Blockchain Climate Risk Crop Insurance

LAB INSTRUMENT ANALYSIS
September 2019

DESCRIPTION & GOAL —
A standardized, digital index crop insurance platform for smallholder farmers that addresses the impacts of climate change on crop production by making insurance more transparent, efficient, and scalable

SECTORS —
Agriculture, financial services

PRIVATE FINANCE TARGET —
Private finance from venture capital
Potential need for demand-side donor support

GEOGRAPHY —
For pilot phase: Kenya
In the future: sub-Saharan Africa, South Asia, and South-East Asia

The Lab identifies, develops, and launches sustainable finance instruments that can drive billions to a low-carbon economy. The 2019 Global Lab Cycle targets four specific sectors across mitigation and adaptation: blue carbon in marine & coastal ecosystems; sustainable agriculture for smallholders in West and Central Africa; sustainable energy access; and sustainable cities.

1. CONTEXT

Despite threats of increasing climate vulnerability and decreasing food security, only 20% of smallholder farmers in developing countries have access to agricultural insurance coverage.

In developing countries, as many as 270 million smallholder farmers are underinsured. Only 20% have access to agricultural insurance coverage, and in sub-Saharan Africa - despite the fivefold increase in agricultural microinsurance registered between 2011 and 2014 (McCord et al., 2015) - this percentage falls further to 3% of smallholders (ISF Advisors, 2018).

At the same time, climate vulnerability of crops is increasing, posing a significant threat to food security. On average, smallholder farmers with landholdings under 5 hectares are responsible for 50% of global food production (Ricciardi et al., 2018). Further, an estimated 58% of rural households depend on subsistence production (Sibhatu et al., 2017). Climate change could raise food prices and erode the ability to afford purchased food[1] or, in the extreme, threaten food access and its utilization by smallholders (IPCC, 2014).

Despite increasing vulnerability, smallholders have not yet fully developed the capacity to respond to climate change, and agricultural techniques and infrastructure remain antiquated. Innovative technologies are rarely implemented, increasing vulnerability to climate change.[2] Communities manage risks via solidarity, cooperation, and trust among rural communities (Tadesse et al., 2015), while individual farms mitigate risks of extreme events through diversification. However, this can result in lower yields and income. Smallholders also face the challenge of bearing the incremental cost of shifting from conventional practices towards climate-smart agricultural practices and climate-resilient value chains (Mc Sweeny, 2016).

The Blockchain Climate Risk Crop Insurance aims to increase smallholder farmers' resilience to climate change through offering a more accessible index insurance product[3] at scale. The instrument offers the possibility to create standardized and customized insurance products, along with significant innovations to automate payouts, reduce transaction costs and claim cycles, enabled through blockchain. The policy will be available via mobile phones to smallholders, who will be able to react promptly to weather events, increasing resilience of vulnerable crops in remote locations.

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[1] This is particularly true for crops that are more sensitive to weather variability but more profitable on average (McSweeny, 2016; ATAI, 2016). As a result, climate change in certain cases might force smallholders to adopt low-risk low-return crops. An example of this event is the shift from groundnut to millet of smallholders in Senegal (CIAT and BFS/USAID, 2016). In Andhra Pradesh, farmers shifted from red gram and sorghum to the cash crops castor and groundnut after receiving insurance (ATAI, 2016).

[2] For example, only 6% of Africa's land uses irrigation technologies. (Bayer Crop Science, 2018)

[3] GIIF (2019) identifies index-insurance as "insurance provision that pays out benefits on the basis of a predetermined index (e.g. rainfall level) for loss of assets and investments, primarily working capital, resulting from weather and catastrophic events." Index insurance can take the form of either an area yield index, crop weather index or Normalized Difference Vegetation Index (NDVI). Weather-index insurance is a "type of insurance whereby, the indemnity is based on realizations of a specific weather parameter measured over a pre-specified period of time at a particular weather station or for a given satellite grid. The insurance can be structured to protect against index deviations that are expected to cause crop losses." For area yield insurance "indemnity is based on the realized (harvested) average yield of an area such as a county or district. The insured yield is established as a percentage of the average yield for the area". Finally NDVI relates moisture deficit to pasture degradation.

2. INSTRUMENT MECHANICS

The Blockchain Climate Risk Crop Insurance is a standardized and digital index platform to increase smallholders' access to insurance and strengthen their resilience.

Blockchain Climate Risk Crop Insurance offers a different kind of crop insurance that's both affordable and accessible to smallholder farmers at scale. Each insurance policy is plugged into smart contracts on a blockchain[4] and indexed to local weather. During an extreme weather event, the policies are automatically triggered on the technology platform, which facilitates timely and fair pay-outs. Compared to traditional index-based insurance, this system is much faster and much more transparent, leading to reduced costs and increased trust for both farmers and insurers alike.

The instrument relies on three main elements: 1. an insurance provider or, on its behalf, insurance service and a data provider; 2. a user interface; and 3. an application layer linking insurance policies to a blockchain. There are variations in the role and responsibilities for each of these components in the pilot phase and subsequent phases.

2.1 MECHANICS DURING THE PILOT PHASE

The pilot phase of the instrument involves a market test in Kenya, with some variations in the mechanics which will allow the concept to be tested on an existing index insurance.

Figure 1: Instrument mechanics for the pilot phase

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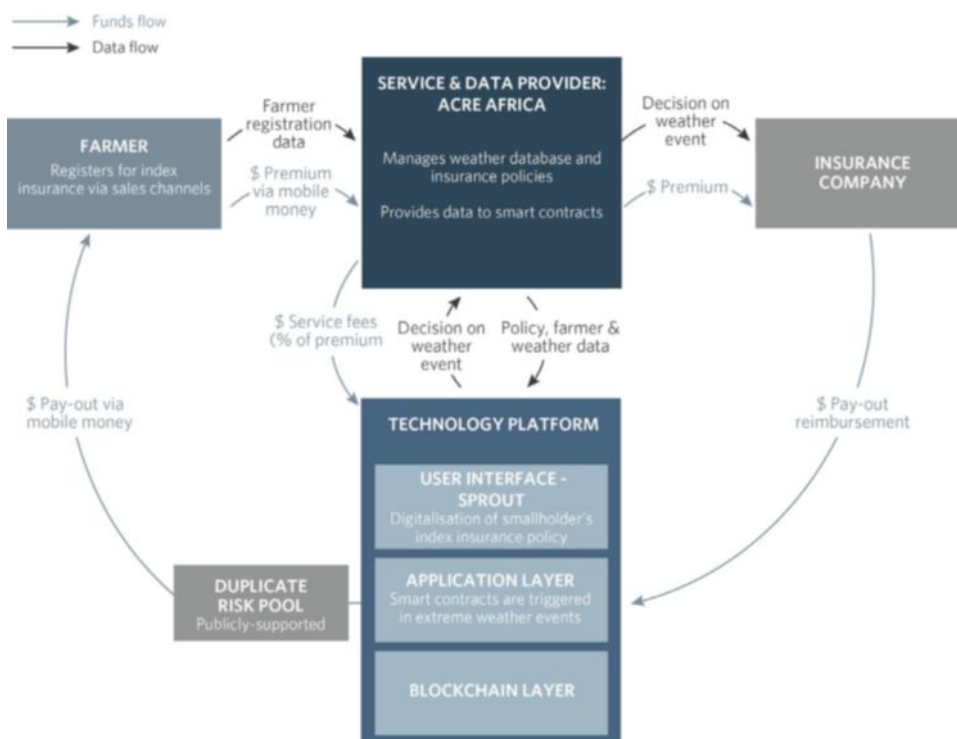
[4] Blockchain or Distributed Ledger Technology (DLT) can be defined as a ledger of individual blocks of data, linked and secured through encryption technology (hashes). Copies of the ledger are stored on a distributed network and updated when a transaction occurs (Voshmgir and Kalinov, 2017).

There are three key partners for the pilot phase (see Figure 1):

- An **insurance service and data provider,** ACRE Africa, designs of the insurance product, processes the premium payments, and manages the commercialization of the product and customer care.[5] It also collects and manages the weather data, which is used for the creation of a risk model and the verification of the occurrence of extreme weather events.[6]
- A **user interface**, designed and managed by Sprout Insure, registers the insurance policies as smart contracts[7] on a private blockchain[8]. This will harmonize payment processing, farmer data, and policy information that are currently siloed, ultimately reducing transaction costs.
- An **application layer,** developed by Etherisc, provides the smart contract infrastructure on the Ethereum blockchain (blockchain layer) where the user interface is built.

The other actors and components in the mechanism are:

- An **insurance company,** UAP Holdings, will manage the risk pool and perform pay-outs via mobile money.[9] To prove the concept of faster and transparent pay-outs, a duplicate risk pool managed within the technology platform may be created, which would anticipate payments on behalf of the insurance and demonstrate fast and trustworthy pay-outs to farmers. After verifying the pay-outs, the insurance company will reimburse the technology platform.[10]
- **Distribution channels** will bundle the index insurance with crop seeds from certified distributors. The product will be distributed as a scratch card attached to a seed bag and sold in agrovet shops, available in remote areas, or through cooperatives and accessible to all farmers with a simple mobile phone.[11]
- **A mobile money provider,** M-Pesa, will enable the financial transactions between the end-users and the index-insurance product.

2.2 MECHANICS DURING THE SCALE-UP PHASE

Once the concept has been proven, the medium-term structure will include further standardization and automatization of the insurance process. The blockchain platform will have a bigger role, with the aim to automatically trigger the payments at the insurance company-level in case of extreme weather events.

In this phase, service providers and insurance companies implement their own index insurance via the user interface (Sprout), in exchange for a service fee based on the premium charged to the smallholder farmer. Now, the blockchain technology platform is

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[5] A detailed registration process of a smallholder farmer can be found in Appendix 8.1.

[6] For the pilot in Kenya remote sensing techniques are used in combination with 80 weather stations spread across Kenya. For the determination of the rainfall thresholds (or index) in the policy, historical data going 30years back in time are being used.

[7] Smart contracts enable parties to execute agreements in a secure manner through a set of predefined rules, implemented as a piece of code on top of the blockchain layer. It will automatically execute a transaction only when the parties fulfil the predefined set of rules (Voshmgir and Kalinov, 2017).

[8] A private blockchain, e.g. working on a Proof-of-Authority (PoA) protocol, refers to an infrastructure whereby access permissions are controlled, without losing the decentralization and authenticity element. The right to execute the consensus protocol is restricted to a handful of identified nodes (Buterin, 2015) (Jayachandran, 2017).

[9] GSMA, (2010) defines mobile money as "a service in which the mobile phone is used to access financial services."

[10] Managing payments on behalf of an insurance company requires a mutual agreement with the insurance company and a broker license, both of which ACRE Africa currently has in place (IRA, 2019) (CIMA, 2019).

[11] Marketing techniques are primarily radio spots, bulk SMS campaigns, and in-person contact with agents placed in agrovet shops.

fully responsible for the management of financial flows – still occurring via mobile money payments. They will manage premium payments and automatized pay-outs on behalf of the insurance company, without the need of a duplicate risk pool to anticipate payouts.

The actors involved remain the same, but the blockchain technology platform would partner directly with insurance companies, weather data providers (e.g. IBM's Weather Channel) and service providers as a result of the increased centralization of functions. Other distribution channels could be explored in addition to seed packages in agrovet shops. This could include microfinance institutions to offer the index insurance as part of their loans, or as improved credit scoring for farmers alongside CSA practices.

