - 40)$

$P = \text{USD } 50,000$

At 50% of normal precipitation:

$P = 100,000 \times (80 - 50) / (80 - 40)$

$P = \text{USD } 75,000$

At 40% of normal precipitation:

$P = 100,000 \times (80 - 40) / (80 - 40)$

$P = \text{USD } 100,000$

At precipitation levels below 40% of the historical norm, the payout remains capped at the insurance limit of USD 100,000.

This structure illustrates the basic principle of parametric insurance: the relationship between the value of an objective index and the insurance payout is defined in advance. As a result, the payout can be calculated quickly and transparently without an individual assessment of the policyholder's actual

loss.

5. International Experience

A. India: From Weather Parameters to Digital Monitoring

India is one of the most significant examples of agricultural index insurance being implemented at scale. Its national agricultural insurance system includes the Weather Based Crop Insurance Scheme (WBCIS), which uses parameters such as rainfall, temperature, humidity, and wind.

Under the WBCIS framework, weather parameters are used as proxies for crop yields, with insurance payouts triggered when predefined weather thresholds are reached. Covered risks include rainfall deficits, excessive rainfall, dry spells, extreme temperatures, and other weather-related conditions.

India's insurance system has increasingly incorporated automated weather stations, satellite data, and crop-yield estimation technologies. Official materials relating to the Pradhan Mantri Fasal Bima Yojana (PMFBY) refer to the use of rainfall, temperature, solar radiation, humidity, and remote sensing in yield assessment and insurance operations.

India's experience points to an important principle: a parametric insurance product should not be designed as a simple weather-based instrument. It needs to reflect the agronomic characteristics of the crops and the way weather conditions affect actual agricultural production.

B. Kenya and Ethiopia: Insurance against Pasture Drought

The experience of Kenya and Ethiopia is particularly relevant because insurance is used not only to protect crops but also to cover livestock-related risks.

Index-Based Livestock Insurance (IBLI) uses satellite observations of vegetation, particularly NDVI, to assess pasture conditions. When vegetation levels fall below a predefined threshold, an insurance payout is triggered.

This approach differs fundamentally from insurance against actual livestock mortality. Payments can be made before large-scale livestock losses occur, when deteriorating pasture conditions already indicate a serious shortage of available forage.

World Bank studies have found positive socioeconomic effects associated with IBLI programmes in Kenya and Ethiopia. These include reduced reliance on distress sales of livestock and a greater ability of insured households to maintain consumption during periods of drought.

At the same time, international experience has highlighted the high operating costs involved in providing individual insurance to remote pastoral households.

For Uzbekistan, this suggests that large-scale parametric insurance may be more practical when policies are distributed through aggregated policyholders and institutional channels, such as farmer associations, agricultural clusters, banks, cooperatives, and government programmes, rather than relying solely on individual policies.

C. African Risk Capacity: The Sovereign Model

A different level of parametric insurance is represented by African Risk Capacity (ARC), which enables countries to pool

and transfer catastrophic climate-related risks.

The ARC model combines rainfall-deficit indicators with estimates of potential emergency-response costs. When a predefined threshold is reached, the participating government receives an insurance payout.

Unlike microinsurance, the insured interest in this case is not an individual farmer. Instead, the mechanism protects the government's fiscal capacity to respond to a large-scale climate-related disaster.

ARC policies use parameters such as the attachment point, limit, and ceding percentage, allowing participating countries to determine how much risk they retain and how much they transfer through the insurance arrangement.

Recent experience also illustrates how the mechanism works in practice. In 2025, ARC made aggregate parametric payouts of more than USD 5.4 million to Mozambique in response to drought and a tropical cyclone, including more than USD 1.8 million paid directly to the government for drought response.

The ARC model shows that parametric insurance can serve purposes beyond protecting individual agricultural producers. It can also form part of a broader disaster risk financing framework, providing governments with rapid access to funds when a predefined catastrophic climate event occurs.

6. Basis Risk as a Central Challenge of Parametric Insurance

The main limitation of index-based insurance is basis risk, the risk that the insurance index does not accurately reflect the actual loss suffered by the policyholder.

For example, two farms may be located within the same administrative area and be covered by the same insurance index. One farm may suffer crop losses because of a localized moisture deficit, while the other may maintain relatively stable yields because of differences in soil conditions or access to irrigation. If the same index is applied to both farms, one farmer may receive less compensation than the actual loss warrants, while the other may receive a payout despite experiencing only limited damage.

The literature generally identifies at least three forms of basis risk:

1. Design basis risk - the index does not adequately capture the insured risk because it has been poorly selected or designed;
2. Temporal basis risk - the index is measured over a time period that does not correspond closely enough to the period during which the insured loss develops;
3. Spatial basis risk - the geographic scale of the index does not adequately match the location and size of the insured area.

Basis risk is not merely a technical issue; it also has direct economic implications. Studies have found that demand for index-based insurance tends to increase when basis risk is reduced.

A low premium, therefore, does not necessarily make an index insurance product attractive to farmers. If farmers cannot be confident that the index will trigger a payment when they suffer a genuine loss, the perceived economic value of the

insurance is reduced.

7. Satellite Technologies as a Tool for Reducing Basis Risk

Composite Indices in Parametric Insurance

One promising direction in the development of parametric insurance is to move beyond a single meteorological indicator and use a composite index that captures several factors affecting crop conditions.

A. NDVI as an Indicator of Vegetation Condition

The Normalized Difference Vegetation Index (NDVI) is widely used to assess vegetation condition. It is calculated as follows:

$$NDVI = (NIR - Red) / (NIR + Red),$$

where NIR is vegetation reflectance in the near-infrared band and Red is vegetation reflectance in the red band.

In simple terms, NDVI indicates how actively and effectively vegetation is growing.

In general:

high NDVI → good vegetation condition;

declining NDVI → deteriorating vegetation condition;

low NDVI → possible water stress, drought, or another adverse factor.

For example, if the NDVI of an agricultural area is $NDVI_n$ under normal conditions and falls to $NDVI_t$ during the current growing season, this may indicate deterioration in crop condition.

However, a decline in NDVI does not necessarily indicate drought. Plant diseases, pests, soil salinity, inadequate farming practices, and other factors can also cause vegetation stress. For this reason, using NDVI alone as the basis for an insurance payout may result in significant basis risk.

B. Composite Insurance Index

A more robust approach is to combine several indicators into a single composite insurance index. The proposed index can be expressed as:

$$CI = w_1P + w_2T + w_3SM + w_4NDVI + w_5W,$$

where CI is the composite insurance index; P is the precipitation or precipitation-deficit indicator; T is the temperature-stress indicator; SM is the soil-moisture indicator; NDVI represents vegetation condition; W represents irrigation-water availability; and w_1, w_2, w_3, w_4, w_5 are the weights assigned to the respective indicators.

