Parametric Climate Insurance Using Blockchain Technology

A Feasibility Study on Technical and Economic Viability in Fiji

The Commonwealth

Rerevaka na Kalou ka doka na Tui

IPP COMMON SENSING

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Glossary

Blockchain	Distributed ledger with confirmed blocks organised in an append-only, sequential chain using cryptographic links. Note to entry: Blockchains are designed to be tamper-resistant and to create final, definitive and immutable ledger records.
CHIRPS	Climate Hazards Group InfraRed Precipitation
Consensus mechanism	Rules and procedures by which consensus is reached. Note to entry: A 'consensus' refers to an agreement among Distributed Ledger Technology (DLT) nodes at which a transaction is validated and that distributed ledger contains a consistent set and ordering of validated transactions.
Distributed Ledger	A ledger that is shared across a set of DLT nodes and synchronised between the DLT nodes using a consensus mechanism. Note to entry: A distributed ledger is designed to be tamper-resistant, append-only and immutable, containing confirmed and validated transactions.
Distributed Ledger Technology (DLT)	Technology that enables the operation and use of distributed ledgers.
ECMWF	European Centre for Medium-Range Weather Forecasts
ERA5	ECMWF Reanalysis 5th Generation Description – The fifth generation of ECMWF atmospheric reanalyses of the global climate, providing hourly estimates of a large number of atmospheric, land and oceanic climate variables.
IBTrACs	International Best Track Archive for Climate Stewardship
Node	Device or process that participates in a network and stores a complete or partial replica of the ledger records.
Oracle	Service that updates a distributed ledger using data from outside of a DLT system.
Smart contract	A computer program stored in a DLT system, wherein the outcome of any execution of the program is recorded on the distributed ledger. Note to entry: A smart contract can represent terms in a contract in law and create a legally enforceable obligation under the legislation of an applicable jurisdiction.
Parametric insurance	An insurance product that uses data to make a loss assessment, instead of a human checking the level of damage from an event and paying based on a subjective loss estimate. Parametric insurance uses datasets as its index and a trigger to make a payment.

Parametric trigger	The parametric trigger is based on measurable parameters, such as wind speed or earthquake magnitude. Investors appreciate this structure because claims are settled quickly and there is hardly any risk of moral hazard. However, it is less attractive for the sponsor given the high basis risk.
Basis risk	This arises when the index measurements do not match an individual insured's actual losses. There are two major sources of basis risk in index insurance: first, poorly designed products and the others from geographical elements. As the geographical area covered by the index increases, basis risk increases as well.
Area-based Index Insurance	Insurance contracts are written against specific perils or events defined and recorded at a regional level (country or district in the case of yields, a local weather station in the case of insured weather events). Indemnities are paid based on losses at the regional rather than farm level.
Covariate Risk	Covariant risk arises when many farms/households in one area are adversely affected by a single phenomenon such as a natural disaster, epidemic, unexpected change in world prices, macroeconomic crisis or civil conflict. This is distinct from individual risks, which randomly affect individual house-holds.

Acronyms and Abbreviations

ACCF	Accident Compensation Commission of Fiji
ADB	Asian Development Bank
AI	Artificial intelligence
ATP	Ability-to-pay
BAU	Business-as-usual
BCI	Blockchain and Climate Institute
BBCCI	Blockchain-based climate catastrophe insurance
BBPI	Blockchain-based parametric insurance
CCRIF	Caribbean Catastrophe Risk Insurance Facility
CHIRPS	Climate Hazards Group InfraRed Precipitation with Station data
COVID-19	Coronavirus disease (COVID-19)
CTP	Compulsory Third Party
DLT	Distributed Ledger Technology
ECMWF	European Centre for Medium-Range Weather Forecasts
ERA5	ECMWF Reanalysis 5^{th} Generation
FNPF	Fiji National Provident Fund
GDP	Gross domestic product
GPS	Global positioning system
HH	Household
IBTrACs	International Best Track Archive for Climate Stewardship
IoT	Internet of things
ILO	International Labour Organization
K	Thousand
MVE	Minimum viable ecosystem
MVP	Minimum viable product
Mt	Metric ton
PCRAFI	Pacific Catastrophe Risk Assessment and Financing Initiative