Figure 2: Instrument mechanics and stakeholders for the scale-up phase
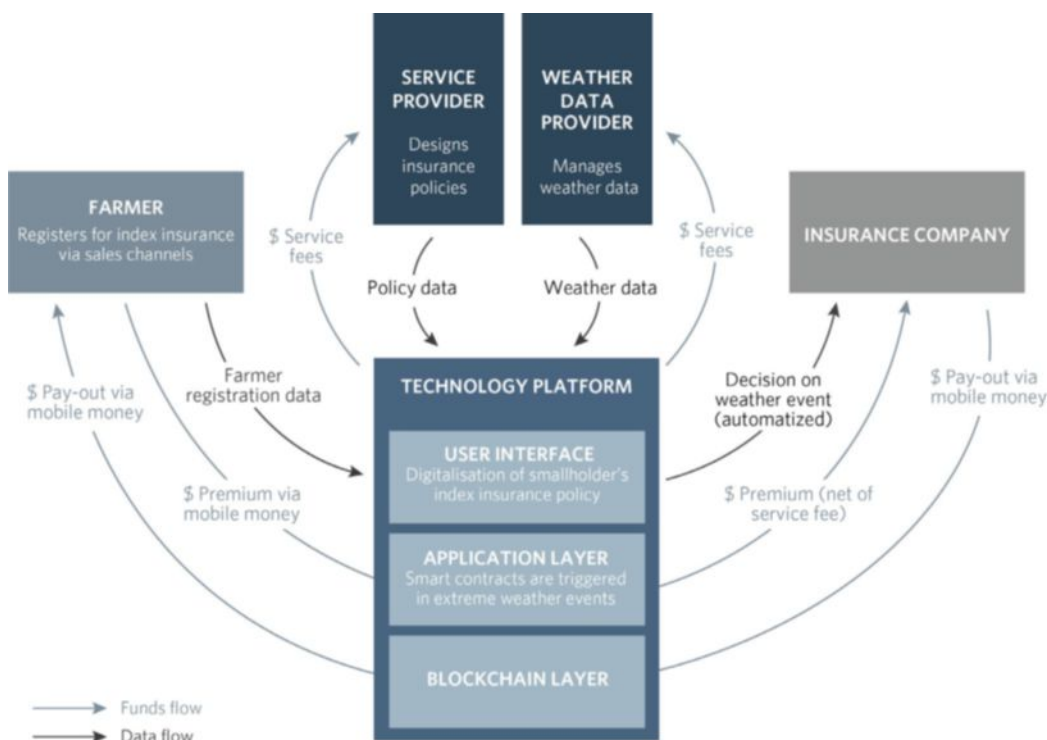
In the long-term, the blockchain technology platform would become a one-stop-shop insurer by renting an insurance license, and internalizing the risk pool within a public blockchain system, which would allow for further reduction of transaction costs, and scale up of crop insurance. Here, the different stakeholders (e.g. weather data providers, policy providers, etc.) accessing the user interface and underlying application layer would be interacting through a token structure[12] (Hampton, 2018),[13] with a risk pool internalized on the blockchain platform. This system would require smart contracts to be implemented on the public blockchain.[14] Smallholder farmers could pay and be reimbursed through a third party

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[12] A token is a unit of value within a specific cryptocurrency ecosystem.

[13] The details on the long-term strategy can be found in the Appendix 8.1.

[14] A public blockchain works on an open, decentralized network. A public blockchain protocol is the Proof-of-Work (PoW) consensus algorithm, which refers to the protocol whereby miners solve a computational problem with the first one solving it being able to add a new block to the chain. Other miners can then verify the correctness based on values in the block (Porat et al.) (PWC, 2017). Ethereum requires a gas fee whenever a new policy is executed. This corresponds to a reward

offering a payment gateway to remove the need for end-customers to own tokens,[15] which would be pegged to a local currency (Etherisc, 2017).

3. INNOVATION

The Blockchain Climate Risk Crop Insurance addresses barriers on both the demand and supply side of the crop insurance market. Compared to traditional insurance, the instrument is faster and more transparent, leading to reduced costs and increased trust for both farmers and insurers alike.

3.1 BARRIERS ADDRESSED: ACCESSIBILITY, AFFORDABILITY, AND TRANSPARENCY

Key barriers for insurance in the market include limited demand and limited supply, and lack of trust between insurer and farmers due to delayed pay-outs or absence of pay-outs to the insured.

There is limited demand mainly due to many smallholders' limited awareness of how agricultural insurance can reduce risk exposure (Fisher et al., 2017). More importantly, insurance products are perceived as costly, with limited coverage and long claim cycles, which make them a difficult value proposition for smallholders. Furthermore, there is a general lack of trust between insurer and farmers, fueled by delayed or defaulted pay-outs (ISF Advisors, 2018).

On the supply side, Di Marcantonio and Kayitakire (2017) argue that "the most common constraints are lack of quality data, start-up costs and related economic support by the government, and difficulty in transferring covariate risk[16] to the international reinsurance market." Additional constraints are represented by the fact that policies are developed and distributed by intermediaries who lack the infrastructure to scale the product at low cost and effectively track real-time weather data linked to multiple policies (ACRE, 2019a).

The Blockchain Climate Risk Crop Insurance addresses these supply and demand barriers by improving insurance with reduced claim cycles and transaction costs, and increased transparency and trust via smart contracts on a blockchain.

Reduced claim cycles: Instead of lengthy processing of claims, weather data automatically triggers pay-outs, giving farmers the means to react promptly to the weather event. The proponents, Sprout Insure and ACRE, estimate that the time needed to process pay-outs in the pilot phase will be reduced from 3 months to 1 week,[17] assuming the adoption of the duplicate risk pool.[18] A 1 week pay-out could also be achieved if claims are processed

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for the miners inherent to the current Proof-of-Work consensus algorithm of the Ethereum blockchain. The fee is composed of a gas limit and gas price. The gas limit, which is directly related to the amount of code that needs to be executed. The gas price is variable and voluntary. The higher the gas price, the more likely your transaction is going to be mined first (Modi, 2018). Ethereum is moving to a Proof-of-Stake consensus algorithm, which will lower the gas fee.

[15] E.g. through a cryptocurrency exchange similar to Bitpesa.

[16] Covariate risk is the risk that neighboring smallholders would suffer similar shocks in the case of a single risk event. This means that if the risk pool is not diversified enough in terms of geographies and risks covered, it would determine payouts above available resources, hence the need to reinsure risk to make coverage viable.

[17] Assumption based on the est. time currently needed by ACRE to manage the payment for 1m customers (ACRE, 2019).

18 Four weeks if no duplicate risk pool is used.

directly through the insurance's application programming interface (API) in the medium-term strategy, while a few hours payment would be possible if crypto-based pay-outs are enabled, in the long-term.

Reduced transaction costs: The use of index insurance, as opposed to indemnity-based insurance,[19] reduces costs since the system relies on easily verifiable data, and loss assessment at an individual level is no longer needed, with a lower cost of processing claims and probably lower fraud potential (IFAD, 2017). The automatization of the verification and payment process through blockchain, mobile money, and other digital platforms can further reduce costs. The proponent estimates that transaction costs can reduce by 30-80% (up to 60-80%)[20] which frees resources for scale-up.

Increased standardization: By creating templates for blockchain-based insurance products, the Etherisc platform gives farmers, cooperatives, donors, buyers or even end-consumers the tools to create their own customized insurance product, at a lower cost (Sprout, 2018a). The infrastructure allows for a standardized process in the monitoring of the claims, by verifying real-time weather data for a variety of policies. This removes the need for an intermediary to track policies on a company level and as such makes the process trustworthy and reduces transaction costs. Moreover, it creates the possibility to launch index-insurance products at scale for a variety of products at different geographies in emerging markets. The unchangeable structure of smart contracts integrated with real-time weather data tracking allows for the systematic, prompt verification of whether the amount of rainfalls triggers a payout. Furthermore, since multiple parties are sharing and updating policy and weather data, blockchain technology makes the process secure and trustworthy (PWC, 2017).

3.2 INNOVATION: A NEW CONCEPT IN HIGH IMPACT COUNTRIES

There has been a fivefold increase in agricultural microinsurance registered in 2011-2014 (McCord et al., 2015). Different types of agricultural index insurances, both for crops and livestock, have been piloted in sub-Saharan Africa, but this instrument is only one of two to integrate a blockchain in the region, and the only one proposing a standardized, scalable approach.

Broadly speaking there are two types of microinsurance agricultural products: indemnity-based crop insurance and index insurance. Major actors in sub-Saharan Africa involved in the index-insurance market include ACRE Africa (with over 1,000,000 customers), Sum-Africa, Pula Advisors, Ghana Agriculture Insurance Pool, R4 initiative (mostly East Africa) and Planet Guarantee (mostly West Africa). These actors have been driving or supporting initiatives as intermediaries alongside national insurance actors as UAP in Kenya, NIRSAL in Nigeria and CNAAS in Senegal.

However, to date, only one other initiative in sub-Saharan Africa combines parametric crop insurance products with blockchain - WorldCover, a major mobile microfinance actor in Ghana, which launched a blockchain initiative through its existing peer to peer

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19 Indemnity-based cover compensation is based on measured loss or damage measured as shortfalls of actual yield at the individual farm level compared with expected yield and requires an insurer to make individual farm visits to set up coverage and to assess loss.

20 Estimate based on pilot phase data. Currently 3-4 people are employed for verifying payments. The use of blockchain technology may reduce their costs by 60-80% (ACRE, 2019). Sprout estimates an overall reduction in intermediary and claim processing costs of around 30% (Sprout, 2018b).

microinsurance platform at the end of 2018 (Socialfintech, 2018). Beyond sub-Saharan Africa, Etherisc is implementing a blockchain-based index insurance pilot in Sri Lanka (AON, 2019). A complete list of comparable instruments reviewed is in Appendix 8.2.

3.3   CHALLENGES TO INSTRUMENT SUCCESS

While the pilot is plugging into an existing market with the infrastructure in place to support demand, persistent lack of demand, high basis risk,[21] and perceived environmental concerns around the use of blockchain protocols along with other challenges specific for the insurance industry, may hinder its ability to achieve its goals in the long-term.

One challenge to the instrument is persisting low demand due to smallholders being unaware of the product's value, or because despite the transaction costs reductions, insurance premiums remain higher than what farmers are willing to pay (ATAI, 2016).[22]

Strategies for managing this challenge include:
- public sector grants to support premiums purchases;
- bundling the insurance product with inputs such as seeds and fertilizers, or services like credit as adoption of the insurance can lead to lower interest rates;[23]
- investing in better climate information, via training and media marketing through radio and television. Farmer organizations, more specifically, are an effective channel to both increase demand – for instance through buying group insurance on behalf of farmers – and raise awareness of index-insurance within their cooperative;[24]
- enabling smallholders to pay premiums in small installments. To facilitate premium payments during the pilot, the proponent will allow for paying the premium over time in small instalments as low as US$ 0.50.

A second challenge to the instrument success is basis risk, which can result from poorly designed products, the distance between the index measurement location and the actual production field, and extension of the area covered and its variability. This reduces farmers' trust in the insurance product, as it cannot be relied upon to cover actual losses incurred.

Strategies for managing this challenge include:
- minimizing basis risk with robust product design and testing of contract parameters;
- decreasing the areas radius covered by the weather station in combination with Earth observation methods (Etherisc, 2019), or satellite data;
- using established weather stations and successfully tested products. For the pilot stage the proponents are working with existing insurance products developed by ACRE Africa to build on existing weather data expertise (ACRE, 2019);
- ensuring the area covered by the index is homogeneous both in terms of weather and farming techniques.

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[21] Basis risk in index insurance arises when the index measurements do not match an individual insured's actual losses. Products with high basis risk could have no pay-out even if the farmer has suffered devastating losses or, alternatively, a pay-out even in the event of no losses at all (ISF Advisors, 2018).

[22] This could be due to lack of reliable climate data, rising levels of risk and disaster, or coverage of extraneous risks under the same policy.

[23] In low collateral environments such as those found in large parts of sub-Saharan Africa, index insurance is most effective when interlinked with credit. In a low collateral environment, substantial risk is carried by the lender, and interlinkage of credit with insurance internalizes the positive externality that insurance has on the stability of the lender's loan portfolio. Without this interlinkage, index insurance is likely to be ineffective as insurance purchased by the farm household primarily benefits the lender (Carter et al., 2014).

[24] Appendix 8.5 provides a quick overview of farmer organizations and cooperatives in target countries.

A third challenge derives from the perception that the use of blockchain protocols may automatically lead to significant environmental co-impacts at scale. Blockchain is considered impactful in terms of carbon emissions, due to the high amount of energy needed to process blocks of transactions through mining. [25] However, this mostly depends from the type of protocols used.

Strategies for managing this challenge include:
- Assessing different options in terms of blockchain protocols, to find the right balance between security, scale/data processing, overall reliability needs of the system (e.g. minimizing error), and energy intensity of the protocol. The proponent during pilot and scale up phase (medium-term view) would rely on a private blockchain, which does not require mining, and has thus no carbon footprint. Most impacts would derive from the use of public blockchain algorithms as per the long-term view for the instrument: here the proponent plans to shift to more efficient protocols which would reduce energy requirements by up to 90-99%.[26]
- Increasing efficiencies, by bundling together multiple transactions;
- Carbon offsetting options.