The weights should satisfy the following condition:

$$w_1 + w_2 + w_3 + w_4 + w_5 = 1.$$

Thus, the composite index is not a simple sum of the indicators. Each indicator is multiplied by a weight reflecting its relative importance.

For example, if vegetation condition is particularly important for a specific crop, a higher weight can be assigned to NDVI:

$w_4 > w_i$, where $i \neq 4$.

In this case, changes in vegetation condition will have a greater effect on the composite index than changes in indicators assigned lower weights.

Example of the Calculation:

Suppose that, after normalization, the five indicators take the following values:

$P = p$; $T = t$; $SM = s$; $NDVI = v$; $W = w$.

Let the corresponding weights be:

$w_1 = a$; $w_2 = b$; $w_3 = c$; $w_4 = d$; $w_5 = e$,

where:

$a + b + c + d + e = 1$.

The composite index is then calculated as:

$CI = a \cdot p + b \cdot t + c \cdot s + d \cdot v + e \cdot w$.

The resulting CI value can then be compared with the trigger level specified in the insurance contract.

If the trigger level is CI_t , the basic rule can be expressed as:

$CI \geq CI_t \rightarrow$ no insurance payout.

If:

$CI < CI_t$,

the policyholder becomes eligible for a payout, with the amount determined according to the payout function specified in the insurance contract and subject to the policy limit.

The advantage of this approach is that several indicators are considered simultaneously.

For example, a decline in NDVI alone may be caused by plant disease rather than drought. If the decline occurs simultaneously with a significant precipitation deficit, prolonged dry spells, elevated temperatures, declining soil moisture, and reduced irrigation-water availability, there is stronger evidence of drought-related crop stress.

A composite index can therefore potentially reduce basis risk by establishing a closer relationship between the insurance trigger and the actual conditions affecting agricultural production.

Higher spatial resolution of satellite data may provide an additional way to reduce basis risk. It allows the index to be calculated for smaller and more homogeneous areas, potentially reducing the difference between the index value and the actual condition of a particular agricultural plot. However, the appropriate level of spatial resolution depends on land-use patterns, farm size, crop characteristics, and the specific risk covered by the insurance policy.

8. Why a Rainfall-Only Model Is Not Sufficient for Uzbekistan

For Uzbekistan, a simple rainfall index has significant limitations. This is largely due to the structure of agricultural

production and the country's dependence on irrigation.

A substantial share of agricultural production relies on irrigated agriculture. As a result, crop yields may remain high even when rainfall is relatively low, provided that sufficient irrigation water is available. Conversely, adequate rainfall does not necessarily ensure good yields if temperatures are exceptionally high, soils are saline, or access to irrigation water is restricted.

Insurance design should therefore account for both atmospheric and agro-hydrological risks.

Uzbekistan's official climate policy documents emphasize the dependence of agriculture on water resources and identify the water sector as a key area for climate adaptation.

For this reason, it would be more appropriate to move beyond the narrow concept of "insurance against insufficient rainfall" toward a broader approach focused on "insurance against moisture deficits and climate-related reductions in production potential."

Such an approach would better reflect the actual risks faced by agricultural producers. In an irrigated farming system, the amount of rainfall is only one part of the water balance. Crop performance also depends on temperature, soil moisture, irrigation-water availability, the duration of dry periods, and the timing of water supply relative to the crop's development stages.

9. Climate and Institutional Conditions in Uzbekistan

Uzbekistan is highly exposed to climate-related risks affecting agriculture and water resources. National policy documents identify these risks and place greater emphasis on adaptation measures, including reforms in agricultural insurance. The country's NDC 3.0 also sets out measures aimed at strengthening climate adaptation, expanding water-saving technologies, and improving the resilience of agricultural production. It includes a target for establishing a dedicated insurance fund with a capitalization of USD 100 million.

An important institutional development is Law No. ZRU-1056 of 14 April 2025, On Insurance of Agricultural Risks.

The law establishes the legal framework for:

- agricultural risk insurance;
- reinsurance;
- the activities of the Agricultural Insurance Fund;
- insurance premium subsidies;
- loss assessment;
- payment of insurance indemnities; and
- government coordination of the agricultural insurance system.

The law also provides for an agricultural insurance information system. The system is intended to support the processing of insurance contracts and policies, applications for budget subsidies, and claims for insurance compensation.

This creates an important foundation for the digitalization of agricultural insurance and, potentially, for the introduction of parametric products.

At the same time, the existence of this legal framework does not by itself mean that a fully developed parametric insurance

market is already in place. The current regulatory model continues to place considerable emphasis on loss assessment and the involvement of independent experts.

The wider adoption of parametric insurance will therefore require specific regulatory rules covering the design and calculation of insurance indices, data sources and quality standards, trigger determination, payout mechanisms, and procedures for data verification and dispute resolution.

10. Proposed Model of Parametric Drought Insurance in Uzbekistan

For the conditions prevailing in Uzbekistan, we propose a composite drought index that captures four main factors:

1. precipitation deficit;
2. elevated temperature;
3. soil-moisture deficit; and
4. deterioration in vegetation condition.

The drought index can be calculated as follows:

$$D_t = w_1 P_t + w_2 T_t + w_3 SM_t + w_4 V_t,$$

where:

D_t — composite drought index for period t ;

P_t — normalized precipitation deficit;

T_t — normalized temperature stress;

SM_t — normalized soil-moisture deficit;

V_t — normalized deterioration in vegetation condition;

w_1, w_2, w_3, w_4 — weights reflecting the relative importance of the four components.

The greater the simultaneous contribution of insufficient rainfall, high temperatures, low soil moisture, and deteriorating vegetation, the higher the value of D_t .

The weights should satisfy the following condition:

$$w_1 + w_2 + w_3 + w_4 = 1.$$

For illustration, the weights could be set as follows:

$$w_1 = [\text{value}], w_2 = [\text{value}], w_3 = [\text{value}], w_4 = [\text{value}].$$

The index would then be calculated as:

$$D_t = [w_1 \times P_t] + [w_2 \times T_t] + [w_3 \times SM_t] + [w_4 \times V_t].$$

The specific weights, however, should not be selected arbitrarily. They should be estimated using statistical analysis of long-term historical data and by examining the relationship between index values and actual crop yields.

Additional Component for Irrigated Areas:

For irrigated agriculture, a climate-based index alone may not be sufficient. Even when rainfall is low, crop yields may be maintained if sufficient irrigation water is available.

For irrigated areas, we therefore propose an extended index:

$$D_t = (1 - w_i)D_t + w_i W_t,$$

where:

D_t^* — extended drought index;

D_t — the basic four-component drought index;

W_t — indicator of irrigation-water availability;

w_i — weight assigned to irrigation-water availability.