PoC	Proof of concept
PICAP	Pacific Insurance and Climate Adaptation Programme
PSIDS	Pacific small island developing states
RBF	Reserve Bank of Fiji
UNCDF	United Nations Capital Development Fund
UNISDR	United Nations International Strategy for Disaster Reduction
USAID	United States Agency for International Development
V20	Vulnerable 20 (group of countries)
WMO	World Meteorological Organization
WTP	Willingness-to-pay

Summary of Findings

1. **Blockchain technology has the potential to drive efficiencies throughout the insurance value chain.** Implementing blockchain-based solutions to automate processes, eliminate duplications and improve the overall quality of data analytics could reduce costs and enhance the customer experience. Parametric insurance products do not indemnify the pure loss. They make ex-ante payments when triggering events – based on predefined parameters – occur. Such triggering events can relate to temperature, rainfall, wind speed, or other catastrophic events like earthquakes, cyclones, etc. In Fiji the predominant events are tropical cyclonic storms, so the parametric insurance is aligned to the relevant parameters, such as wind speed and rainfall. **This study aimed to investigate the likely customer demand for, technical feasibility and economic viability of blockchain-based climate catastrophe insurance (BBCCI) in Fiji. The report analysed BBCCI's application in the context of Fiji by undertaking a technical feasibility assessment, which was followed by an economic feasibility assessment. Based on these assessments, a roadmap for the implementation of BBCCI in Fiji is recommended.**

2. Blockchain is a distributed ledger technology in which transactions are recorded chronologically and publicly. It emerged to address the pitfalls of centralised databases, such as data manipulation, fraud, embezzlement and theft. Although the first major use-case was the cryptocurrency, Bitcoin, the blockchain technology that underpins its transaction system extends far beyond this cryptocurrency. Blockchain enables a near friction-free, inexpensive and transparent mechanism for peers to transact without an intermediary, and to monitor, report on and verify the validity of the transaction between members of complex networks. This facet ensures transparency and consistency in data channels, which is fundamental to providing transparent reporting of policy premiums and claims pay-outs.

3. **Blockchain has the potential to deliver key digital opportunities, reduce duplication of processes, increase process automation, help reduce costs, drive efficiencies, enhance customer experience and engagement, and improve the overall data quality, collection and analytics.** Parametric insurance is an insurance product that does not compensate the pure loss, but agrees to make a predetermined payment upon the occurrence of a triggering event that is based on predefined parameters. This triggering event can be in relation to temperature, rainfall, wind speed or any other catastrophic events like earthquakes, cyclones, etc. In the case of Fiji, the predominant events are related to tropical cyclonic storms and hence parametric insurance will be broadly aligned to relevant parameters like wind speed and rainfall.

4. The key advantages of adopting blockchain technology over conventional digital technologies for climate catastrophe insurance are: (a) rebuilding trust in the claims process; (b) increased standardisation; and (c) lowering transaction costs. The use of index insurance instead of indemnity-based insurance lowers the costs of processing claims, removes the need for individual-level loss assessments, and makes system data easier to verify. The potential for fraud is also lower.

Technical feasibility assessment

5. The report undertook, first, a technical feasibility assessment on two different criteria, as follows:

    a. **Climate risk frequency of localised climate data** was assessed, examining the feasibility of implementing a solution within the country as a whole. Weather data can be fed into smart contracts using bridges known as 'oracles'. Using this method to cover disaster risks at multiple locations is not technically complex. In Fiji, policy-holders are spread across the country, and their payments can be managed by smart contracts that, once the policy's underlying weather data are updated, determine pay-outs for each location.

b. **Market barriers and infrastructure** were also analysed to study the capability to disburse payments at the local level; that is, to collect premiums from the policy-holder and disburse payments based on trigger events to the policy-holder. More than 63 per cent of Fijian farmers were found to have a bank account and well over half owned a mobile phone. The primary study results from the Pacific Insurance and Climate Adaptation Programme (PICAP) study used as part of the present research indicated that more than 96 per cent had access to a mobile phone, with 72 per cent of the farmers having access to mobile money.