A broader overview of challenges is included in Appendix 8.3.

MARKET TEST AND BEYOND

4. IMPLEMENTATION PATHWAY AND REPLICATION

The pilot in Kenya will target 1.2 million farmers over two to four years. The instrument has great potential for scale-up, particularly in African and Asian markets.

4.1   PILOT IMPLEMENTATION

The instrument is under development by Sprout Insure, a digitization and automatization solution provider for index insurance products on a blockchain. The strong partnerships between Sprout, ACRE Africa, and Etherisc are key to the implementation of the instrument. ACRE Africa is a recognized intermediary for index insurance across sub-Saharan Africa, currently covering over 1 million smallholder farmers. Etherisc is a smart contract developer for different types of index insurance products with experience in emerging markets.

The pathway towards implementation consists of two phases: pilot and scale-up.[27]

The pilot will take place for two to four years (four to eight seasons) starting from April 2020 and will target 1.2 million farmers in Kenya. Sprout has already signed an MoU with ACRE

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[25] Mining is the act of validating Blockchain transactions, an activity performed by a third party on a public blockchain getting rewards in exchange for using their computing power to solve complex algorithms.
[26] Ethereum plans to move from Proof-of-Work protocols, to less energy intensive Proof-of-Stake algorithms, although such transition may not happen smoothly (Lee et al. 2018). For an overview of the impact of different protocols refer to Appendix 8.3
[27] For the scale up phase we hereby refer to the medium-term structure outlined in paragraph 2.2.

Africa and Etherisc[28] and has selected the crop – maize[29] – and the risk model – ACRE Africa's Bima Pima insurance product, covering droughts in four stages of the crop growth cycle (from plantation to pre-harvest), at a 10% premium rate per season.

Before the pilot, 1 season (from April-October 2020) will be dedicated to farmer observation and assessment of the current processes and information systems used by Acre, M-Pesa and UAP, to guarantee the integration with the proposed technology platform. Simultaneously, the proponents will engage with private sector investment groups for venture capital funding and will apply for long-term regulatory approval from Kenya Insurance Regulatory Authority (IRA) to enable the use of Sprout across Kenya, through a broker license. The proponents will also carry out legal and operational tasks, hire technical experts, start grant fundraising, refine the risk model, and establish relevant stakeholder relations.

From October 2020, Sprout will pilot the product to the target farmers. Potential implementation risks during the pilot stage, and strategies for management are described in the table below.

Table 1: Implementation risks and related management strategies.

Implementation risk	Management strategy
Delays for approval from the Kenya Insurance Regulatory Authority (IRA) may delay implementation of pilot.	Discussions are already ongoing through ACRE. Sprout will formally request approval from the IRA during the pre-pilot phase. A rigorous pre-pilot, with the identification of robust Key Performance Indicators (KPIs) would further increase the chances of success.
As the instrument moves from pilot to scale up, partnership structure (e.g. with brokers, insurers etc.) may change, with potential confusion on roles and expectations.	Roles and service fees of different partners will be defined upfront for different partnership configurations.
Difficulties in fundraising from the private investment	Public sector support - both financial and as endorsement of the instrument and recognition of the importance of the challenge it addresses - would reduce risk perception by private investors. This is particularly important during the early stages of the project, where discussions with venture capital providers are expected.

In the scale-up phase, starting between 2022-2024 onwards, Sprout will roll out a range of index insurance products targeting multiple crop types in different geographies. Therefore, they will engage with relevant stakeholders focusing on brokers, aggregators, and insurers. At the same time, Sprout will work with Etherisc to roll out a technical implementation of smart contracts on the Ethereum blockchain, including a risk pool on blockchain. Sprout also plans to become an insurance provider. In its long-term structure, the instrument would reach full commercialization whereby risk is recovered through premiums and the company is financed through profit reinvestments and commercial financing. In the long-term, Sprout envisions a strategy whereby the risk pool will be integrated on the blockchain platform using Etherisc's smart contract infrastructure.

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[28] Before starting the pilot Etherisc would to assess systems used by Acre Africa and Insurer UAP Holdings, M-Pesa, and needs to integrate the platform with the current systems.
[29] Maize is the most common crop for subsistence farmers in Kenya, and one of the crops for which index insurance already exists commercially, thus particularly suitable for a test. Other crops initially considered for the model were sorghum, potatoes and livestock.

A more detailed timeline with the pathway to implementation is in Appendix 8.4.

## 4.2 POTENTIAL TARGET COUNTRIES

Kenya was selected as the pilot location based on its conducive environment for insurance products, and existing strong partnerships on the ground.

To identify potential replication among non-OECD countries, we looked at: conducive environments (supportive environment for blockchain technology, microinsurance, mobile money, and public support for adaptation), climate vulnerability (food security, drought and food risk), and market size expressed as agricultural land owned by smallholders. The full methodology can be found in Appendix 8.5.

Sub-Saharan Africa provides the best opportunities for replication, especially Burkina Faso, Senegal, and Mali in West Africa and Kenya, Uganda and Rwanda in East Africa. Asian countries also have a lot of potential, mainly in South Asia (India, Bangladesh, and Nepal) and Southeast Asia (Cambodia, Thailand, and the Philippines).

Enabling factors in high impact countries in sub-Saharan Africa are principally defined by the high adoption rate of mobile money accounts and progressive regulation and subsidy schemes for index-insurance, while uncertainties have mostly to do with the unclear stance of some governments regarding the adoption of blockchain technology, and high variability of distribution channels for index insurance among farmer organizations which may impact on their effectiveness. An overview of enabling factors and challenges for the replication of the mechanism in high-impact countries in sub-Saharan Africa is available in Appendix 8.5.

Figure 3: Target countries for replication
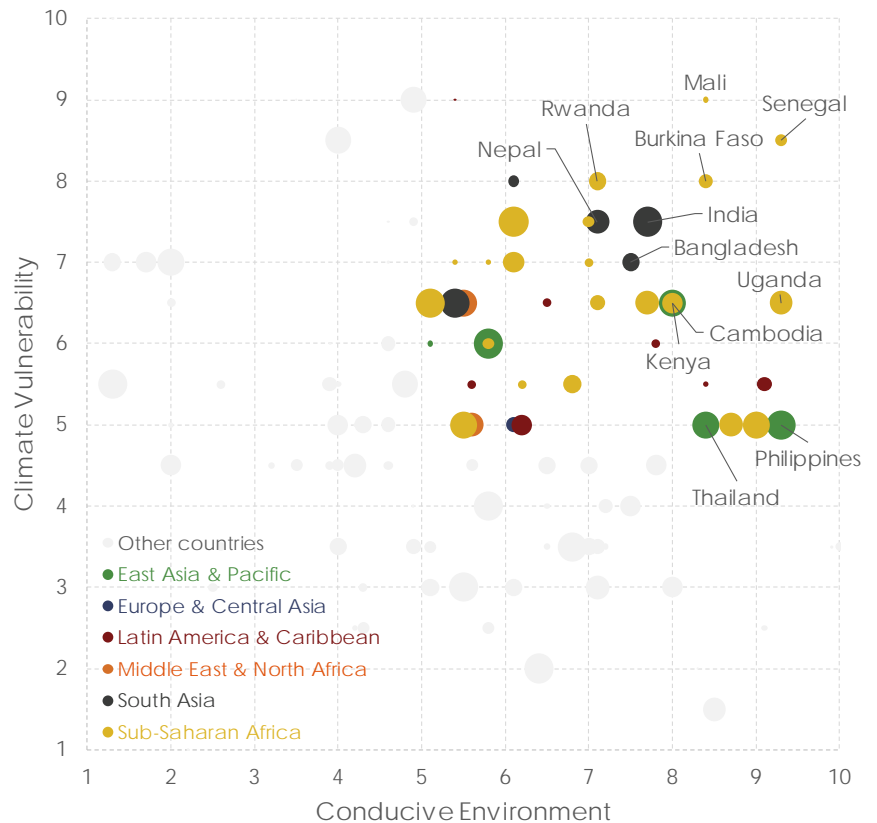
5. IMPACT

Blockchain Climate Risk Crop Insurance lowers costs for both insurers and farmers. It can reduce the cost of issuing a policy by 40%, and in turn reduce farmer premiums by 30%, with faster pay-outs, thus helping increase community resilience and reduce recovery times when disasters strike.

5.1 QUANTITATIVE MODELLING

5.1.1 IMPACT OF THE BLOCKCHAIN TECHNOLOGY PLATFORM AND FINANCIAL REQUIREMENTS

To estimate returns for the blockchain technology platform, we built a cashflow model based on the pilot, targeting 1.2 million maize farmers in Kenya for four years.[30] We then ran a simulation for four different scenarios reflecting increased degrees of integration of weather index crop insurance activities on the platform, which will unfold as the instruments moves from pilot to scale-up.[31] The model assumptions are in Appendix 8.7.

Key takeaways include:
- **The initiative is profitable under all scenarios**, particularly during scale-up phase with an integrated insurance platform model (scenario B2), where return on investment may reach as much as 38%;
- **In the long term, an integrated insurance platform model (scenario B2) can reach up to 41% reduction of levelized costs needed to issue a policy**. This reduction can partly be transferred to the smallholder farmers in the form of a premium reduction of up to 30%.

Figure 4: Levelized cost for issuing a single policy under different scenarios, with increasing centralization of insurance functions on blockchain

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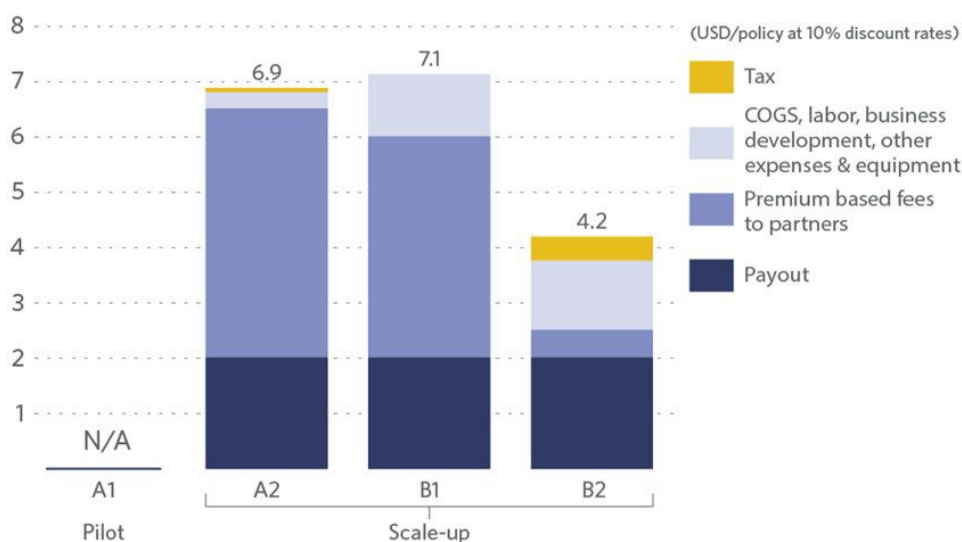
[30] As mentioned in section 4.1 the proponent targets 2 to 4 years for the implementation of the pilot.

[31] Mechanics, costs and structure of the relation between partner are assessed for the following four scenarios, all representing increasing levels of centralization and integration of insurance services on blockchain: A1 (short-term pilot in Kenya), A2 (mid-term scale-up in sub-Saharan Africa), B1 (mid-term scale-up in other regions), B2 (long-term scale-up in other regions). Details on the scenarios and full analysis are in Appendix 8.7.

Financial needs for the pilot include:

- **An initial investment up to US$ 620,000** for the pilot to be tested (scenario A1),[32] from implementing entity and venture capital, and additional US$ 200,000 from partners for system integration on blockchain.
- **US$ 10.8 million premium subsidies – supported by the public sector – to guarantee that enough demand is driven in the market along with an expanded (thus more effective) insurance coverage for farmers.** Demand-side support in the form of premium subsidies may be also important in the medium term, when a shift towards a more integrated business model is started (scenario B1), more costs are internalized, and a higher turnover of customers (1,000,000) is needed to break even.
- **A potential public grant of up to US$ 468,000** to support business and product development activities from partners, along with US$ 5 million to fund the duplicate risk pool during the testing phase of the project.

Table 2: Public and private financial requirements for the pilot.