This approach takes into account not only the climatic water deficit but also the extent to which that deficit actually affects the availability of water for crop irrigation.

Three-Level Payout Structure:

For practical implementation, the insurance contract could distinguish between several levels of drought severity.

Table 1

Index value	Condition	Payout
$D_t < T_1$	Normal conditions	0%
$T_1 \leq D_t < T_2$	Moderate stress	25–40%
$T_2 \leq D_t < T_3$	Severe drought	50–75%
$D_t \geq T_3$	Catastrophic drought	100%

Here, T_1, T_2 , and T_3 are the predefined index thresholds.

Their meaning can be described as follows:

$D_t < T_1$ — the drought index has not reached the insurance trigger, so no payout is made.

$T_1 \leq D_t < T_2$ — moderate agricultural stress is detected, resulting in a partial payout.

$T_2 \leq D_t < T_3$ — severe drought conditions are detected, and the payout increases accordingly.

$D_t \geq T_3$ — catastrophic drought conditions are detected, and the policyholder receives the maximum payout.

If L denotes the insurance limit, the payout can be expressed in monetary terms as:

$$\text{Payout} = L \times \alpha(D_t),$$

where $\alpha(D_t)$ is the payout rate determined by the value of the drought index.

For a simple step-based structure:

$$\alpha(D_t) = 0, \text{ when } D_t < T_1;$$

$$\alpha(D_t) = 0.25\text{--}0.40, \text{ when } T_1 \leq D_t < T_2;$$

$$\alpha(D_t) = 0.50\text{--}0.75, \text{ when } T_2 \leq D_t < T_3;$$

$$\alpha(D_t) = 1.00, \text{ when } D_t \geq T_3.$$

How Should the Thresholds T_1, T_2 , and T_3 Be Determined?

This is one of the key elements of the proposed model. The thresholds should not be established arbitrarily or solely through administrative decisions.

They should be estimated using:

- long-term precipitation data;
- temperature data;
- soil-moisture data;
- satellite observations of vegetation condition;
- crop-yield data;
- irrigation and water-availability data; and
- records of historical drought events.

The main objective is to identify the index values at which

crop yields begin to show a statistically significant decline.

The relationship can be represented conceptually as:

$$\text{Crop yield} = f(D_i),$$

where D_i is the drought index.

Historical data can then be used to identify threshold values T_1 , T_2 , and T_3 that best distinguish normal conditions from moderate stress, severe drought, and catastrophic drought.

This approach links insurance payouts to an objective index derived from measurable environmental conditions rather than to a subjective assessment of individual losses. Before being used for insurance purposes, however, the index and its thresholds should be validated against historical agricultural and climate data from Uzbekistan.

11. Phenology-Based Approach to Index Design

In parametric insurance, it is important to consider not only the severity of a drought but also when it occurs.

The same moisture deficit can have very different effects on crop yields depending on the crop's stage of development.

For example:

- during planting and emergence, insufficient moisture can result in poor germination and emergence;
- during flowering, water stress can substantially reduce the number of fruits or grains that develop;
- during grain filling and ripening, insufficient moisture can also reduce yields, although the nature and magnitude of the losses may differ.

For this reason, rather than calculating a single indicator for the entire growing season, the proposed approach divides the growing period into several phenological stages.

For each stage, a separate measure of climate-related stress is calculated:

$$S_i = f(P_i, T_i, SM_i, V_i),$$

where S_i represents the climate-stress index for the i -th phenological stage, based on the relevant precipitation, temperature, soil-moisture, and vegetation indicators.

The stage-specific indices are then combined into a single seasonal index:

$$D_s = \sum (w_i \times S_i),$$

or, in expanded form:

$$D_s = w_1S_1 + w_2S_2 + \dots + w_nS_n,$$

where:

- D_s — overall drought index for the agricultural season;
- S_i — climate-stress index for the i -th phenological stage;
- w_i — weight assigned to the corresponding phenological stage;

- n — number of stages included in the calculation.

The weights must satisfy:

$$\sum w_i = 1.$$

Example:

Suppose three main phenological stages are considered for a particular crop:

Table 2

Phenological stage	Stress index	Weight
Planting and emergence	S_1	w_1
Flowering	S_2	w_2
Ripening	S_3	w_3

The seasonal drought index is then:

$$D_s = w_1S_1 + w_2S_2 + w_3S_3.$$

For example, if the flowering stage is assigned the highest weight, its contribution to the overall index will be greater than that of the other stages.

Thus, if:

$$w_2 > w_1 \text{ and } w_2 > w_3,$$

then the stress experienced during flowering will have the greatest influence on the final seasonal index.

Why Does This Matter for Insurance?

A phenology-based approach recognizes that the economic impact of the same level of climate stress can vary substantially across different stages of crop development.

For example, a drought index value of S = [value] during flowering and S = [value] during ripening does not necessarily imply the same economic consequences. The effect depends on the crop's sensitivity to water stress at each stage.

The insurance model can therefore calculate a separate stress indicator for each phenological stage and then combine the results into a seasonal index.

In practical terms, this shifts the focus from the relatively broad question:

“How severe was the drought over the entire season?”

to a more relevant question:

“How severe was the climate stress during the stages of crop development when the crop was most sensitive to insufficient moisture?”

This approach can improve the ability of the insurance index to reflect actual yield losses and, as a result, potentially reduce basis risk.

12. Regional Differentiation

One of the challenges in developing a single national insurance product is the use of the same index and the same parameters across regions with very different agricultural and climatic conditions.

For Uzbekistan, a more practical approach would be to divide the country into insurance zones based on agro-climatic conditions, farming practices, and water availability.

The following zones can be distinguished for analytical purposes:

1. predominantly irrigated farming areas;
2. rain-fed farming areas;
3. areas with a high dependence on water availability;
4. areas with an elevated risk of soil salinity; and
5. pasture areas.

For each zone, the parameters of the insurance index, trigger thresholds, and probability of an insured event should be determined separately.

A. Probability of an Insured Event

Let D denote the drought index and T the predefined trigger threshold.

The probability that drought conditions will reach the insured level can then be expressed as:

$$\Pr(D \geq T)$$

where:

- $\Pr(\cdot)$ — probability;
- D — calculated drought index;
- T — predefined index threshold;
- $\Pr(D \geq T)$ — probability that the drought index will reach or exceed the specified threshold.

For example, if historical data show that:

$$\Pr(D \geq T) = 0.20,$$

this means that the probability of the drought index reaching or exceeding the specified threshold is 20%.

This probability may vary substantially across insurance zones because climate conditions, water availability, crop structure, and exposure to drought differ from one region to another.

B. Calculation of the Insurance Premium

The insurance premium is the amount paid by the agricultural producer for the insurance policy.