Economic feasibility assessment

6. Next, an economic feasibility assessment was undertaken to assess the affordability and willingness of farmers to adopt blockchain-based climate catastrophe insurance (BBCCI). To undertake this assessment, on-the-ground market surveys with the target customer pool (i.e., farmers) were required. Given the prevailing conditions related to the coronavirus pandemic, the on-the-ground survey with local farmers to assess farmers' willingness-to-pay (WTP) for a potential BBCCI product was not feasible. Notwithstanding that producing accurate estimates of the ability-to-pay (ATP) was not feasible due to the unavailability of micro-level data (i.e., at the level of farmers or farming households), the study was able to produce a **top-level estimate** based on single data points from various sources. The estimated average farming household's ability-to-pay was 0.0469 Fiji dollar (F$; approximately US$0.0225) per square meter of farmland, according to this study's estimates based on mathematically computed results from the recently released census data in Fiji. Hence, for a small farm of 0.2 hectares (2,000m^2), a household is likely to be able to afford to pay approximately F$94 (US$45.1) per year for a parametric insurance product. This correlates to the **PICAP study,** where it showed farmers' ability to afford an insurance product costing F$100 per year, with a modest share being able to afford a more costly product, at F$200.

7. ATP is the ability-to-pay, an affordability metric that assesses one's capacity to pay for a product and/or service based on relevant disposable income and personal expenses. As an individual's disposable income increases, their ability to pay more for a specific service also increases. On the other hand, the willingness-to-pay metric is a subjective parameter that takes into account the individual's perceived importance for a given service. This measure is typically calculated based on direct interviewees' responses when asked about how much they would be willing to pay for the said service and/or product. However, the identified limitations of the study meant that direct interviews could not be conducted with farmers. The proximate information was derived based on the study conducted by PICAP and presented in this report. The methodology for calculating ATP and WTP are explained in section 5.3.1.

8. Given the lack of publicly available income survey data in Fiji (at a household or individual level) for farmers in Fiji, and the inability to conduct bespoke data collection from on-the-ground surveys, it was difficult to conduct a regression analysis that would yield rigorous and robust results.

9. Different studies have identified that blockchain-based climate catastrophe insurance can reduce the cost of issuing a policy by 40 per cent and, in turn, reduce farmer premiums by 30 per cent (Global Innovation Lab for Climate Finance 2019). However, taking the risk profile and inherent technological challenges that are prevalent in the Fijian context, along with the lack of primary data on consumers, the report on a conservative approach projects a potential cost reduction in the range of 5–10 per cent from existing premiums if blockchain-based agriculture insurance programmes are adopted in the country.

10. The proposed BBCCI product is envisaged to have a structure that will focus on automation of both the insurance and payment processes,

with the inclusion of a service provider, an insurance company, a mobile money provider and a user interface.

11. These conclusions affirm the viability and feasibility of a BBCCI product targeting farmers in Fiji, contingent on its affordability. A similar project in a different geographical community in its initial phase ensured a US$150 insurance coverage for a premium fee of approximately US$13 a year for a pool of a few hundred farmers with an average per capita annual income of roughly US$1,000. The crop insurance covered risk against drought and excess rainfall.

12. The report indicates that the average farmer (facing the risk of cyclones) produces more than one crop and would be willing to pay more for a parametric insurance product. Moreover, those who believed that a major weather event was likely to occur in the next five years were in the higher income category, and therefore more willing to pay for this type of product. On the other hand, farmers that prefer lower risk coverage would be willing to pay less for an insurance product against environmental hazards. Similarly, farmers that prefer bundled insurance products, which cover an additional risk (health or life insurance), would also be willing to pay less for a parametric insurance product. Surprisingly, other key variables – such as the age and gender of respondents, access to mobile money, and the number of workdays lost from the onset of a weather event – were all found to be statistically insignificant.