Financial flow type	No public support (US$)	Full public support (US$)	Source of finance	Use
Private equity	200,000	0[33]	Partner / service provider	Investment in mobile system integration
Private equity	620,000	352,000[34]	Venture capital / implementing entity	Business develop/t & Upfront investment
Private savings	10,770,000	10,770,000	Smallholder farmers	Premium purchase
TOTAL Private	**11,590,000**	**11,122,000**		
Public grant	0	468,000	DFIs	TA grant for business & product develop/t
Public grant	0	10,770,000[35]	Government/DFIs	Premium subsidy grant
Public (concessional) debt	0	5,000,000	DFIs	Liquidity facility for risk pool
TOTAL Public	**0**	**16,238,000**		

5.1.2 BENEFITS FOR FARMERS

To estimate the cashflow for a farmer under the pilot, and the impact of weather events on expected returns, we developed a farmer model based on a maize crop growth cycle. We used Kenya-specific data on costs incurred through the four stages of the crop growth cycle, plus harvesting, and applied terms and thresholds of the Bima-Pima insurance to estimate probability of payouts. We assume that the farmers would pay an average premium of US$ 5 per season, and the possibility that payouts occur within each of the four stages of the crop growth cycle. The model assumptions and full analysis are in Appendix 8.8.

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[32] This estimate reflects investments needed to develop the platform and make it operative (once agreements are set in place and partnerships are established). It has been calculated making sure that the platform has enough liquidity to perform payments during the roll out, as result from the modeling exercise. As an online platform, although managing high volumes of transactions, upfront capital requirements would be comparatively low with respect to operation costs. For a more comprehensive review of costs requirements, please refer to Appendix 8.7.

[33] If supported by technical assistance public grant

[34] If supported by technical assistance public grant

[35] We assume that the premium subsidy would be used by farmer to increase the insured amounts, their financial commitment remaining equal.

Key takeaways include:

- **Coverage up to 30% with increased integration:** during the **pilot phase**, a US$ 5 insurance premium would buy farmers US$ 50 coverage,[36] corresponding to up to **13-16%** of the cost of inputs (seeds, fertilizer, etc.). If operations are **fully integrated** in the platform and lower premiums are achieved, the potential coverage would ramp up to **15-20%**, or **21-30%** if farmers convert this cost-benefit into higher coverage;

- **Improved returns by up to 8.5% in the event of crop failures within individual stages of the crop growth cycle:** during the **pilot phase** a maximum payout (25% of coverage) would enable an increase of up to **6.5-8.5%** of returns to a farmer's total agricultural inputs;

- **Further improvement in returns by up to 35% if payouts are allowed during the planting stage and full automation of pay-outs is achieved:** faster pay-outs can increase trust in insurance, but financial benefits emerge mainly **during the planting stage**, where quicker pay-outs of 25% (the maximum within each crop stage) can allow for additional replanting, increasing return on agricultural inputs by up to 8-35% vis-à-vis similar – but slower - pay-outs;

- **Improved returns by up to 17% if subsidies covering 50% insurance premium are introduced:** insurance subsidies are important at the launch of an insurance product to encourage uptake. A 50% premium subsidy would also help smallholders increase their coverage (e.g. from US$ 50 to US$ 100) and raise their return on agricultural inputs in each stage of the crop growth cycle **up to 13-17%**. For a four-year pilot targeting 1.2 million farmers, this may require public support of around **US$ 10 million in subsidies**.[37] Subsidies could be phased out if marginal cost reductions are achieved in a fully integrated blockchain system and transferred to smallholders as reduced premiums.

5.2 ENVIRONMENTAL AND SOCIAL IMPACT

The pilot would serve an average of 500,000 smallholder farmers every year and provide protection for crop production equivalent to the yearly caloric needs of 280,000 Kenyans. The pilot targets 1.2 million farmers through different phases of market expansion, with an average of 500,000 served every year, assuming a 50% retention rate between seasons, and a total of 2.15 million policies sold in four years. Policies sold would provide financial coverage to US$ 25 million worth of crop outputs every year, or the equivalent of around 2.5% of the annual production of maize in Kenya, the staple food for most households in Kenya (NAFIS, 2019).

By enabling increased uptake of index-based insurance, the instrument can also increase the uptake of improved practices and technologies, including climate smart agricultural practices, further increasing climate resilience. Better managing risks associated with climate variability may help to build adaptive capacities for climate change (IPCC, 2014). Carter et al. (2014) argues that if index insurance can cover most of production risk faced by farmers, it can increase the uptake of improved technological and economic opportunities by 20-60% of the population.

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[36] It's important to note that based on the current policy-trigger design, however, a payout corresponding to the entire coverage would be rare E.g. assuming a (purely speculative) 20% chance for a full payment in each stage, the combined probability that pay-out would occur for all stages would be 0.16%.

[37] Support is in some cases already available from governments, as discussed in Appendix 8.5. Nevertheless, international development finance institutions can bridge temporary gaps in support (e.g. in Kenya, existing government subsidy only covers a specific product type, Area Yield insurance).

The energy intensity of the use of blockchain technologies would only be relevant in the long-term, if there is no alternative to the use of PoW algorithm. For the long term the proponent assumes the transfer of the platform on a public blockchain. In this case we estimate that emissions would be equivalent at least to the amount of power consumed by 2,200 people in Kenya, increasing each smallholder beneficiary emissions by around 0.1% assuming a family of four.[38] As mentioned under the long-term scenario, the proponent committed to shift to more efficient protocols such as PoS, which would reduce expected impacts by up to 99%.

5.3   PRIVATE FINANCE MOBILIZATION AND REPLICATION POTENTIAL

For the pilot phase, the project would mobilize up to US$ 11.6 million in private finance over four years. We expect that every dollar of public support can leverage at least US$ 0.68 in private investment, up to US$ 24 if only technical assistance grants are considered. The instrument would mobilize an aggregate US$ 352,000-820,000 for platform development and integration, and purchases in premiums from farmers equivalent to US$ 10.8 million over four years, while public finance needs may range from as little as US$ 468,000 for technical assistance, to as much as US$ 16.2 million.[39]

If scaled up and replicated in the targeted high-impact countries, the instrument can potentially mobilize up to US$ 6 to 10 billion in annual premiums, or 180-320 million under the conservative assumption that it would only manage to into the existing offer of agricultural insurance for smallholders. The market potential of the instrument at scale is valued up to US$ 6 (for smallholders <2Ha) 10 billion (<5Ha) in premiums[40]. South Asia's market is the largest, with potential annual premiums of US$ 3-6 billion, followed by the Saharan African market, at up to US$ 1.5-2 billion in premiums. Figure 5 presents market potential under 3 different increasingly optimistic scenarios regarding the potential uptake of the instrument, based on observed country-specific penetration rates 1) agricultural insurance market (low scenario), 2) microinsurance market (mid scenario), 3) top 3 most advanced microinsurance markets (high scenario).[41]

Figure 5: Value of the target markets expressed in potential annual premiums
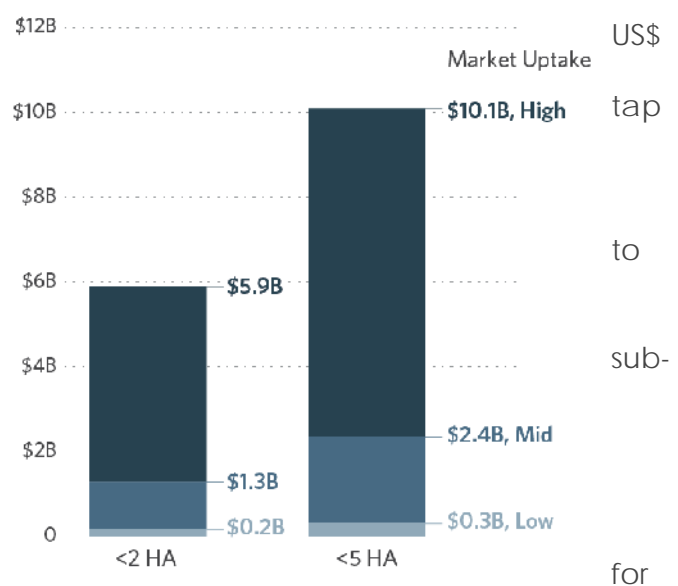
Note: Assessment is performed for smallholder farmers with land ownership below 2 and 5 hectares (HA)

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[38] Emissions may increase significantly, if secondary trading of cryptocurrencies is enabled.

[39] Read paragraph 5.5.1 for estimate of investment requirements and finance mobilization

[40] This is in line with ISF Advisors' 2018 estimate of US$ 6-8 billion in premiums for smallholder farmers in developing countries (ISF Advisors, 2018).

[41] The assumptions and methodology for the market valuation can be found in Appendix 8.6, as well as a regional market valuation.

6. KEY LAB TAKEAWAYS

6.1 2019 LAB FOCUS SECTOR: SUSTAINABLE AGRICULTURE

The main goal of the Lab's sustainable agriculture for smallholders in West and Central Africa stream is to address barriers to smallholder's financial returns due to climate change and mobilize climate investment to benefit smallholders and rural economies in the region. The instrument addresses the barriers of uncertain crop harvest due to extreme events by increasing access to crop insurance. The blockchain infrastructure enables the offering of index insurance at scale and the smart contracts provide transparency, timely payouts and lower transaction costs.

6.2 LAB ENDORSEMENT CRITERIA

Blockchain Climate Risk Crop Insurance offers a solution to a market that is currently highly underserved, with less than 20% of smallholders globally having access to agricultural insurance coverage and less than 3% in sub-Saharan Africa (ISF Advisors, 2018). It meets the Lab criteria for endorsement in the following ways:

Innovative: Blockchain Insurance-as-a-service is a new concept in the targeted high-impact region, addressing the lack of trust in insurance products by smallholders, at the same time enabling higher standardization of insurance products, with increased offer of insurance products. The instrument allows for faster pay-outs and in a fully integrated structure, transaction cost reduction can lead to a decrease in premium of up to 30%.

Financially Sustainable: The business model is commercially viable under all scenarios from a business perspective assuming that demand levels are maintained. However, to ensure maximum impact for smallholders, public support will be needed to guarantee enough demand is driven in the market together with an expanded insurance coverage for the farmers. Public support would then be phased out if cost-efficiencies driven by increasing centralized models, are transferred as premium reductions to the market.

Catalytic: Private finance mobilization during the pilot stage is expected to be around US$ 11.6 million, with a public-private leverage for every dollar of public finance of US$ 0.68 if all support options are considered, or US$24 if a technical assistance grant for product development is provided. The market is currently highly underserved and at the same time valued up to US$ 6 to 10 billion in annual premiums. There is a clear market gap here, which provides substantial replication potential for blockchain index insurance mechanisms.

Actionable: Regulation in sub-Saharan Africa is supportive for index-insurance, and includes subsidy schemes. However, there are uncertainties mostly to do with the unclear stance of some governments regarding the adoption of blockchain technology, and high variability of distribution channels for index insurance among farmer organizations which may impact on their effectiveness. Existing partnerships with established actors in both the crop insurance and blockchain markets, and a pilot stress-testing the technology for two to four years (four to eight seasons), will help proponents achieve their milestones.

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8. ANNEX

8.1 INSTRUMENT MECHANICS

8.1.1 INSURANCE REGISTRATION PROCESS OF A SMALLHOLDER DURING PILOT

1. When the farmer **buys a bag of seeds** there is a scratch card attached with the insurance policy on. The respective farmer registers on the farm on the day he is planting through the USSD menu on the phone. To activate the Service, the farmer dials a USSD code(*800*15*code#) as indicated on card and click on send. You will receive a USSD confirming successful activation. Location and time of activation are important parameters to capture the correct data.
2. Mobile money is used for transaction purposes: When the farmer activates the policy via the USSD menu, **the farmer will need to enter their mobile money pin number**. The payment will pass through M-Pesa to ACRE Africa, who passes on the relevant payments to an insurance company. The farmer has the option to pay in instalments, starting from US$ 0.50 within a predefined timeframe related to the coverage period (within the given season). In the case of Maize, the timeframe for the premium collection runs for 40days.
3. **When the contract is created**, the smallholder gets a confirmation SMS. The data parameters collected from the smallholder during the policy subscription are the name, GPS location, mobile phone number and premium paid via the USSD menu on the smallholder's phone. The use of the USSD menu is widely known amongst farmers and requires not much training.
4. The **smallholder receives weekly weather update information** at a cost of 1KES per SMS on ACRE AFRICA's expense. ACRE AFRICA's weather database, which is linked to Etherisc's smart contracts through an API, collects the information provided by the farmer and provides the input for the threshold on the smart contract.
5. **When the weather falls outside the policy parameter**, the threshold of the smart contract is triggered this is automatically communicated to Sprout.
6. **The pay-out is managed by Sprout through a duplicate risk pool and done via mobile money**. The risk pool is used to prove the concept of faster pay-out times, until trust in the blockchain technology platform is established from the insurance company's side. After verifying the pay-outs, the **insurance company will then replenish the duplicate risk pool.**

8.1.2 LONG-TERM MECHANISM -- TOKEN STRUCTURE

The token structure in the long-term mechanism could rely on 2 tokens:

The Decentralized Insurance Protocol (DIP) token only has value within the network of stakeholders that are collecting fees on the platform. Its primarily goal is to bind participants to the platform and assure the quality of service (Etherisc, 2017). The functions of traditional insurance are embedded in this network structure on the blockchain, such as distributors of the insurance, aggregators, risk modelling etc. The DIP token supports the coordination and the economical incentivization of actors in the decentralized insurance ecosystem (Etherisc, 2017). The token is mostly materialized as a reward for the provided service, but this depends on the function of the stakeholder.