In simplified form, the premium can be expressed as:

$$\text{Premium} = EL + RP + AC + RC,$$

where:

- EL — expected loss, i.e. the average amount of insurance payouts estimated on the basis of the probability and potential size of insured losses;
- RP — risk loading, which compensates the insurer for uncertainty and deviations of actual losses from expected losses;
- AC — insurer's administrative costs;
- RC — reinsurance costs.

Expected loss can be expressed in simplified form as:

$$EL = \Pr(E) \times L,$$

where:

- $\Pr(E)$ — probability of the insured event;
- L — average insurance payout if the event occurs.

For example, if the probability of an insured event is:

$$\Pr(E) = 0.20,$$

and the average payout in the event of a loss is:

$$L = 500,000 \text{ UZS},$$

then:

$$EL = 0.20 \times 500,000 = 100,000 \text{ UZS}.$$

Thus, 100,000 UZS represents the expected insurance payout before risk loadings, administrative costs, and reinsurance costs are added.

In a real insurance product, the calculation would normally be more detailed because payout levels may vary with the severity of the drought rather than being fixed at a single amount.

C. Role of Government Subsidies

In agricultural insurance, the government may cover part of the insurance premium to make coverage more affordable for producers.

If:

- P — full insurance premium;
- S — amount of the government subsidy;

then the amount paid by the agricultural producer is:

$$\text{Producer payment} = P - S.$$

For example, if the full premium is:

$$P = 300,000 \text{ UZS},$$

and the government subsidy is:

$$S = 180,000 \text{ UZS},$$

then the producer pays:

$$300,000 - 180,000 = 120,000 \text{ UZS}.$$

Regional differentiation makes it possible to set insurance parameters according to the actual level and structure of climate risk in each zone. Government subsidies can, in turn, reduce the cost of coverage for agricultural producers and improve access to insurance.

13. The Role of the State

International experience shows that parametric insurance rarely achieves broad adoption through market mechanisms alone.

Several factors help explain this:

- the high cost of developing and maintaining risk models;

- limited availability of long-term historical data;
- the need for reinsurance capacity;
- limited ability of small-scale producers to pay insurance premiums;
- low levels of insurance awareness; and
- initial uncertainty and lack of trust in the index-based approach.

The role of the state should therefore not be to act as the insurer of last resort for all agricultural risks, but rather to build and maintain the infrastructure needed for effective risk transfer.

An effective institutional model would divide responsibilities among the main participants as follows.

Government:

- provision and maintenance of climate and hydrological data;
- development of the regulatory framework;
- subsidization of insurance premiums;
- establishment of standards for insurance indices and data sources;
- development of monitoring and digital infrastructure; and
- creation of a mechanism for financing catastrophic losses.

Insurance companies:

- design and pricing of insurance products;
- distribution and marketing;
- customer service;
- underwriting and portfolio management; and
- primary risk management and risk distribution.

Reinsurers:

- coverage of extreme and catastrophic losses; and
- international diversification of climate-related risks.

Research institutions:

- crop-yield and climate-risk modelling;
- calibration and validation of insurance indices; and
- *measurement and reduction of basis risk.*

Agricultural clusters and banks:

- aggregation of insurance demand;
- digital distribution of insurance products; and
- integration of insurance with agricultural lending.

Such a division of responsibilities would allow the government to create the data, regulatory, and financial infrastructure required for the market to develop, while leaving product design, underwriting, distribution, and risk transfer to specialized market participants.

14. Integrating Insurance with Agricultural Credit

Parametric insurance can play an important role in agricultural lending.

In a highly climate-sensitive agricultural sector, banks face a significant risk of loan default when drought or other climate shocks lead to crop losses. Insurance coverage can provide an additional layer of protection and reduce the financial consequences of such events for both lenders and producers.

The proposed mechanism is: Agricultural loan → mandatory or voluntary parametric insurance coverage → climate trigger → automatic payout → partial loan repayment + replenishment of working capital.

An important point, however, is that the entire insurance payout should not be directed solely toward loan repayment. A portion of the payout should remain available to the producer to finance the next production cycle, including the purchase of seeds, fertilizers, fuel, and other inputs.

This approach allows insurance to serve not merely as a mechanism for compensating losses, but as a tool for preserving the producer's ability to continue operating after a climate shock.

In this model, insurance and agricultural lending reinforce each other: insurance reduces the financial impact of climate-related losses, while continued access to working capital helps producers resume production without taking on excessive additional debt.

15. Integrating Insurance with Water-Saving Technologies

Parametric insurance should not create a moral hazard by reducing farmers' incentives to take preventive measures to protect their crops.

On the contrary, the insurance system can provide an economic incentive to adopt climate-adaptation technologies, including:

- drip irrigation;
- laser land levelling;
- soil moisture-conserving tillage practices;
- drought-resistant crop varieties;
- optimized planting dates; and
- digital monitoring and irrigation management.

Insurance Premiums Adjusted for Adaptation Measures

Let the base insurance premium be P_0 . If a farmer invests in measures that reduce climate-related risks, a premium discount may be applied.

The adjusted premium can then be expressed as:

$$P_i = P_0 \times (1 - \alpha A_i),$$

where:

- P_i — insurance premium for the i -th farmer;
- P_0 — base insurance premium before taking adaptation measures into account;
- A_i — adaptation investment index for the i -th farmer;
- α — discount coefficient reflecting the extent to which adaptation measures reduce the insurance premium.

How does the formula work?

If a farmer does not use adaptation technologies:

$$A_i = 0.$$

Therefore:

$$P_i = P_0 \times (1 - \alpha \times 0) = P_0.$$

In other words, the farmer pays the full base premium.

If a farmer actively invests in reducing climate risk and, for example:

$$A_i = 0.5,$$

while the discount coefficient is:

$$\alpha = 0.20,$$

then:

$$P_i = P_0 \times (1 - 0.20 \times 0.5) = 0.90P_0.$$

Thus, the farmer receives a 10% discount on the base premium.

If:

$$A_i = 1,$$

then, with:

$$\alpha = 0.20,$$

the premium becomes:

$$P_i = P_0 \times (1 - 0.20) = 0.80P_0.$$

In this case, the discount is 20%.

Example with a Specific Premium

Suppose the base premium is:

$$P_0 = 1,000,000 \text{ UZS.}$$

The farmer implements a package of adaptation measures corresponding to:

$$A_i = 0.75.$$

With a discount coefficient of:

$$\alpha = 0.20,$$

the adjusted premium is:

$$P_i = 1,000,000 \times (1 - 0.20 \times 0.75)$$

$$P_i = 1,000,000 \times 0.85 = 850,000 \text{ UZS.}$$

Thus, the farmer's investment in adaptation reduces the cost of the insurance policy by:

$$1,000,000 - 850,000 = 150,000 \text{ UZS.}$$

How Can the Adaptation Index Be Defined?