13. In deploying blockchain-based climate catastrophe insurance solutions and developing a roadmap for implementation, due consideration must be given to ensuring that the application-level roadmap is compatible with the existing infrastructure and also aligns with the strategic goals of Fiji in adapting to climate change. Blockchain-based solutions should be viewed holistically, as the technology has wider application in other sectors, such as peer-to-peer energy solutions, traceability of agriculture produce and associated certification activities, the circular economy, monitoring of climate finance, etc. Hence, it will be necessary to build the capacity of stakeholders on the potential of blockchain as a differentiator to increase efficiency in e-governance and foster innovations. The role of emerging digital technologies (including artificial intelligence and blockchain) should be recognised in tackling corruption and fraud, through structured monitoring and verification protocols and product management.

14. The way forward would be to pilot a BBCCI product as an additional ('top-up') layer onto the existing PICAP (details presented in section 5.1.2) insurance product. This approach would ensure that the underlying PICAP insurance product, which has been tested already, continues and the new layer of BBCCI can be validated for adoption in Fiji. Based on the results of this pilot, further steps towards large-scale adoption of BBCCI may be considered. It should be emphasised that this is not a competitive product, but a complementary product to enhance the reach of parametric insurance and build the resilience of farmers in Fiji.

Key limitations of the study

15. The study suffered from key limitations and drawbacks directly related to the nature and quality of the underlying survey data. These included:

    a. **The small sample size** (i.e., the limited number of observations): although the sourced survey data covered some 256 farmers in Fiji through group interviews, the data were collected on a group level rather than on an individual level, which meant that the total number of observations available was reduced to only 61. This represented a crucial drawback, as it increased the probability of bias in the results and decreased the representativity of the sample, which rendered inference at a more general (population) level impossible.

    b. **The qualitative nature of the collected data:** the survey questions covered more qualitative characteristics (e.g., perceptions, preferences, etc.) rather than quantitative aspects. This meant that most of the variables were either categorical or binary, which restricted the choice of regression models and made the interpretation of the findings more challenging.

c. **The absence of farming income-related data:** the survey did not cover any income-specific questions, so leaving out a key and crucial determinant of individuals' willingness to pay for a given service. The data also did not cover the size of farmland owned by these farmers. Both elements are key differentiating characteristics that are imperative to assessing willingness to pay. Therefore, the absence of these characteristics implied the presence of an omitted variables problem, which could result in biased findings.

16. Although the survey covered key questions relative to Fijians' perceptions and trust in financial products and institutions, it omitted some key interests – notably related to income levels and the financial performance of the farming business of the interviewed groups.

1. Theoretical Concept Design of the Blockchain-Based Climate Catastrophe Insurance (BBCCI)

Climate disasters impact all countries and aspects of development – economic, social and environmental – with far-reaching effects, unprecedented in scope and scale. Evidence suggests that disasters like droughts, heat waves, floods, hurricanes and wildfires have already increased or intensified over the last few decades due to climate change (V20 2015). Such phenomena translate into financial damages, equalling US$181 billion annually today, with developing countries bearing a disproportionate burden: approximately US$65 billion, or roughly 2.5 per cent of their gross domestic product (GDP) (Buhr et al. 2018). The Intergovernmental Panel on Climate Change (IPCC) has confirmed that a 1.0°C increase in warming has occurred, and it estimates a 1.5°C increase is *'less than 12 years away'* (IPCC 2018).

The developing countries will be more vulnerable in a warming world. According to The Global Climate Risk Index (Kreft et al. 2016), the Vulnerable Twenty (V20)[1] group of developing countries, which include small island developing states, least developed countries and African countries (Yamineva 2016), are most vulnerable and are most at risk to suffer weather and climate-related losses (UNISDR 2018). When considering V20 contributions to climate change being merely 2 per cent, by 2030, they will probably have absorbed more than half of the attributed economic cost (V20 2015; Tol 2018).

