The Rainy-Day Fund: Decentralized Parametric Insurance for Smallholder Farmers in Kenya

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Abstract

Smallholder farmers in Kenya face serious challenges due to climate variability, as more than 98% of agriculture depends on rain-fed systems and much of the country's arable land lies in arid and semi-arid regions (ASALs). Frequent droughts, unpredictable rainfall, and extreme weather events have reduced crop yields, threatened food security, and put rural livelihoods at risk. Traditional risk mitigation strategies, including crop diversification and off-farm income, remain insufficient, while irrigation development is limited due to infrastructural and environmental constraints. Weather index insurance (WII) has emerged as a practical solution because it provides affordable, quick, and reliable payouts based on objective weather data, while reducing administrative costs and moral hazard. Building on this idea, the Rainy-Day Fund introduces a decentralized, blockchain-based parametric insurance system. By using smart contracts and mobile payment platforms, it can deliver timely payouts to farmers, strengthen their resilience, and help them reinvest in their farms. This approach not only protects farmers from the financial shocks of extreme weather but also offers a transparent and efficient way to support sustainable agricultural livelihoods.

Keywords: Smallholder farmers; Kenya; climate change; weather index insurance; parametric insurance; blockchain; agricultural resilience; arid and semi-arid lands.

Contents

1 Introduction and Motivation

The goal of the Rainy Day Fund is to design a decentralized parametric insurance solution that can provide smallholder farmers with affordable, fast, and trustworthy protection against climate-related risks. By leveraging blockchain technology, the project seeks to overcome mistrust, high administrative costs, and inefficiencies that have limited adoption of weather index insurance. The motivation lies in addressing urgent climate vulnerabilities, reducing poverty traps, and creating scalable financial safety nets in one of the world's most underserved insurance markets.

Agriculture is the backbone of Kenya's economy, contributing approximately 21.3% to the country's GDP in 2024 (Bank 2024). It is the largest employer in the country, providing livelihoods for over 40% of the total population and more than 70% of the rural population (Food and Organization 2024b). Smallholder farmers form the majority of agricultural producers, yet they remain highly vulnerable to climate variability.

Kenya's Arid and Semi-Arid Lands (ASALs) cover more than 80% of the country, host over 70% of livestock, and are home to around 36% of the population (IUCN 2021; (NDMA) 2021; DHI 2021). Farmers in these regions depend almost entirely on rain-fed crops and livestock, making them extremely vulnerable to droughts and erratic rainfall.

The drought between 2020 and 2023, the worst in four decades, illustrates the severity of this risk: yields declined by up to 70%, 2.6 million livestock were lost, and 4.4 million people required urgent food assistance (Star 2024; (NDMA) 2024). These shocks highlight the fragility of rural livelihoods and the absence of effective financial safety nets to protect farmers.

Our guiding research question is: *How can blockchain-based weather insurance provide affordable, transparent, and automatic protection for rural farmers in Africa who are exposed to increasing climate risks?*

1.1 Problem Analysis

Smallholder farmers in Kenya are uniquely vulnerable to climate risks. About 98% of Kenya's agricultural systems are rain-fed (Kenya 2017), while irrigation development is limited due to infrastructural and environmental constraints (Wairimu n.d.). Traditional coping strategies such as crop diversification, off-farm work, and borrowing are insufficient to withstand the growing severity of climate shocks. As a result, households often fall into poverty traps, selling livestock or assets after droughts and struggling to recover in subsequent seasons. The recent 2020–2023 drought, the worst in four decades, illustrates the magnitude of the challenge: in some regions, crop yields dropped by up to 70%, more than 2.6 million livestock died, and 4.4 million people required urgent food assistance (OCHA 2023; Star 2024). These shocks do not only affect farmers individually but also ripple across Kenya's economy, since agriculture contributes over 20% of national GDP and supports the majority of rural livelihoods (Bank 2024).

Conventional agricultural insurance is largely absent in Kenya, and where it does exist, it suffers from deep structural weaknesses. High administrative costs make premiums unaffordable for smallholder farmers (Dominguez 2024). Claims processing is slow and heavily manual, which delays payouts and exacerbates farmers' financial vulnerability during shocks (Chainlink 2021). A lack of transparency around pricing and claims fosters widespread mistrust (Dominguez 2024). Moreover, coverage remains minimal: in Sub-Saharan Africa, fewer than 3% of farmers are insured, leaving more than 97% unprotected (Bank 2022).

Weather Index Insurance (WII) has emerged as a potential tool to address these challenges, because it relies on measurable weather data such as rainfall or temperature thresholds to trigger payouts. This reduces delays, administrative costs, and moral hazard compared to traditional indemnity-based insurance (Baagoe 2020; Sibiko 2018). Studies show that WII adoption can reduce poverty, improve household welfare, and encourage investment in improved seeds and fertilizers. Yet despite this potential, uptake remains very limited. Farmers often lack awareness or financial literacy, making WII appear too complex (Janzen 2020). Basis risk remains a major concern, as mismatches between weather station data and on-farm realities can result in payouts that do not reflect actual losses, undermining trust (Jensen 2016). Affordability is another barrier, since many farmers lack liquidity at the beginning of the planting season, precisely when premiums are due.

1.2 Benefits of Blockchain in Insurance

Blockchain technology, with its decentralized ledger and automated smart contracts, is particularly well-suited for microinsurance solutions targeting smallholder farmers. By eliminating intermediaries, automating claims, and ensuring transparency, blockchain can reduce operational costs, increase trust, and make insurance accessible even in remote areas (Dominguez 2024; Shetty 2022). Moreover, parametric microinsurance, where payouts are triggered by measurable weather events, benefits from blockchain's immutable and auditable infrastructure, ensuring rapid and verifiable payments. ...