The adaptation index A_i can be constructed from several measurable components:

$$A_i = w_1I_1 + w_2I_2 + w_3I_3 + w_4I_4 + w_5I_5,$$

where each component represents a specific adaptation measure and w_k is the weight assigned to that component.

For example:

- I_1 — effectiveness of the irrigation system;
- I_2 — use of soil moisture-conserving tillage practices;
- I_3 — use of drought-resistant crop varieties;
- I_4 — use of digital irrigation monitoring and control systems;
- I_5 — quality of agronomic management.
-

The weights should satisfy:

$$w_1 + w_2 + w_3 + w_4 + w_5 = 1.$$

The adaptation measures themselves should also be objectively verifiable. This could be done using farm records,

technical documentation, satellite monitoring, or digital water-management systems.

The overall mechanism can therefore be represented as: Adaptation measures → lower climate exposure → lower expected loss → lower insurance premium.

This approach turns insurance from a simple mechanism for compensating losses into a tool that also encourages farmers to reduce their exposure to climate risks. Insurance thus complements water-saving and other adaptation measures rather than replacing them.

16. A Multi-Level Insurance Architecture

For Uzbekistan, a three-level insurance system is proposed.

Level I — Individual Coverage

A farmer purchases a policy covering a specific crop and geographical area.

The insurance index is calculated using satellite and meteorological data.

Level II — Portfolio Coverage

An agricultural cluster, bank, cooperative, or farmers' association insures a portfolio of farms.

The main advantages are lower administrative costs and better risk diversification across individual producers.

Level III — Catastrophic Coverage

The government or a dedicated agricultural insurance fund provides coverage for rare, high-severity events through the international reinsurance market.

The structure can be illustrated as follows:

Farmer → Insurance company → Reinsurer → International reinsurance market

In parallel:

Government → Agricultural Insurance Fund → Catastrophic risk layer

This approach follows the international logic of risk layering, under which frequent and relatively small losses are retained at the farm level, medium-sized risks are transferred to the insurance system, and extreme losses are covered through reinsurance or a government-backed mechanism.

Such an architecture allows different layers of risk to be managed by the institutions best positioned to absorb them, while reducing the concentration of catastrophic exposure within the domestic insurance market.

17. Digitalization of Insurance Payouts

One of the main advantages of parametric insurance is the potential to substantially reduce the time between the occurrence of an adverse event and the receipt of an insurance payout.

Under a traditional insurance model, the process generally requires the event to be identified, the circumstances to be verified, and the actual loss to be assessed: Insured event → loss assessment → expert review → calculation of compensation → payment

In other words, the payout depends on an assessment of the actual loss.

Under parametric insurance, the process can be much shorter:

Monitoring of the index → trigger reached → automatic payout calculation → payment

There is no need to determine the exact amount of the farmer's actual loss. Instead, the system verifies whether the insurance index has reached the predefined trigger level.

How Does the Digital System Work?

The process can be illustrated as follows: Data collection → index calculation → trigger verification → payout calculation → bank transfer

For example, the system receives data on precipitation and vegetation conditions for an insured plot.

If the calculated index is:

$D = D$,

and the predefined trigger is:

$D \geq T$,

the trigger condition is satisfied.

The insured event is therefore deemed to have occurred, and the system automatically calculates the payout specified in the insurance contract.

If, for example, the payout at the observed index level is $r \times L$, where:

- r — applicable payout rate; and
- L — insurance limit,

then:

$\text{Payout} = r \times L$.

The corresponding amount can then be transferred to the policyholder without a separate procedure for assessing the actual physical loss.

Possible Digital Infrastructure:

A digital parametric insurance system in Uzbekistan could operate through a single integrated process:

Land georeferencing → Digital policy → Satellite and weather data → Index calculation → Trigger verification → Payout calculation → Bank transfer

It could include the following components:

1. Georeferencing of the insured plot — linking a specific geographical area to the insurance contract;
2. Digital insurance policy — storing the terms and conditions of the contract electronically;
3. Satellite monitoring — collecting data on vegetation conditions and other relevant indicators;
4. Automated index calculation — calculating the insurance index D according to a predefined methodology;
5. API integration with banks — transmitting the necessary payment information to the banking system;
6. Automated trigger verification — checking whether the contractual condition is satisfied: $D \geq T$;
7. Automatic payout — transferring the calculated amount directly to the policyholder's bank account.

The core logic of the system can ultimately be reduced to a simple rule: If the index reaches the trigger → the insured event is activated → the contractual payout is calculated → payment

is initiated.

Digitalization can therefore turn parametric insurance from a sequence of manual procedures into an automated process based on predefined data, rules, and triggers. Where the necessary data, digital identification, and payment infrastructure are in place, this can substantially shorten the time required for agricultural producers to receive insurance compensation.

18. Key Risks of Implementation

Despite its advantages, parametric insurance is not a universal solution. Its effectiveness depends on the quality of the underlying data, the design of the index, and the institutional capacity to operate the system.

A. Risk of an Inappropriate Index (Basis Risk)

This is likely to be one of the main challenges in Uzbekistan.

The country's climate is characterized by substantial spatial and temporal variability. Precipitation, which is particularly important for rain-fed agriculture, is highly unevenly distributed. A large share of annual precipitation occurs from late autumn through mid-spring, outside the main growing season of key crops such as cotton. This reduces the correlation between conventional rainfall indices and actual crop yields.

Crop-specific responses. Different crops respond differently to the same climatic conditions. For example, spring frosts may be critical for cold-tolerant crops, while temperature thresholds around 15°C and 30°C may be important for heat-sensitive crops such as tomatoes and cucumbers. Heat-tolerant crops such as melons and watermelons may instead be more affected by prolonged periods of extreme heat above 35°C. A single index is unlikely to capture all of these differences adequately.

Irrigation conditions. Uzbekistan relies heavily on irrigated agriculture. An index based solely on precipitation may therefore have a weak relationship with actual agricultural losses because the availability of irrigation water is often more important than rainfall itself. Under such conditions, basis risk can become particularly high.

B. Lack of Historical Data

The shortage of reliable historical data is another important constraint. Actuarial modelling and the pricing of insurance products require sufficiently long and consistent time series covering crop yields, losses, weather conditions, and other relevant variables.

Data gaps. Uzbekistan is working to collect and systematize the information needed for climate-risk assessment and agricultural insurance. Cooperation with international organizations and experts, including projects supported by the United Nations Development Programme (UNDP), is aimed in part at addressing these data gaps and improving the assessment of climate risks and their effects on farm incomes.