One such climate disaster was Tropical Cyclone Winston, which caused widespread damage in Fiji. More than 44 people died. Damage to the property and consequent economic destruction was estimated to be about one-fifth of the country's GDP. These floods can be linked to the increasing frequency of El Niño events that continue to impact food production by torrential rainfall, leading to landslides and waterlogging that kill crops and inundates infrastructure (Thirumalai et al. 2017).

Disasters like these represent the physical risk of climate change: the socio-economic damages linked to the increased frequency and severity of climate- and weather-related events (Dafermos et al. 2018). The United Nations International Strategy for Disaster Reduction (UNISDR) shows that during the period 2005 to 2010, *'over 700,000 people have lost their lives, over 1.4 million have been injured and approximately 23 million have been made homeless as a result of disasters'* (UNISDR 2015). Climate change will only exacerbate both the frequency and impact of disasters, by 130 per cent at 1.5°C and 340 per cent at the 2.0°C warming levels (Kharin et al. 2018). This will be potentially devastating for V20 countries which, are the least resourced to adapt to such increased risk and to fund independent recovery efforts (Fernandez and Schäfer 2018).

1.1 Introduction

For climate-vulnerable countries, natural disasters present a clear and imminent threat. With evidence showing that such events have increased over the last few decades (Dafermos et al. 2018; Mahendra 2012), and forecasts suggesting the frequency and intensity will increase further, the need to adapt has become critical.

As the frequency of climate-related disasters increases, so do the negative consequences of the associated risks. The resulting financial damage is significant and disproportionately burdens developing countries. Estimates suggest that the economic loss for developing countries globally may be as much as US$65 billion or approximately 2.5 per cent of their GDP (Buhr et al. 2018). This puts extra pressure on the already strained mitigation measures and magnifies pre-existing inequalities that exist within these societies.

1 For more information: https://www.v-20.org/about

The Southwest Pacific is highly susceptible to extreme meteorological events. Tropical cyclones are the most serious of these threats and cause the majority of economic loss (Chand and Walsh 2009). For Pacific small island states, such as Fiji, the threat is abundantly clear. Fiji is ranked the 12th most hazardous country by the World Risk Index, due to its high exposure and low coping capacity (Day et al. 2019, p.56).

On average, Fiji suffers from one tropical cyclone per year, causing annual losses equivalent to 5.8 per cent of GDP (Government of Fiji 2017a). At the time of compiling this report, the country had already suffered from two severe tropical cyclones (Yasa and Ana) during 2021. The estimated damage from Yasa was to the tune of approximately US$250 million, impacting infrastructure, livelihoods and agriculture. After a detailed damage assessment by the Ministry of Agriculture, Fiji projected total damage amounting to US$72.5 million caused to the agricultural sector alone (RNZ 2021).

In 2016, Tropical Cyclone Winston, a Category 5 storm, caused a GDP loss of 20 per cent, with the agricultural, forestry, commerce and tourism sectors accounting for 87 per cent of these losses. By 2050, with expected wind speed increases and sea level rise, the damaging effects of tropical cyclones in Fiji are projected to increase from an annual average of 5.8 per cent to 6.5 per cent of GDP (Barnes 2020).

Insurance is recognised as an important tool for managing the risks associated with natural disasters. Until recently, most of Fiji's agricultural sector had no insurance cover, although this sector occupies 50 per cent of the country's economic activity. In partnership with the Ministry of Economy, the World Bank and the International Monetary Fund (IMF), the Reserve Bank of Fiji (RBF) has initiated a process of deploying parametric insurance for the country's informal workforce in a bid to cover designated areas affected by Category 3 cyclones. The RBF is also exploring opportunities to introduce agriculture insurance to Fiji's agricultural sector (Elbourne 2020).