The risk pool token represents the distribution of the expected value and capital cost for covering weather risks, in the case of this crop insurance. The value depends on the underlying risks structure of the insurance products offered by Etherics and as a result the token has a value outside the network. Therefore, it can be either collateralized and traded in the form of tokenized fractions or reinsured. The risk pool is located within the Etherisc infrastructure on the blockchain and completely automated driven by the following parameters: risk pool solvency confidence level, fixed service fee on premiums, target return rate on reinsurance pool, target maximum liability at launch and target policy throughput (Etherisc, 2017).

8.2   LIST OF COMPARABLE INSTRUMENTS

Due to its advantages in terms of operational costs and ease of settlement,[42] index-based insurance is the focus of our mapping exercise for the lab analysis. More specifically we reviewed more than 30 between instruments and programs - summarized in the table A1 - from 20 countries from the high-impact Sub-Saharan region, with enabling regulatory framework.

Table A1: overview of main actors on weather-index insurance in SSA.

Insurance types -------------- Countries	Weather index - blockchain	Weather index - satellite	Weather index - weather station based	Area yield index	Mixed
Benin		Planet Guarantee, AMAB, EARS, FECECAM (MFI)			
Burkina Faso		AfDB and African Risk Capacity (ARC)		Planet Guarantee	Planet Guarantee, Allianz and EARS
Chad		AfDB and African Risk Capacity (ARC)			
Cote d'Ivoire		AXA, Atlantique Assurances			
Ethiopia		WFP and other stakeholders; JICA and government of Ethiopia; R4 initiative	NISCO - Nyala Insurance Share company		Pula
Gambia		AfDB and African Risk Capacity (ARC)			
Ghana	WorldCover		GAIP - Ghana Agriculture Insurance Pool	GAIP - Ghana Agriculture Insurance Pool	

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[42] In terms of ease of design and basis risk mitigation, parametric insurance products (area yield, weather or satellite based) are relatively harder to design, conditional to the accuracy and reliability of reference yield data and existence of weather stations and satellite data, respectively. Additionally, their development cost can be high if weather stations need to be installed and require trained manpower. However, their lower operational costs and ease of settlement that are fast and triggered automatically when a threshold of the index is reached make them much more cost effective compared to traditional indemnity crop insurance.

Kenya	Sprout	ACRE Africa; R4 initiative; KLIP; ILRI.			Pula
Madagascar		AfDB and African Risk Capacity (ARC)			
Malawi		AfDB and African Risk Capacity (ARC); R4 initiative			Pula
Mali		Planet Guarantee, Allianz, IFC and AECF; AfDB and African Risk Capacity (ARC); SUM-Africa			
Mauritania		AfDB and African Risk Capacity (ARC)			
Niger		AfDB and African Risk Capacity (ARC)			
Nigeria				NIRSAL	Pula
Rwanda		ACRE Africa			Pula
Senegal		WFP, Planet Guarantee, IRI (Columbia University); AfDB and African Risk Capacity (ARC); R4 initiative	Planet Guarantee, CNAAS		
Tanzania		ACRE Africa, Airtel Tanzania, Seedco and UAP Tanzania			ACRE Africa
Uganda		SUM-Africa			Pula
Zambia		R4 initiative			
Zimbabwe		R4 initiative	Mercy Corps, EcoFarmer (Econet), and the Zimbabwe Farmers Union		

Source: GIIF (2019b), Planet Guarantee (2019), ARC and AfDB (2019), JICA (2018), WFP and Oxfam (2018), Nyala Insurance (2019), Pula (2019), ACRE Africa (2019), GAIP (2019), PM News Nigeria (2018), Weld (2018), EARS (2018), Esiara (2015)

8.3   FINANCIAL SUSTAINABILITY: CHALLENGES TO LONG-TERM GOALS

8.3.1   OVERVIEW OF CHALLENGES AND MITIGATION STRATEGIES

While the pilot is plugging into an existing market with the infrastructure in place to support demand, there are however some challenges which may hinder its ability to achieve its goals in the long-term. The following paragraphs present such challenges and how they are meant to be addressed in order of relevance.

Table A2: Challenges to the instrument pursuing its stated long-term objectives, risk classification and mitigation strategies.

Risk	Description	Mitigation Strategy
CUSTOMER RISK		

High - Lack of demand due to high price	Can be due to Insurance for smallholder farmers in Africa still being piloted, lack of reliable climate information, higher levels of risk of disaster in the region, and coverage of multiple risks under the same policy	- Investing in better climate information, and working with local partners, governments and institutions to foster voluntary uptake. Experience has shown that farmers will accept indices that are technically complex if they can rely on trusted organizations or key farmers in rural areas; - Public sector grants supporting the purchase of premiums. - Bundling the product with pre-existing farmer aggregation and services, such as credit, In-kind labor, or inputs such as seeds and fertilizer. Over 90% of the catalogued index insurance solutions are bundled with, or offered alongside, credit, inputs, or information services by aggregators. - Enabling smallholders to pay insurance premiums in small installments.
Medium - Challenges related to use and design of mobile apps	Can be related to high servicing cost and inadequate infrastructure like weak network in remote areas as well as design flaws of mobile applications in relation to the needs for and use of the information and technology by farmers	- involvement in the initial phase of the design process to ensure that mobile application is tailored to target needs and their understanding.
PRODUCT RISK		
High - Basis risk	The misalignment between the calculated (weather) index and the actual productivity loss of the farm can be due to poorly designed products, or distance between measurement location and production field, or to high variability of the covered area	- Product design basis risk is minimized with robust product design and testing of contract parameters - Geographical basis risk is reduced when the area covered by the index are homogeneous both in terms of weather and in terms of farming techniques, or when the density of weather stations is minimized.
Medium - Coverage of a limited amount of risks at once (e.g. only droughts and floods in the case of weather index insurance)	The insurance available may cover only part of the risks that smallholders are subject, thus ultimately providing insufficient coverage.	- Piloting different types of index insurances and aligning the risk of a region with the right type of index insurance - Support of Area Yield Index Insurance – when enough historical data exist - which indirectly covers different risks causing crop losses at once.
BLOCKCHAIN TECHNOLOGY RISK		

Medium - Poor design of smart contracts	Smart contracts are in principle not amendable, thus if not carefully designed they may lead to overpayment or underpayment of premiums to stakeholders.	- Implementing smart contracts on a private blockchain[43], as part of a step by step approach to test and slowly delegate governance to blockchain. - Stress-testing of smart contracts with 3rd party audits
Low- Energy intensity of specific blockchain protocols (PoW)[44]	Blockchain has a reputation for being impactful in terms of carbon emissions, due to the high amount of energy needed to process blocks of transactions	- Upfront assessment of different options in terms of blockchain protocols, to find the right balance between security, scale/data processing, overall reliability needs of the system (e.g. minimizing error), and energy intensity of the protocol. For the pilot PoA is used, which is not energy intensive. - Blockchain developers are increasingly moving towards Proof-of-stake (PoS) schemes that are energy efficient, faster and more scalable. - Sprout will move to the public Ethereum blockchain once they updated their consensus algorithm to PoS.
Low - Payments in cryptocurrency may be sensitive to price fluctuations	Price of cryptocurrencies has been varying significantly over the past years and there is a possibility that it would affect premiums in the long-term structure of the instrument	- In the long-term structure , cryptocurrencies could be pegged to stable national currencies
STAKEHOLDER RISK		
Low - Reluctancy of reinsurance market in providing coverage to insurance provider	Lack of data about historical risk exposure or potential scale of the program can make reinsurers reluctant to enter the market, or be willing to do so at a high cost	- Access to reinsurance has generally ceased to be a limiting factor in starting index insurance programs. Reinsurance support is usually derived from business opportunity, portfolio diversification or commitment to corporate social responsibility
Low - Reputational risks related to links with unvetted seed distribution systems	That use of specific seeds has in the past determined negative impacts on indigenous crops, often resulting in public outcry and reputational damage	- Link with certified seed distribution channels audited by local institutions

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[43] The immutability argument does not hold for a private blockchain.
[44] An overview of the energy intensity of different blockchain protocols is provided in table A3

8.3.2 FOCUS ON BLOCKCHAIN IMPACT

The following table provides an example of the potential amount of emissions needed for each transaction under different protocols, compared with emissions from the use of centralized systems such as VISA. With more transactions per block, Ethereum has a lower carbon footprint per transaction than the Bitcoin blockchain. With Proof-of-Stake Ethereum's energy requirement could collapse by more than 90-99% (Cebokli, 2017; Spectrum, 2019), although transition may not happen smoothly (Lee et al., 2018). Finally, with Proof-of-Reputation can lower energy requirement further, by increasing transaction per second to 1300 (up from the 13/second of Ethereum). However, no cryptocurrency can yet handle as many transactions per second as the VISA network does (South pole, 2017).

Table A3: overview of carbon intensity of consensus protocols

Technology	Energy needs per transaction (KWh)	CO2 Emissions per transaction (tCO2)
PoW protocol (Bitcoin)	**469** - 1005	0.222 - **0.43**
PoW protocol (Ethereum)	**26**	**0.01**
PoS protocol (Ethereum) [45]	0.26 - 2.6	0.0001 - 0.001
PoR protocol (GoChain)	0.026	0.00001
VISA	0.00169	**0.00000033**

Source: Cleancoin (2019), Digiconomist (2019), Statista (2018), Cebokli (2017), Spectrum (2019), Steemit (2019).

8.4   IMPLEMENTATION PATHWAY

8.4.1   TIMELINE

Figure A1: overview of activities planned by the proponent
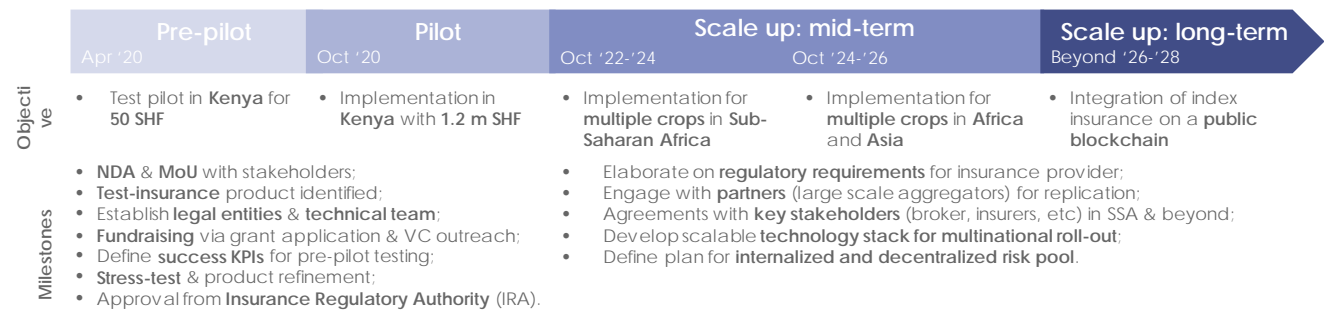
8.5   TARGET COUNTRIES ANALYSIS

8.5.1   APPROACH FOR THE IDENTIFICATION OF POTENTIAL TARGET COUNTRIES

Analysis covers developing countries, identified as non-OECD countries. From this group we then excluded:
- High income countries

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[45] Not yet implemented.