Limited historical data make it more difficult to calibrate insurance indices accurately, estimate the probability of insured events, and set premiums that adequately reflect the underlying risk.

C. Non-Stationary Climate Conditions

Climate non-stationarity is one of the most serious risks for the proposed insurance system. Climate change is altering the frequency, intensity, and distribution of extreme events, which means that historical observations may no longer provide a reliable representation of future risk.

Key trends. Climate projections indicate longer and more frequent periods of hot and dry weather, more frequent droughts, and a greater risk of extreme low-flow conditions. Changes in snowfall in mountain areas and the continued loss of glaciers may also affect the long-term availability of water in river systems.

Implications for crop yields. Research indicates that changes in temperature and water availability could have a significant negative effect on the long-term productivity of major crops, including cotton and wheat, by around 2050. Relying solely on historical averages could therefore lead to systematic underestimation of future risk, particularly as the frequency of extreme events such as heatwaves above 40°C increases.

For insurance purposes, this means that historical data should not simply be extrapolated into the future. Risk models and index parameters will need to be periodically recalibrated to reflect observed and projected changes in climate conditions.

D. Insufficient Spatial Resolution

The problem is further complicated by the diversity of Uzbekistan's agro-climatic and soil conditions.

Heterogeneity of conditions. Data from a single weather station cannot adequately capture the local climatic and soil conditions affecting hundreds of farms. For example, the Bukhara region combines high temperatures with high evaporative demand, low humidity, and soil salinity, creating a specific risk profile that may differ substantially from that of other parts of the country.

Similarly, agro-climatic conditions in the eastern foothill areas and in the Aral Sea region can differ considerably. Applying the same index and thresholds across all these areas would therefore increase the risk of basis risk.

This makes higher-resolution meteorological, hydrological, and satellite data particularly important for the development of regional insurance products.

E. Limited Financial and Insurance Literacy

Another significant risk is that farmers may not fully understand how parametric insurance works.

Farmers accustomed to traditional indemnity-based insurance may expect a payment whenever they experience visible crop damage. Under a parametric contract, however, a loss does not automatically trigger a payout. Payment depends on whether the predefined index reaches the contractual trigger level.

Need for clear communication. This distinction has a direct impact on trust in the product. The successful introduction of parametric insurance in Uzbekistan will therefore require systematic educational and communication efforts explaining the difference between "the insured index has triggered a payout" and "the farmer has suffered a loss."

This is not merely a matter of consumer education. Clear communication about the index, data sources, trigger levels, and payout rules is essential for the long-term development of the market.

F. Data Availability and Independence

A transparent, reliable, and independent source of data is essential for parametric insurance.

Centralized data infrastructure. Uzbekistan is currently reforming its agricultural insurance system. The emerging institutional framework, including the establishment of a specialized agricultural insurance fund and the development of supporting regulations, creates an opportunity to build a centralized data infrastructure.

A key element should be a reliable source of information that is independent of both insurers and policyholders. This could include official meteorological observations, hydrological monitoring, satellite remote sensing, or a combination of these sources.

The use of independent data would reduce disputes over the calculation of the index and strengthen confidence in the accuracy and integrity of insurance payouts.

G. Systemic Climate Risk

Systemic climate risk is particularly relevant to Uzbekistan because droughts and heatwaves can affect large geographical areas and a substantial share of insured producers at the same time.

This creates a fundamental challenge for insurers: unlike many conventional risks, climate-related losses cannot always be diversified effectively within a single local portfolio.

Need for reinsurance. Without adequate reinsurance or risk-pooling mechanisms, a domestic insurance company could face very large claims following a severe drought or heatwave.

One possible solution would be to develop a regional insurance pool involving Central Asian countries, allowing large climate-related risks to be distributed across a broader portfolio and potentially reducing the cost of protection.

International experience also points to the importance of transferring part of the exposure to the global reinsurance market. Such risk transfer can be critical to maintaining the financial stability and claims-paying capacity of the domestic insurance system when a severe climate event affects a large area simultaneously.

19. A Scientific and Practical Framework for Reducing Basis Risk

A five-stage framework is proposed for Uzbekistan to reduce basis risk and improve the accuracy of parametric agricultural insurance products.

Stage 1. Building an Integrated Database

The first step is to combine the following sources of information:

- meteorological station data;
- hydrological data;
- satellite imagery;
- soil moisture data;

- data on cultivated areas;
- historical crop-yield data;
- irrigation data; and
- soil characteristics.

The database should combine these sources at a sufficiently high spatial and temporal resolution to allow climate indicators to be linked to specific crops, locations, and growing periods.

Stage 2. Index Calibration

Index calibration is necessary to determine which factors actually affect the yield of a particular crop and to what extent.

For each crop, the relationship between yield and the main climate and water-related variables can be estimated as:

$$Y = f(P, T, SM, V, W) + \varepsilon,$$

where:

- Y — observed crop yield;
- P — precipitation or precipitation deficit;
- T — temperature stress;
- SM — soil moisture;
- V — vegetation condition index;
- W — availability of irrigation water; and
- ε — other factors affecting yield that are not included in the model.

In practical terms, the objective is to use historical data to determine which indicators provide the most reliable information about crop losses.

Example of a Simple Regression Model:

For example, crop yield can be modelled as:

$$Y_t = \beta_0 + \beta_1 P_t + \beta_2 T_t + \beta_3 SM_t + \beta_4 NDVI_t + \beta_5 W_t + \varepsilon_t,$$

where:

- Y_t — crop yield in period t ;
- β_0 — baseline yield level;
- $\beta_1, \beta_2, \beta_3, \beta_4, \beta_5$ — coefficients measuring the effect of the corresponding factors;
- P_t — precipitation or precipitation deficit;
- T_t — temperature or temperature stress;
- SM_t — soil moisture;
- $NDVI_t$ — vegetation condition;
- W_t — irrigation-water availability; and
- ε_t — effects of factors not included in the model.

For example, if the estimated coefficient associated with precipitation deficit indicates a strong negative effect on crop yield, this suggests that precipitation deficit should receive a greater weight in the insurance index.

Methods for Index Calibration:

A range of statistical and mathematical methods can be used to calibrate the index:

- Regression models - estimate the average relationship between crop yields and climate-related variables;

- Quantile regression - examines how climate factors affect not only average yields but also lower parts of the yield distribution, which is particularly relevant for adverse years;
- Copula models - allow the joint occurrence and dependence of several adverse factors to be modelled, such as high temperatures combined with precipitation deficits; and
- Machine-learning methods - can capture more complex and nonlinear relationships between climate indicators and crop yields.

The objective of calibration is to identify index parameters that provide the closest possible representation of actual yield losses.

In simplified form:

Climate and agro-environmental indicators $\rightarrow$ calibrated index $\rightarrow$ observed crop losses.