The Caribbean Catastrophe Risk Insurance Facility (CCRIF) provides one of the first examples of parametric insurance, paying out more than US$100 million towards the after-effects of hurricanes, excess rainfall and earthquake perils, since its inception in 2007 (World Bank 2010; CCRIF 2017). These pay-outs are intended to cover immediate action, providing emergency relief and work by disbursing them within 14 days of the disaster.

Parametric insurance has several noted drawbacks. Basis risk refers to the relationship between the pre-selected parameter and actual losses incurred, as the damage is estimated in advance. This issue is due to a lack of comprehensive and reliable long-term data impacting claim estimations. Furthermore, poorly designed parametric insurance may fail to pay out when losses are incurred, while paying sometimes when no damage has taken place. Both instances lead to a lack of trust in index insurance from both the insurer and policy-holder. WorldCover, a US-based InsurTech start-up, provides affordable crop insurance via smartphone to 20,000 farmers in Kenya, Uganda and Ghana (Bird 2018). Built on blockchain-based smart contracts, this avoids the need for paperwork. Furthermore, the insurance focuses on rainfall as an index parameter, instead of relying on manual assessments or decision-making. Therefore, distributed ledger technology provides validity to transactions and builds trust in the system. It is, nonetheless, necessary to understand the Fijian context and specifically the agriculture sector, which faces the greatest impact from extreme weather events.

1.2 The case for focusing on agriculture and tourism sectors

The Fijian economy relies on strong agriculture, tourism and textile industries. Fiji has a low unemployment rate, but a high rate of informal employment and a high level of dependency on subsistence activities. In 2016, 54 per cent of the population participated in the labour market, but 60 per cent of the employed population (78% in rural areas, 37% in urban areas) engaged in informal industries or subsistence activities (ILO 2017). The tourism sector is vital to the Fijian economy, contributing 34 per cent to GDP in 2019 (UNCDF 2020a). Despite the tourism industry's vulnerability to extreme weather events and the presence in coastal zone, damage to infrastructure has been limited. As seen during Tropical Cyclone Winston, limited structural damage occurred to tourism infrastructure and properties. Those that were affected drew on insurance to repair damages, without having to rely on government intervention (WTO 2019). Therefore, the study will instead focus on the agricultural sector, as highlighted below.

Agriculture is a key component of the Fijian economy, making up 36 per cent of employment and contributing 8.3 per cent of GDP in 2016, down from 12.1 per cent in 2001 (Singh-Peterson and Iranacolaivalu 2018). This downturn may be attributed to several factors, including the growing impact of extreme weather events. Sugarcane is the dominant crop in Fiji, accounting for 18 per cent of exports, directly and indirectly supporting nearly 25 per cent of the population (Government of Fiji 2016).

Agriculture is the sector most vulnerable to climate change due to its high dependence on climate and weather conditions. Cyclones cause extensive damage to crops, trees, livestock and farming equipment (Government of Fiji 2017a). The inability to protect smallholder farmers against the strong winds and temperature extremes that result in low yields and hence, low incomes, has a great impact on the capacity for future yields (FAO 2015). The large percentage of smallholder farmers in agriculture means it is highly vulnerable to natural hazards (Mahendra et al. 2011). Half of those living below the national poverty line rely on agriculture for at least part of their income (Government of Fiji 2017b). Most of these people are small-scale farmers, who are extremely vulnerable to natural hazards, while their financial fragility limits their capacity to cope. This was highlighted during Tropical Cyclone Winston in 2016, with 350,000 people affected, and damage to crops and livestock totalling US$104 million (FAO 2016). Furthermore, boosting the agricultural sector has been recognised as a primary vehicle through which rural communities can emerge from poverty (Singh-Peterson and Iranacolaivalu 2018).