- Countries with a private sector investment score below 35%, as calculated according to the methodology of Tonkonogy et al. (2018).[46]

For each of the 115 shortlisted countries, we assessed three compounded indicators, (1) the level of vulnerability of the country (the higher the vulnerability, the higher the priority), (2) the conduciveness of the environment and (3) the market size. Sub-indicators used for each of the dimensions are illustrated in the sections below.

The compound indicator "**Climate vulnerability**" was derived from the following formula:

$$Country\ vulnerability = average[CV1, \max(CV2, CV3)]$$

Table A4: overview of data used for the assessment of climate vulnerability

Variable	Description
CV1 = Food vulnerability	The Notre Dame-Global Adaptation Index (ND-GAIN) Country Index is a free opensource index that shows a country's current vulnerability to climate disruptions. To prioritize countries for the replication of the instrument we are looking at Food Vulnerability Indicator.
CV2 = Drought vulnerability	Aqueduct's global water risk mapping tool dataset contains the average drought times from 1901- 2008 per basin in a certain country, therefore the average of the different basins per country is taken to determine the scores for droughts.
CV3 = Floods vulnerability	Aqueduct's global water risk mapping tool contains the number of floods recorded from 1985-2011, per basin in a certain country, therefore the average of the flood occurrences of the different basins per country is taken to determine the scores for flood vulnerability.

Sources: ND-GAIN (2019), WRI (2019).

The compound indicator "**Conducive Environment**" was derived from the following formula:

$$Conducive\ environment = \\ average[average(CE1, CE2), average(CE3, CE4), CE5, average(CE6, CE7)]$$

Table A5: overview of data used for the assessment of conducive environment

Variable	Description
CE1 = Mobile Use	The indicator applies to all mobile cellular subscriptions that offer voice communications. Data is sourced from the International Telecommunication Union, World Telecommunication/ICT Development Report and database. Data from the year 2017 has been taken for most of the countries. If 2017 data was missing, the latest year available ranging from 2012-2016 was used as a proxy for 2017 data.
CE2 = Mobile money use	The Worldbank global findex 2017 data contains an indicator for the share of mobile money accounts registered per country (as from the age of 15). The indicators in the database are drawn from survey data of approx. 150,000 people in 144 economies. A sample of approx. 1000 participants per country have been interviewed (Worldbank, 2017b). If data is unavailable the Mobile Money Regulatory Index, developed by GCMA, was used. The index, scores

[46] https://climatepolicyinitiative.org/wp-content/uploads/2018/01/Blended-Finance-in-Clean-Energy-Experiences-and-Opportunities.pdf

	81 countries based on the extent to which their regulatory framework enables widespread mobile money adoption.
CE3 = Use of microinsurance	The Microinsurance Network launched a World Map of Microinsurance to provide market data on microinsurance in over 120 countries. The indicator used is the average of the total microinsurance coverage ratio and the microinsurance coverage ratio for agriculture, each using the latest values available between 2012 and 2016.
CE4 = Regulation on microinsurance	The a2ii (Access to Insurance Initiative) is a global partnership working to promote inclusive insurance for all by enhancing regulatory and supervisory capacity, growing financial inclusion and advancing insurance markets. In the yearly report, they provide an assessment of the state of regulation on microinsurance in developing countries. We converted their qualitative assessment of country level state of the regulation, in 0-2 score based on the availability of regulation.
CE5 = Regulation on blockchain	Three different sources have been used to assess the state of regulation for blockchain technology and cryptocurrency per country. The first one is a study by Baker McKenzie that evaluated the reception and regulation of both blockchain and cryptocurrency in Africa. To complement unavailable data, a second source was used, mapping the legality of bitcoin per country, rather strict proxy for the reception and regulation of blockchain technology and cryptocurrency in general. Finally, to complement unavailable data from the second source, a third source was consulted, mapping the legality of cryptocurrency by nation. As all sources consulted are based on qualitative assessment, they were converted into numeric score (0-4) based on the legality and receptiveness of blockchain.
CE6 = Donor support to microinsurance	The OECD database has been used to determine the donor support to microinsurance. We filtered data in the database looking at micro-insurance and crop insurance projects and accounted for the disbursements of donors, both governments and multilateral development banks. More specifically, the disbursements per country have been summed up over the years 2014-2017 to create the indicator.
CE7 = NDA supportive of adaptation	The Tool for Assessing Adaptation in the NDCs (TAAN) is a knowledge platform that aims at providing an overview of, and detailed information on adaptation content included in the NDCs. The data of TAAN is qualitative, we used a 0-2 scoring approach based on NDC and adaptation component availability at country level.

Sources: Coin dance (2019), GSMA (2019), Microinsurance Network (2015), OECD (2019), Stolp et al. (2019), Reese (2019), TAAN (2018), Wiedmaier-Pfister and Ncube (2018), Worldbank (2019a), Worldbank (2017a),

Finally, a "market size" indicator is created to provide a measurement of potential customers for an index-insurance in the targeted countries. The indicator is used to determine the size of the bubbles in the figure below.

8.5.2   OVERVIEW OF ENABLING FACTORS AND CHALLENGES IN SUB-SAHARAN AFRICA

Enabling factors are principally defined by the high adoption rate of mobile money accounts and progressive regulation and subsidy schemes for index-insurance. 24%-73% of the adult population has a mobile money account in the target countries (World Bank, 2017). Therefore, the technological infrastructure is in place for a microinsurance product at scale.[47] Regulators have often adopted a reactive approach on microinsurance, [48] but they

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[47] Note that smallholder farmers tend to be illiterate, which means that working with mobile money can be challenging for the target group

[48] i.e.in response to products that have been introduced to the market; or to engagements with players in the value chain that approached the supervisor e.g. technical service providers (TSPs) or mobile network operators (MNOs)

are **generally supportive of mobile insurance** (Ouattara, 2018).[49] Regulation in the CIMA region[50] is in favor of agricultural microinsurance integrated with mobile money technology and it is designed to encourage micro insurance agents to enter the market (World Bank, 2015; Wiedmaier-Pfister and Ncube, 2018). Senegal and Kenya both have a strong presence of the government in the sector: CNAAS in Senegal is underwriting crop and livestock insurances and participated in the development of a groundnut index insurance (CIAT and BFS/USAID, 2016). Further, some governments offer **subsidy schemes** to support the agricultural insurance sector and the most supportive schemes in Kenya and Senegal are offering a 50% subsidy on the premium (One Acre Fund, 2018).[51]

Uncertainties for the scale-up and replication of the instrument in these countries have mostly to do with the unclear stance of governments regarding the adoption of blockchain technology, and uncertainty over the effectiveness of distribution channels for index insurance. More specifically:

- The stance on cryptocurrency and blockchain technology in almost all countries is unclear, and most countries do not have a regulatory framework in place yet. Despite a blockchain market estimate of US$ 1.5 million, Kenya's central bank has forbidden banks from dealing with cryptocurrencies, which may hamper blockchain technology's regulatory developments (Russon, 2019). Senegal is the only country that is progressive towards the technology by launching a national cryptocurrency, the eCFA (Stolp et al., 2019).

- **Rising temperatures alongside poor farm management techniques introduce soil degradation, erosion and pest and diseases in the sector and reduce areas potentially eligible for coverage in the long term.** In the north of Mali, desertification presents a challenge, and in the south, areas are becoming arid (USAID, 2018). In Rwanda, rising temperatures, severe land degradation and an already unconducive geography are proving challenging to the sector (World Bank and CIAT, 2015). Therefore, weather index insurance might not only cover part of the risks that smallholders are subject, thus ultimately providing insufficient coverage. This might be mitigated by launching index insurance products in line with the most prominent risks of the area.

- **The effectiveness of distribution channels might differ from region to region.** Farmer organizations remain an effective channel to both increase demand – for instance through buying group insurance on behalf of farmers – and raise awareness of index-insurance within their cooperative. In the CIMA region, Planet Guarantee showcased their success by going through centralized farmer organizations for index-insurance distribution (Adegoke et al., 2017). Working with farmer organizations, moreover, facilitates the enrollment of poorer smallholder farmers and women. According to

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[49] While some are still trying to understand the risks and challenges and considering whether to implement any regulatory change for index insurance, some others do not see the need to regulate index and digital insurance because there are such products in their particular jurisdictions, customer enrolments are quite low and therefore posing little risk; or index insurance is not a priority.

[50] CIMA region is an integrated organization of the insurance industry which comprises 14 African member countries in Central and West Africa (Benin, Burkina Faso, Cameroon, Central African Republic, Congo, Côte-d'Ivoire, Gabon, Guinea Bissau, Equatorial Guinea, Mali, Niger, Senegal, Chad, Comoros and Togo).

[51] the Kenyan government offers a 50% premium subsidy through the Kenya Agriculture Insurance Programme for Area Yield Index Insurance covering maize and wheat (One Acre Fund, 2018), and has partnered with the Kenyan Livestock Insurance Programme (KLIP), a Normalized Difference Vegetation Index (NDVI) insurance for livestock, providing a 100% subsidy (KLIP, 2018). CNAAS provides a 50% subsidy in Senegal (CommodAfrica, 2015); the Ugandan government offers a 70% subsidy for smallholder and commercial farmers for agriculture insurance growing the sector by 17% (One Acre Fund, 2018); Rwanda developed a National Agriculture Insurance Scheme (NAIS) enabling farmers to benefit from agro-insurance cover, 60% will be covered by insurance companies and 40% subsidized by the government. Hence, there exists a substantial incentive for launching pilot projects in the sector.

Fisher et al. (2017) distribution of ACRE Africa's scratch card through agrovets also builds trust. However, education of agrovet shop owners and consumers will still be needed in this model, to ensure usage of the insurance.

8.6 APPROACH FOR MARKET VALUATION

Market assessment is based on the following assumptions:

- Target **countries** are those described in paragraph 4.2.
- Target **clients** are smallholders with landholdings smaller than 2ha[52] , and smaller than 5ha.[53]To calculate their importance, we looked at the share of agricultural land they use as a total share of agricultural land in the country, mainly using database from Lowder et al. (2016), complemented by Samberg (2016), GRAIN (2014) database and regional data[54] [55]
- Target **crops** are those that have been proven to be technically eligible for weather index insurance as per their current implementation in existing commercial or piloted insurance products are considered for the market valuation. In the absence of specific literature on the matter, we verified this through a combination of expert feedback and key-word data scraping for individual crops on search-engine.[56] The full list of crops identified where index insurance is being implemented includes:
  - o Crops with commercial stage index insurance (frequency of results >10): Seed cotton, Maize, Rice;
  - o Crops with pilot stage index insurance (frequency of results <10): Tea, Groundnuts, Apples, Vegetables (fresh and leguminous), Cocoa, Coffee, Grain, Wheat, Cassava, Tomatoes, Rubber, Cereals, Beans, Cauliflowers and Broccoli, Citrus, Mangoes, Mangosteens, Guavas, Potatoes, Tobacco, Watermelons, Barley, Millet, Rapeseed. Sesame seed, Sorghum, Soybeans, Sunflower seed.
- Within each country we estimated the asset covered, or the country-specific value of production of crops by looking at crop specific **production volumes** (tonnes) (FAO, 2019a) and **producer prices** (US$/Tonnes) (FAO, 2019b).[57]

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[52] 2.2ha is the average farm size in Africa (GRAIN, 2014)

[53] Samberg (2016) argues that a smallholder farm determined by size is smaller than 5Ha

[54] Regions are defined as: Latin America and Caribbean, East Asia and Pacific, sub-Saharan Africa, South Asia, Europe and Central Asia, Middle East and North Africa

[55] The dataset for the market size is mainly derived from a study of 2016 analyzing "The Number, Size, and Distribution of Farms, Smallholder Farms, and Family Farms Worldwide". The dataset contains the amount of agricultural land belonging to farmers, categorized by the size of a farm in (Ha). If data was missing, the dataset was complemented by the data from the study Samberg, (2016) looking at the subnational distribution of average farm size and smallholder contributions to global food production. A percentile score for the indicators from the first source complemented with data from the second source was then taken.
The missing values of the calculated score were complemented by the percentile score of a dataset including the amount of square km agricultural land in a certain country, which was derived from the World bank. Finally, the ratios from the GRAIN database have been used to complement the missing data from the previous sources. If none of the sources provided data, then an average of the regional data has been used as a proxy

[56] "weather index insurance for **crop-type**" OR " **crop-type** weather index insurance" OR "**crop-type** index-based insurance" OR "index-based insurance for **crop-type**"

[57] These are prices received by farmers for primary crops as collected at the point of initial sale (prices paid at the farm-gate). Producer prices in US$/tonnes are used when available. Prices are derived in US Dollars by applying the exchange rate of the selected year from IMF. Annual data are provided and the latest available data from 2013-2017 has been used in the market valuation assessment. If producer prices are not available, then the product of the export value and export quantity is used. Here the latest data between 2013-2017 used as well. If none of the above-mentioned data is available then an average of the regional data is used as a proxy, created by taking the average of the production price per region.