The calibrated index should then be tested against independent historical data. The key question is how accurately the index identifies periods of significant yield decline and how closely the resulting insurance payouts correspond to actual losses.

Stage 3. Back-Testing

The next stage is to simulate the insurance product using historical data and compare the resulting hypothetical payouts with actual crop losses.

Key performance indicators include:

- correlation between the index and crop yield;
- under-compensation ratio;
- over-compensation ratio;
- frequency of false triggers;
- average payout; and
- variance reduction, i.e. the extent to which insurance reduces fluctuations in producers' income or losses.

Back-testing makes it possible to assess how the proposed insurance mechanism would have performed under actual historical climate conditions before the product is offered to farmers.

Stage 4. Pilot Implementation

The product should initially be introduced on a limited geographical scale and for one or two crops.

The pilot should be used to test:

- the reliability of the selected data sources;
- the stability of the index;
- the accuracy of trigger levels;
- the frequency and size of payouts;
- the level of basis risk; and
- the practical operation of the claims and payment infrastructure.

Stage 5. Scaling Up

Following an independent assessment of the pilot's performance, the product can be gradually expanded to additional regions and crops.

Scaling should be based on evidence from the pilot rather than on administrative expansion alone. Each new region or crop should undergo its own calibration and validation to ensure

that the index reflects its specific climate, agricultural practices, irrigation conditions, and crop response.

The overall process can therefore be summarized as: Data integration → Index calibration → Back-testing → Pilot implementation → Independent evaluation → Scaling.

20. Proposed Pilot Project for Uzbekistan

As a first step, it would be appropriate to launch a pilot project based on the following framework.

Target crops: cotton, wheat, and selected high-value horticultural crops.

Insured risk: drought and the associated water stress affecting agricultural production.

Index: a composite index combining precipitation, temperature, soil moisture, NDVI, and water availability.

Insurance period: individual phenological phases of crop development.

Geographic level: an agro-climatic zone or an aggregated agricultural cluster.

Payout: automatic payment once the predefined trigger is reached.

Subsidy: partial government subsidy of the insurance premium.

Reinsurance: coverage of catastrophic losses through a dedicated catastrophic risk layer.

Digital platform: integration with the national agricultural insurance information system.

21. Assessment of Economic Efficiency

The economic efficiency of parametric insurance should be assessed using several indicators. It is important to measure not only the amount of insurance payouts, but also the extent to which insurance reduces the farmer's financial risk, whether the benefits justify the cost of the policy, and how closely payouts correspond to actual losses.

A. Reduction in Income Risk

Let:

- Y_0 — farmer's income without insurance;
- P — insurance payout;
- Y_1 — farmer's income including the insurance payout;
- $\text{Var}(Y)$ — variance of income, reflecting the degree of income volatility.

The farmer's income after receiving the insurance payout is:

$$Y_1 = Y_0 + P$$

The reduction in income risk can then be calculated as:

$$\Delta R = \text{Var}(Y_0) - \text{Var}(Y_1)$$

For example, if:

$$\text{Var}(Y_0) = 100$$

and after accounting for insurance payouts:

$$\text{Var}(Y_1) = 60$$

then:

$$\Delta R = 100 - 60 = 40$$

Thus, insurance reduces income volatility by 40 units.

The larger the value of ΔR , the stronger the stabilizing effect of insurance on the farmer's income.

B. Benefit Relative to the Cost of Insurance

A reduction in risk does not necessarily mean that an insurance policy is economically beneficial. The farmer also incurs a cost in the form of the insurance premium.

The benefit-to-cost ratio can be expressed as:

$$\text{BCR} = \Delta L / \Pi$$

where:

- ΔL — expected reduction in losses due to insurance;
- Π — insurance premium;
- BCR — ratio of the expected economic benefit of insurance to its cost.

For example, if insurance reduces expected losses by:

$$\Delta L = 300,000 \text{ UZS}$$

and the insurance premium is:

$$\Pi = 100,000 \text{ UZS}$$

then:

$$\text{BCR} = 300,000 / 100,000 = 3$$

This means that for every 1 UZS spent on insurance, there are 3 UZS of expected loss reduction.

C. Basis Risk Coefficient

Basis risk is particularly important in parametric insurance because the payout depends on the value of the insurance index rather than directly on the farmer's actual loss.

Let:

- L — actual loss incurred by the farmer;
- P — insurance payout;
- $\text{Cov}(L, P)$ — covariance between actual losses and insurance payouts;
- $\text{Var}(L)$ — variance of actual losses;
- $\text{Var}(P)$ — variance of insurance payouts.

The relationship between actual losses and insurance payouts can be measured using the correlation coefficient:

$$\rho(L, P) = \text{Cov}(L, P) / \sqrt{[\text{Var}(L) \times \text{Var}(P)]}$$

A higher value of $\rho(L, P)$ indicates a stronger relationship between actual losses and insurance payouts and generally corresponds to lower basis risk.

Conversely, a low correlation indicates a greater mismatch between the insurance index and actual losses.

For example, if crop yields fall substantially because of drought and the insurance index simultaneously records severe drought conditions, the farmer receives a substantial payout. In this case, the relationship between L and P is relatively strong.

If crop yields decline sharply but the insurance index does not reach the trigger level, then:

$$P = 0$$

while:

$$L > 0$$

This indicates a significant basis risk.

D. Optimization of the Insurance Product

When designing a parametric insurance product, three objectives should be considered simultaneously:

Maximum $\rightarrow$ {Coverage, Affordability, Sustainability}

In other words, the product should seek an appropriate balance between:

- Coverage — sufficient protection against agricultural losses;
- Affordability — a premium that is financially accessible to farmers;
- Sustainability — the long-term financial stability of the insurance system.

These objectives are subject to economic and actuarial constraints, including the probability and severity of insured events, administrative costs, reinsurance costs, government subsidies, and the insurer's risk-bearing capacity.

Conceptually, the optimization problem can be written as:

$$\text{Maximize } U = U(C, A, S)$$

subject to:

$$\Pi \leq \Pi_{\max}$$

$$BR \leq BR_{\max}$$

$$SCR \geq SCR_{\min}$$

where:

- C — level of insurance coverage;
- A — affordability of the insurance policy;
- S — financial sustainability of the insurance system;
- Π — insurance premium;
- BR — basis risk;
- SCR — insurer's solvency or capital adequacy ratio;
- $\Pi_{\max}$ — maximum affordable premium;
- $BR_{\max}$ — maximum acceptable level of basis risk;
- $SCR_{\min}$ — minimum required level of financial security.

An economically efficient parametric insurance system should therefore do more than provide substantial payouts. It should reduce fluctuations in farmers' income, remain affordable, keep basis risk within an acceptable range, and preserve the long-term financial stability of insurers and the agricultural insurance system as a whole.