2 Business Model and Perspective

Smallholder farmers in Kenya, particularly those living in the Arid and Semi-Arid Lands (ASALs), represent the primary target market for decentralized parametric insurance. These regions cover more than 80% of the country's land area, host over 70% of the livestock population, and are home to roughly 36% of the national population (IUCN 2021; DHI 2021). With more than 98% of agriculture dependent on rain-fed systems, smallholder farmers are disproportionately exposed to climate variability and shocks (Kenya 2017). Agriculture employs around 40% of Kenya's total population and over 70% of the rural population, yet fewer than 1% of farmers currently purchase agricultural insurance, leaving the vast majority unprotected (Food and Organization 2024a; Agriculture 2023).

2.1 Target Market

The stakeholders in Kenya's agricultural insurance ecosystem are diverse and interdependent. Farmers are the primary end-users. Insurers and micro-insurers underwrite and distribute weather-index products, while global reinsurers provide the capital buffers needed to make large-scale coverage feasible (Artemis 2017; BASIS 2017). The Government of Kenya, through its National Agricultural Insurance Policy (NAIP), and regulatory agencies play a critical role in shaping policy and supervising products (Initiative 2024; Agriculture 2023). International donors and development partners fund pilots, subsidize premiums, and provide technical assistance, as seen in the Kenya Livestock Insurance Program (KLIP) (Bank 2022). Mobile money providers such as Safaricom's M-Pesa enable efficient premium collection and direct payouts(Oxford 2017).

2.2 High-Level Concept

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3 Implementation

Overview of implementation goals.

3.1 Implementation Strategy

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3.2 Macro Architecture

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3.3 Micro Architecture / Technical Design

The project is built around a Solidity smart contract using the Ethereum Virtual Machine. This central RainyDayFund contract can be called using the front end and holds all the exposed functionality for the consumer. Investors use the `invest()` and `withdraw()` methods while insurees can buy and claim their policies in batches using the `buyPolicy()` and `claimPolicies()` functions. ...

As shown in Figure 1, the initial contract made use of the `1155 token standard` for the `policyTokens`, to take advantage of the cost-efficient batch operations (Ethereum 2025). To help with testing the (Mock)-MUSCD was created, implementing the ERC20 interface, to emulate the behavior of common stablecoins like USDC, which are used as payment and funding for the riskpool. This allowed for the free minting and full control over the coins and made testing the functionality of the main contract possible, even within the bounds of Remix VM . Therefore, testing was quicker and easier at the beginning, without the need to always deploy on the Sepolia Testnet or an immediate, complete setup, for example with hardhat.

Initially there were multiple issues:

1 **Mapping for storing addresses:** Initially we used a mapping to store who had bought policies and was thereby eligible to claim them. However, there were some issues with this: Firstly, the policies lost all their value when they were resold, because the address of the new owner would not be tracked in the mapping. Moreover, storing all of this data was very gas-inefficient and redundant, because ownership of the policyToken is proof of ownership for the policy.

2 **No proper incentive for investors:** We had already planned to give the investors some incentive to keep their funds in the riskpool, even after the season would end, to increase liquidity for the next season. The idea to achieve this, was, to use compound interest or

create some other form of yield over time. However, implementing this with the initial setup proved difficult and created vastly unfair results Hier vllt nochmal genauer erklären

3 **Weather oracle:** The initial mock-up for the weather oracle was just a number that could be accessed and stored on the contract directly, as an initial mock-up for testing purposes. Nevertheless, this was far from the goal of using chainlink as a decentralized oracle to reliably and transparently access the data.

4 **Attack vectors:** Lastly there were some attack-vectors, especially for the owner. The `startNewSeason()` function could be used at any point during the season, thus rendering unclaimed policyTokens worthless and not allowing for investment-withdrawals to be made.

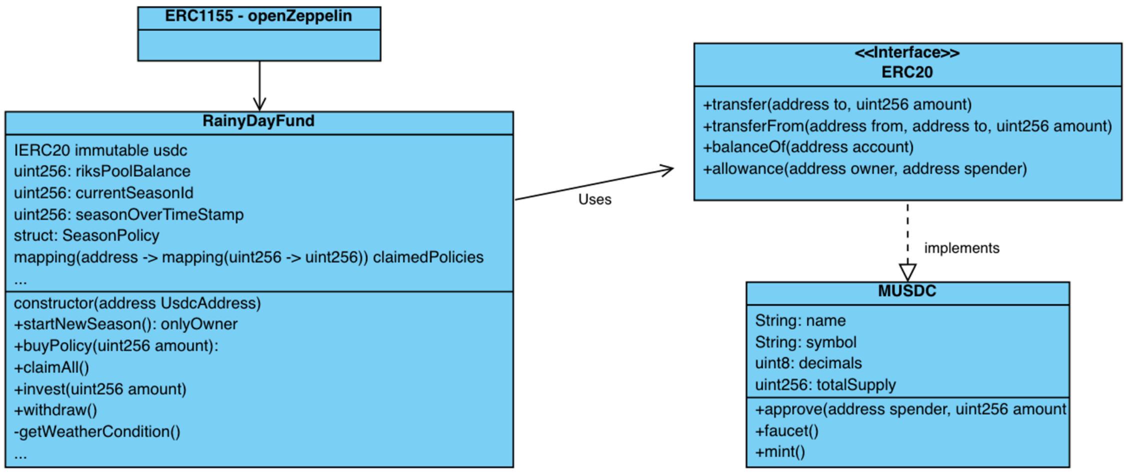

Figure 1: Initial Contract Design
Source: Author's own.

3.4 Challenges and Risk Mitigation

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3.5 Outlook and Next Steps

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4 Conclusion

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Appendices

Add any supplementary material here.