- The **premium** in the market valuation is assumed to be 10% per season, in line with average premiums observed for crop insurance and in the 5-20% range observed by ISF Advisors (2018).
- Finally, the **market share** per country, region and globally was determined for 3 scenarios using the World Map of Microinsurance dataset (Microinsurance Network, 2015).
  - A first conservative scenario where blockchain insurance only taps into existing weather index insurance as a technical improvement. This scenario looks at existing country-specific coverage of agriculture insurance market;
  - A second mid scenario where blockchain insurance expands in line with micro-observed country-specific insurance market penetration ratios;
  - A third optimistic scenario using market penetration rates of 30%, observed in the most progressive top-3 countries for micro-insurance.

Figure A2: Potential value of the blockchain crop insurance market in high-impact countries under different hypothesis of market uptake *(focus on landholdings smaller than 2HA)*
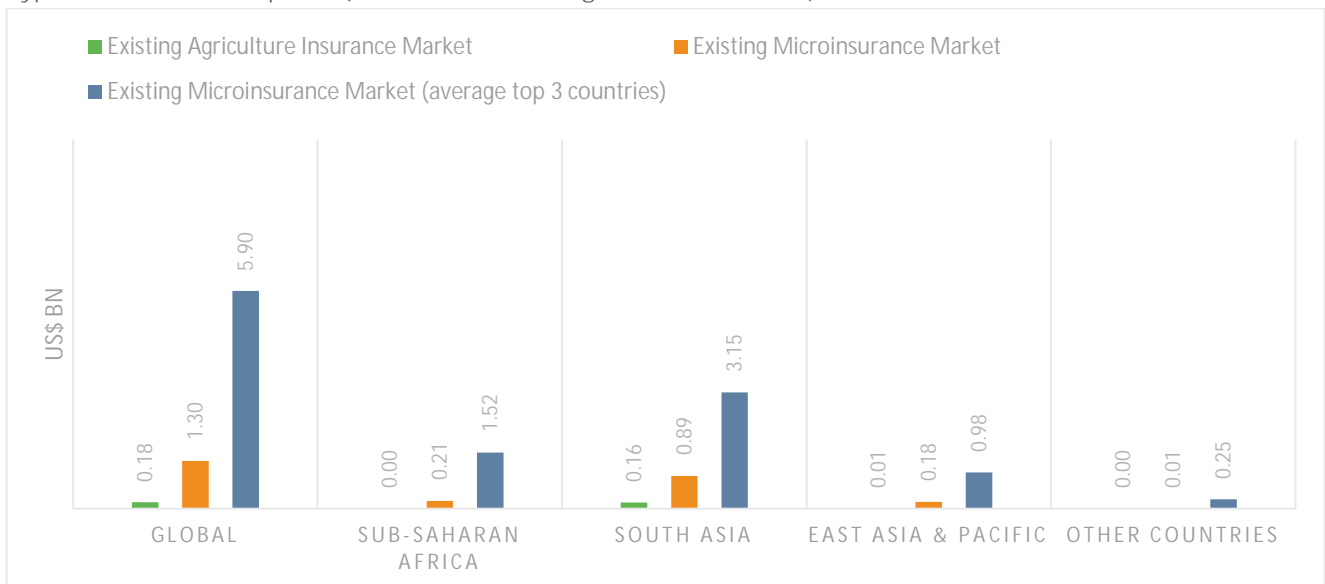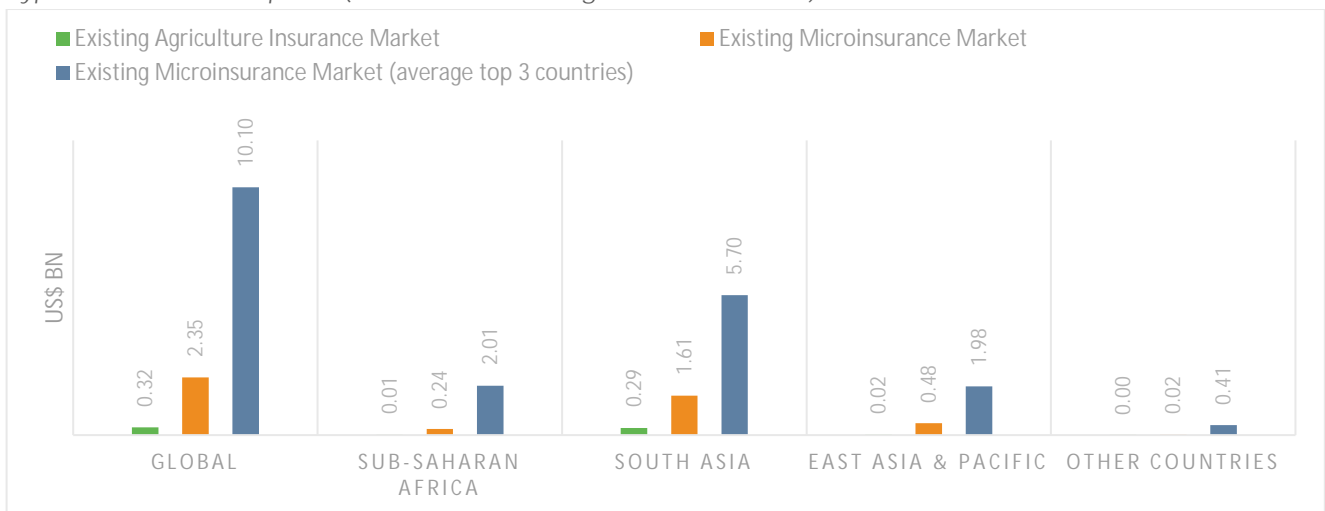

Figure A3: Potential value of the blockchain crop insurance market in high-impact countries under different hypothesis of market uptake (focus on landholdings smaller than 5HA)

8.7 TECHNOLOGY PLATFORM BUSINESS MODEL ASSUMPTIONS AND TAKEAWAYS

The goal of this analysis is to estimate returns for the blockchain technology platform under 4 different scenarios which reflect increased degrees of integration of weather index crop insurance activities on the platform, starting from a partnership model relying largely on the role of local insurance service providers (e.g. as in the case of the pilot with ACRE), where the platform acts as support service to insurance, to fully integrated insurance services models, where activities and costs are internalized, including the management of risk pool via blockchain. The analysis also tries understanding whether and how the benefits of increased integration can be transferred to smallholders, and what the potential needs for public finance can be. For this purpose, we built a cashflow model of the platform covering four-years of activities of the platform and targeting an audience of 1,200,000 farmers.

1. Assumptions

	Scenario A: Blockchain as support service to index-insurance		Scenario B: Integration of index-insurance service on blockchain	
	A1. Pilot (SSA with ACRE): Transferring of insurance contract on blockchain	**A2. Scale-up (Medium term, SSA with ACRE):** + management of payments triggers and data flows	**B1. Scale-up (Medium term, other countries & partners):** + internalization of support functions, marketing, data sourcing, customer service	**B2. Scale-up (Long term, other countries & partners):** + transformation from service provider to insurance provider, moving financial transaction on blockchain, internal risk pool
	The local insurance service provider is central in the functioning of the insurance, as it manages data and interactions with the client and the insurer. The blockchain technology platform only supports these activities, by hosting insurance contract as smart contracts on the blockchain. To benefit of increased speed in transactions, a duplicate risk pool is formed to anticipate payments to the smallholder on behalf of the insurer, which then replenishes the risk pool.	The blockchain technology platform still relies on the local insurance service provider for weather data and interactions with the client, but premium payments and decisions regarding pay-outs are now managed directly by the blockchain technology platform, which reduces transaction further.	The blockchain technology platform manages all data and builds a full team to manage client interaction and marketing activities, externalizing only sales agent activities to best benefit of local knowledge in the target markets. Premium payments and decisions regarding pay-outs are managed directly by the blockchain technology platform on behalf of the insurance, which manages the risk pool.	The blockchain technology platform manages all data and relies on a full team to manage client interaction and marketing activities, externalizing only sales agent activities to best benefit of local knowledge in the target markets. Premium payments and decisions regarding pay-outs are managed directly by the blockchain technology platform, who also manages the risk pool, thus retaining all premium payments.
Target markets				
-target markets	1'200'000 new maize, producers progressively reached via a 4-stage sales campaign, with a conservative 50% inter-seasonal retention rate.			
Investment requirement				

-upfront equity commitment[58]	$ 619,590 ($ 314,454 w/o duplicate risk pool)	$ 314,454	$ 757,624	$ 655,078
Revenues				
-premium	10% for an average coverage of $ 50 dollars and 10% deductible			
-fee paid to technology platform	10% of premium	100% of premium		
	$ 0.10 sprout infrastructure fee.			
-premium split	-	20% intermediary 70% insurer	10% sales agent 70% insurer	10% sales agent
Costs				
-pay-out	5% average pay-out estimated for Kitale based on weather patterns and policy termsheet.			
	within a month, reimbursed by insurance after 3 months	Within a week, then instantly reimbursed by insurance		Within a week
-blockchain infrastructure fees	PoA (private blockchain) at a cost of $ 1188 per year. This is estimated using Google Cloud and assuming a total of 4 nodes (parties) involved, the data being transferred is only text bases so very low costs occur, and the cost includes the suggested monitoring and maintaining costs (e.g. to install an update now and then). Running on 3 Nodes would bring down the price to $891 per year.			PoW (public blockchain) at a cost of $ 0.04 per financial transaction. We assume that transaction on the blockchain would only occur at registration stage and whenever pay-outs are made.
-mobile fees	-	$ 0.10 message at policy activation, US$ 1 for customer service calls following trigger event, US$ 0.20 as mobile pay-out transaction.		
-weather data	-	$ 321/month fixed for up to 2 million data requests, and $ 1.82 per 10000 data requests beyond threshold (IBM standard plan). Assuming 50 customers per area pixel on average.		
-salaries	1 General manager at $ 5'000 / month			
	-	5 sales managers at $ 1,000 / month, 10 customer care agents at $ 600 / month, 5 marketing assistants at $ 300 / month.		
-other costs	-	Marketing material ($ 0.20/month/farmer), other staff ($ 200/month), office expenses ($ 50/month), insurance ($ 100/month), motor vehicles expenses ($ 300/month).		
-fixed assets	-	1 car at $ 10'000 and 7 computers at 1000 each amortizable in 5 and 3 years respectively.		
-business development costs	Design and hosting Website ($15.000), Human Resource Costs for 8 Months conception and evaluation phase, including 2 Full Time Product Managers ($ 50.000) and 1 Part Time Technical Engineer: ($ 30.000); Human Resource Costs from Partners ($48.000); business development including participation to conferences, events and engaging with key stakeholders. ($ 25.000); Upfront investment costs for analysing the current state of insurance systems ($ 100,000).			
	-	$ 200,000 for mobile money integration, covering: SMS Sender ID Acquisition and Configuration; USSD Back end portal adaptation for blockchain; USSD system Configuration to blockchain; M-Pesa Paybill Back end portal design, configuration and integration (includes other mobile networks in Africa); USSD Monthly Rental and maintenance fee; Shortcode monthly fees (balance query); Unique Code Validation; Bulk SMS's; Unique Code/Token generation.		
Other assumptions				
-inflation rates	5% inflation rate for developing country, 2% for developed country			
-CO2 emissions data	0.01 tCO2 per transaction for PoW Ethereum, 0.0001 - 0.001 tCO2 per transaction for PoS.			