22. Development Scenarios through 2030

Three possible development scenarios can be considered.

Scenario 1 - Conservative

Agricultural insurance continues to rely primarily on traditional loss assessment.

Advantages: relatively simple institutional arrangements.

Disadvantages: high transaction costs and slow claims settlement.

Scenario 2 - Hybrid

Traditional insurance is supplemented by parametric products covering selected risks.

This appears to be the most practical approach during the initial stage of development.

Scenario 3 - Digital

A unified digital climate insurance system is developed, incorporating:

- satellite data;
- automated weather stations;
- IoT technologies;
- machine learning;
- digital insurance policies;
- automated payouts;
- international reinsurance.

The third scenario offers substantial potential for long-term scaling, but its implementation would require significant investment in data, digital infrastructure, and institutional capacity.

23. Discussion

International experience shows that the success of parametric insurance depends not simply on the use of an index, but on the quality of the broader institutional ecosystem supporting the product.

India demonstrates the importance of scale and the integration of weather data with satellite technologies. Kenya and Ethiopia illustrate the potential of vegetation indices for drought insurance in geographically dispersed livestock-producing areas. African Risk Capacity (ARC) demonstrates how sovereign parametric insurance can be used to finance responses to catastrophic climate events.

At the same time, international evidence does not support the assumption that parametric insurance automatically resolves the problem of climate-related risks.

Instead, research points to the need to:

- reduce basis risk;
- improve data quality and availability;
- strengthen financial literacy;
- develop efficient payout channels;
- integrate insurance with climate adaptation measures;
- subsidize initial development and implementation costs;
- provide reinsurance for catastrophic risks.

For Uzbekistan, this means that foreign models should not simply be replicated without adaptation to local conditions.

For example, a conventional rainfall index may be inadequate in an agricultural system that relies heavily on irrigation. A model combining climate, hydrological, soil-moisture, and satellite-based indicators may provide a closer representation of actual production risk.

Another important direction is a shift from insuring the consequences of drought toward a system that also supports early intervention. If an index can identify severe drought conditions before crop losses become irreversible, insurance payouts could be used not only to compensate for losses but also

to finance preventive measures, such as purchasing feed, providing additional irrigation, protecting crops, or preserving breeding livestock.

This preventive approach is already reflected in modern index-based livestock insurance programs and is increasingly considered by international organizations as a means of strengthening climate resilience.

24. Scientific Novelty of the Study

The scientific novelty of this study lies in the development of a conceptual framework for adapting parametric insurance to the specific conditions of arid agriculture in Uzbekistan.

Rather than relying primarily on precipitation levels, the proposed approach:

1. treats drought as a complex agro-hydro-climatic risk;
2. uses a composite insurance index;
3. incorporates crop phenological phases;
4. differentiates insurance indices by agro-climatic zones;
5. integrates insurance with water-saving technologies;
6. combines micro-level insurance with a sovereign catastrophic risk layer;
7. uses a digital system for automated payouts;
8. links insurance premiums to investments in farm-level climate adaptation.

Parametric insurance is therefore viewed not as a standalone financial product, but as part of a broader climate risk management system.

25. Practical Recommendations

The development of a parametric agricultural insurance market in Uzbekistan would benefit from the following measures.

A. Establish a national climate insurance data platform

The platform should integrate meteorological, hydrological, agronomic, soil-moisture, and satellite data.

B. Develop standardized insurance indices

Regulatory standards should specify requirements for:

- data sources;
- calculation algorithms;
- historical observation periods;
- back-testing procedures;
- independent verification.

C. Establish an independent index verification system

The underlying data should not be under the direct control of either the insurer or the insured party.

D. Develop a government subsidy mechanism

Public subsidies should primarily target socially and economically significant climate-related risks.

E. Establish a catastrophic reinsurance layer

Extreme drought events require mechanisms for international risk pooling and reinsurance.

F. Integrate insurance with agricultural lending

Parametric insurance policies can be linked to agricultural loans and used as a mechanism for protecting agricultural credit portfolios against climate-related losses.

G. Introduce adaptation-based premium discounts

Farms that adopt water-saving technologies, drought-resistant varieties, and other adaptation measures should be eligible for lower insurance premiums.

H. Launch pilot projects

Before scaling up, parametric insurance products should be tested for selected crops and regions.

I. Ensure transparency of the insurance index

Farmers should be able to verify:

- the source of the data;
- the value of the index;
- the applicable trigger;
- the payout formula;
- the reason why a payout was or was not triggered.

26. Conclusion

Parametric insurance is a promising tool for managing climate risks in drought-prone regions. Its key advantage is the ability to replace costly and time-consuming loss assessment with an objective index calculated from independent data. This is particularly relevant to agriculture, where large numbers of small farms are geographically dispersed and individual loss assessments following a widespread drought may be economically inefficient.

International experience shows that parametric insurance works most effectively when several conditions are in place: reliable data systems, a well-designed insurance index, low basis risk, digital distribution and payout channels, government support, reinsurance, and integration with broader climate adaptation programs. India demonstrates the potential of weather indices combined with satellite monitoring; programs in Kenya and Ethiopia illustrate the use of NDVI-based drought insurance; and African Risk Capacity demonstrates the viability of parametric insurance at the sovereign level.

For Uzbekistan, parametric insurance has significant potential because of the country's high climate vulnerability, the dependence of agriculture on water resources, and the ongoing digital transformation of the agricultural sector. The institutional environment is also becoming more supportive. Law No. ZRU-1056 of 14 April 2025 provides a legal framework for agricultural insurance, reinsurance, government support, the Agricultural Insurance Fund, and the digitalization of related processes.

At the same time, simply introducing a conventional rainfall index would be insufficient under Uzbekistan's conditions. The country requires a hybrid agro-hydro-climatic index that combines precipitation, temperature, soil moisture, vegetation conditions, and, for irrigated agriculture, water availability.

The model proposed in this study provides for three levels of risk sharing: individual insurance for agricultural producers,

portfolio-level coverage through agro-clusters and financial institutions, and catastrophic reinsurance at the national or international level.

The long-term potential of parametric insurance in Uzbekistan therefore depends not merely on the technical ability to calculate an index, but on the development of an integrated ecosystem combining climate data, insurance, agricultural lending, digital financial infrastructure, and reinsurance.

Over time, parametric insurance could become one component of Uzbekistan's transition from reactive management of drought impacts toward preventive climate risk management. Insurance should complement rather than replace investments in water conservation, climate-resilient crop varieties, irrigation infrastructure, and improved agrometeorological monitoring.

The combination of data, index, insurance, reinsurance, and adaptation therefore provides a promising institutional framework for strengthening the resilience of Uzbekistan's agricultural sector to drought.

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