Note: preliminary estimate at the best knowledge of the instrument as for July 2019.
Sources: ACRE (2019a), ACRE (2019b), ACRE (2019d), Cleancoin (2019), Etherisc (2019), Google Cloud (2019), IBM Cloud (2019), KNMI (2019), Sprout (2019a), Sprout (2019b), and World Bank (2019)

2. Financial impact
- **Due to the comparatively small upfront investment cost in fixed assets related to the initiative, the same appears to be profitable under both scenarios A and B**, if

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[58] Upfront commitments are calculated based on ex-ante assessment of liquidity needs for the platform.

demand expectations are met along other with other assumptions. **IRR expectations** remain contained to a 0.6% monthly IRR (6.9% yearly IRR), under an integrated scenario where the blockchain technology platform builds a full team to cover activities previously allocated to insurance intermediaries while still transferring most of the premium to the insurance (scenario B1). However, this scenario is preliminary to a further integration of the technology platform, where a risk pool is managed by the platform (scenario B2), which registers a 10-fold increase in IRR on a similar market expansion pathway.

- **Integrated insurance platform can reach up to 41% reduction of levelized costs needed to issue a policy**. The move towards an integrated insurance platform also **changes the structure of costs**, from a model where the blockchain technology platform transfers most of premium fees to partners (such as ACRE, UIP or vendors), to a model where financial transactions occur directly on a blockchain – requiring additional transaction fees to run on PoW - and where the business internalizes most of the costs to process payments, progressively increasing the share of COGs.

Table A6: Returns in the 4 different scenarios

Scenario	A1	A2	B1	B2
ROI	15.1%	5.1%	0.9%	38.6%
After Taxes (monthly) IRR	2%	3.7%	0.6%	5.5%

- **While increased transparency and speed of repayment are objective advantages of blockchain which can be achieved under all the scenarios described, the financial benefits of blockchain insurance to the farmer - under the form of significant reductions of the cost of the premium - only occur under a fully integrated scenario with a risk pool managed by the platform (scenario B2), where premium can go down by up to 30%.** Depending on the market strategy of the implementer of the initiative, the benefits of reduced costs could be **transferred to smallholder in the form of reduced premiums**. We estimate that such premiums could go down from the 10% currently proposed for the instrument to as low as 7% under a fully integrated structure, if a minimum annual IRR of 15% is targeted. However, in other scenarios premium reductions are more difficult to achieve, and in certain cases (B1) an increase in the premium is required to achieve a minimum return.

Table A7: Premium reduction achievable in 4 different scenarios

Scenario	A1	A2	B1	B2
Premium set to achieve 15% annual IRR	9.64%	9.44%	10.17%	7.49% 7.22% if all partners share reduction

3. Investment needs and public support
   - An initial commitment between US$ 315,000 and US$ 750,000 may be needed for the instrument to be tested with a market of 1,200,000 new farmers. Part of this investment can be supported with public grants, or equity.
   - **Demand-side support may be particularly important when starting to shift to an integrated scenario (scenario B1)**. The minimum number of new customers which the platform needs to successfully target to hit the break-even point also changes depending on the structure. Efficiencies related to the integration of a payment system reduce the break-even point from the 757,500 farmers of the pilot to 376,500 if a risk pool is internalized. However, increasing costs in the early stages of the project, as required at the early stage of the integrated model, would raise the bar needed for break-even to 1 million farmers.

Table A8: Break-even point in 4 different scenarios

Scenario	A1	A2	B1	B2
Number of clients to break even	757,500	473,000	1,079,500	376,500

8.8 FARMER MODEL ASSUMPTIONS AND TAKEAWAYS

The goal of this analysis is to estimate the cashflow for a maize farmer, and the impact of weather events on expected returns under 5 different scenarios which reflect increased degrees of integration of the weather index crop insurance activities on the platform, as well as scenarios with coverage via traditional weather insurance and a scenario without insurance coverage. The analysis also tries to understand what features of the insurance policy manage to increase the impact of the blockchain instrument, and what the potential needs for public finance can be.

For this purpose, we built a cashflow model of the maize farmer over one crop growth cycle, using Kenya specific data regarding the cost incurred through 4 stages of the crop growth cycle and the harvest stage. We performed sensitivities over some instrument features such as amount of coverage, speed of repayment, premium subsidies and average payout, and degrees of crop loss experienced through the 4 pre-harvest stages of the crop growth cycle.

Assumptions regarding the insurance coverage are based on ACRE's current weather index crop insurance term sheet (ACRE, 2019b), which provides specific triggers for each of the 4 pre-harvest stages of the crop growth cycle.

1. Assumptions

	Scenario 00: Counterfactual		Scenario A: Blockchain as support service to index-insurance [59]		Scenario B: Integration of index-insurance service on blockchain [60]
	001. no insurance coverage	**002. The farmer access traditional index-based insurance**	**A1. Pilot (SSA with ACRE):** The farmer access blockchain parametric insurance, with ACRE as main referent and pay-outs via mobile money anticipated by the Blockchain Technology Platform	**A2. Scale-up (Medium term, SSA with ACRE):** + both premium payments and pay-outs are done via mobile money and entirely managed by the Blockchain Technology Platform	**B2. Scale-up (Long term, other countries & partners):** + The farmer access blockchain parametric insurance via local sales agents. All operations are carried out by the Blockchain Technology Platform (long term stage with other partners)

Farm profile

-farm extension	2 hectares, 58% devoted to maize production, with a productivity of **1556.7 kg/Ha**.

Revenues

-sales value	19% production sold to market at a price of **$ 331 /t**, the rest used for self-consumption.

Costs

-Timeline and Costs	Planting season starting in **March** for a season length of **148 days** between land preparation and the end of the harvest period. Cost estimated for the **different stages of the crop growth cycle** (plantation, vegetative growth, flowering, pre-harvest, harvest) for the following items: seeds ($ 36.6/Ha), land preparation ($ 44.2/Ha), planting costs ($ 20.3/Ha), fertilizer cost ($ 72.4/Ha), weeding cost ($ 36.6/Ha, including herbicide costs and labour), harvesting and handling costs ($ 36.6/Ha). We assume that more cash-constrained farmers would only use cash for the purchase of fertilizer and seeds, while all other costs would be provided in-kind. We assume that farmers can buy and **replant seeds in case of crop failure** during plantation period up to the amount allowed by available finances.

Insurance terms

-Premium	-	10% per season		7% per season
	-	$ 50 coverage with 10% deductible		
-pay-out timeline	-	3 months 1 pay-out window	1 month 4 pay-out windows	Instant 4 pay-out windows

Sources: ACRE (2019a), ACRE (2019b), ACRE (2019c), FAO (2019), FAOSTAT (2019), Global Yield Gap Atlas (2019), Kenya Seed Company Ltd (2019), Njagi (2017), Rapsomanikis (2015), Stefanovic (2015), Samberg et al. (2016), WB (2011), Sprout (2019b).

Note: preliminary estimate at the best knowledge of the instrument as for July 2019. Conflicting information has been identified regarding the costs related to farmers' activities, and how much of those require a cash disbursement from the farmer. We assumed average country-specific yield for maize, however, since for the pilot in Kenya farmers are purchasing the product attached to high-yield variety of seed bags, higher productivity could also be assumed.

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[59] For more info regarding how to achieve scenario A under the perspective of the Blockchain Technology Platform, please look at corresponding scenario in Annex 8.7
[60] For more info regarding how to achieve scenario B under the perspective of the Blockchain Technology Platform, please look at corresponding scenario in Annex 8.7

2. Financial impact
   - **With a US$ 5 insurance premium, the blockchain insurance would allow farmers a US$ 50 coverage, with a potential maximum payout[61] corresponding to up to 13-16% of the cost of inputs during the pilot phase (A1).** We estimate that a US$ 5 premium would give back a maximum payout cover of **up to 13.5%** of the value of inputs during the pilot stage. The impact would be more significant for cash-constrained smallholder farmers, where the maximum payout would cover **up to 16%** of the value of inputs.
   - **If operations are integrated (B2) and lower premiums are achieved, the potential maximum payout would ramp up to 15-30% of the value of inputs.** Under an integrated scenario, potential maximum payout may reach 15% of the value of inputs, or 21% if savings from a lower premium are turned into higher coverage by the farmer (from US$ 50 to US$ 71). For cash-constrained smallholder farmers benefits from lower premiums would be even higher as they would allow improvements in return of 21- 30% of the value of inputs.

Table A9: Improvement in Return on Agricultural Inputs (at 10% df) under 6 different scenarios

Scenario	smallholder farmer	cash constrained smallholder farmer
001. BAU	0.00%	0.00%
002. Normal weather insurance (no blockchain)	12.70%	15.04%
A1. Pilot, SSA with ACRE (blockchain)	13.20%	16.09%
A2. Medium term, SSA with ACRE (blockchain)	13.30%	16.28%
B2. Long term, other countries & partners (blockchain)	14.99%	21.70%
B2. Long term, other countries & partners (blockchain) + higher coverage due to lower premium	21.29%	30.64%

   - If crop failures are considered within individual stages of the crop growth cycle, triggered from drought and flood, a maximum payout (= 25% of coverage) of the **instrument at pilot stage (A1) would enable** an increase of up to **6.5% of the return on a farmer's total agricultural inputs** (8.5% for cash-constrained farmers) vis-à-vis uncovered farmers (001).

Table A10: Improvement in Return on Agricultural Inputs for smallholder farmers (pilot vis-à-vis uncovered farmers) assuming maximum payout within crop stage

	crop failure %					
	0%	20%	40%	60%	80%	100%
	delta smallholder					
Plantation stage	-0.51%	0.05%	0.41%	0.70%	1.22%	1.87%
Vegetation stage	-0.56%	0.23%	1.24%	2.55%	4.28%	6.58%
Flowering stage	-0.60%	0.24%	1.26%	2.52%	4.09%	6.06%
Pre-harvest stage	-0.65%	0.24%	1.28%	2.48%	3.87%	5.49%

[61] It's important to note that based on the current policy-trigger design, however, a payout corresponding to the entire coverage would be rare E.g. assuming a (purely speculative) 25% chance for a full payment in each stage, the combined probability that pay-out would occur for all stages would be close to zero, or 0.4%.

- **Faster pay-outs are most beneficial during the plantation stage**. While **faster pay-outs** are important to provide comfort and increase trust in insurance instrument, they become negligible compared to longer repayment frameworks when looking exclusively at financial benefits deriving from them (even when discount rates are applied) except during the plantation period. In this stage, faster payouts can be partly used for replanting the crop, and the insurance product can **increase return on the value of agricultural input by an additional 2-8%**, or 15-35% for cash-constrained smallholders, vis-à-vis longer repayment periods. In this case, since faster payouts can be partly used for replanting the crop, the insurance product can **increase return on the value of agricultural input by 2-8%**, or 15-35% for cash-constrained smallholders, vis-à-vis longer repayment periods, with a net product value improvement of **up to 32 US$**.

Table A11: Improvement in Return on Agricultural Inputs for smallholder farmers (pilot with quicker payout vis-à-vis pilot) assuming maximum payout within crop stage

	crop failure %					
	0%	20%	40%	60%	80%	100%
Plantation stage	0%	0%	0%	2%	7%	8%
Vegetation stage	0%	0%	0%	0%	0%	0%
Flowering stage	0%	0%	0%	0%	0%	0%
Pre-harvest stage	0%	0%	0%	0%	0%	0%

3. Public support needs
   - **Insurance premium subsidies** are important at the launch of an insurance product to guarantee uptake with the purpose that farmers familiarize with the instrument before having to make an investment in the premium, and to increase the coverage of the instrument once adopted by the farmers. Furthermore, continuous support of a 50% premium subsidy would double average farmer's coverage (e.g. from US$ 50 to US$ 100) and increase return on agricultural investment vis-à-vis uncovered farmers in each stage of the crop growth cycle from 6.5-8% **up to 13%,** or 17% for cash constrained farmers.
   - **For a 4-year pilot targeting 1'200'000 farmers, this may require a support of around US$ 10 million in subsidies**. Support is in some cases already available from governments (see Appendix 8.5). Nevertheless, international development finance institutions can bridge temporary gaps in support (e.g. in Kenya, existing government subsidy only covers a specific product type, Area Yield insurance).

Table A12: Improvement in Return on Agricultural Inputs for smallholder farmers (pilot with 50% premium subsidy vis-à-vis uncovered farmers) assuming maximum payout within crop stage

	crop failure %					
	0%	20%	40%	60%	80%	100%
	delta smallholder					
Plantation stage	4.16%	4.23%	4.19%	4.23%	4.95%	5.82%
Vegetation stage	4.08%	5.16%	6.50%	8.19%	10.35%	13.16%
Flowering stage	4.00%	5.07%	6.35%	7.90%	9.79%	12.13%
Pre-harvest stage	3.89%	4.95%	6.16%	7.54%	9.13%	10.97%