In the agricultural sector, while women account for 37 per cent of employment, restrictions exist regarding land ownership for women. Land is usually managed by the most senior male member of a clan unit (*mataqali*), of which there could be one or several in a village. Several tribes (*yavusa*) could exist within one village and there could be several villages within a district (*vanua*). Land ownership is practised through a traditional Fijian social-political organisation the highest level in the organisation is the *vanua*. In some cases, women may have rights to use customary or native land but this is rare (Vuki and Vunisea 2016). Therefore, due to the patriarchal nature of rural Fijian society, there are limitations on the ability of women to have the autonomy to make decisions and become economically self-sufficient. Women in Fiji, therefore, continue to be subject to gender equality issues and struggle to obtain financial independence (Singh-Peterson and Iranacolaivalu 2018).

1.2.1 The gendered digital divide

Disaster literature highlights the gender differences, by emphasising women's disproportionate vulnerability to the effects of natural hazards and climate change (Bogdan et al. 2019). Pre-existing inequalities play a part; far more women are living below the poverty line, they have lower literacy rates, a lack of access to information and fewer economic assets. Women in Fijian society are therefore predisposed to adverse effects from catastrophic events. All these factors contribute to greatly reducing women's ability to respond to hazardous events (Saegar 2014). As highlighted above, gender inequality exposes societal vulnerabilities, which, at present, impact a woman's ability to influence, participate in and benefit from climate change mitigation and adaptation (World Bank 2017). The Gender Action Plan adopted at COP23 acknowledges the need to consider gender differences within climate adaptation measures (Miles and Wiedmaier-Pfister 2018). Gender equality is therefore a key consideration within the design of blockchain-based climate catastrophe insurance.

In Fiji, gender inequality poses a significant challenge, as social roles are heavily influenced by traditional values (Charan et al. 2016). Within both the principal ethnic groups in Fiji, male authority is emphasised, limiting the participation of women in decision-making at the household, community and national levels.

The gender gap also exists in financial inclusion, specifically in regard to insurance access and usage (Miles and Wiedmaier-Pfister 2018). Women are less likely to access agricultural insurance, due to household power dynamics and limited access to formal financial services (Hillier 2018). Furthermore, women are less likely to own agricultural land or property, due to legal and socio-cultural barriers, creating difficulty in drawing support following natural disasters (Miles and Wiedmaier-Pfister 2018).

A study (Delavallade, 2015) comparing uptake of index-based agricultural insurance and other savings instruments found that female farm managers were less likely to purchase agricultural insurance and more likely to prepare for emergencies by accumulating savings. The study also found that a rainfall insurance product appealed less to women than to men. While men and women are equally exposed to agricultural yield risk, women face additional sources of lifecycle risks (ibid.) due to lower levels of trust in financial institutions and lower financial literacy.

The greater vulnerability of women to natural hazards is further compounded by the growing gender digital divide (OECD 2018a). Hurdles relating to access to information, affordability and lack of education inhibit the benefits women could potentially experience from the digital transformation. For example, women in low- and middle-income countries are, on average, 10 per cent less likely to own a mobile phone than men (Miles and Wiedmaier-Pfister 2018). Addressing the gender divide requires enabling enhanced, safer and more affordable access to digital tools and fostering strong stakeholder co-operation to remove barriers and enable full participation in the digital world for women and girls (OECD 2018b). In the context of BBCCI, this is a key hurdle in insurance penetration and, ultimately, will contribute massively to the success of the product.

Based on the phenomenon in other countries and considering the gender related socio-cultural dynamics, it is likely that women in Fiji are currently disadvantaged in accessing agricultural insurance products. Therefore, it is reasonable to hypothesise that the BBCCI, which may offer insurance products at a lower cost and without high-end technology devices, can contribute towards strengthening gender equality in Fijian society. Owing to the constraints in obtaining community-level socio-demographic data during the coronavirus pandemic, the gender dimension of this feasibility study will need to be revisited in due course.

1.3 Disaster risk insurance

In Pacific island states, the effects of natural disasters have traditionally been borne by local populations and local governments, with international organisations acting as a last resort insurer (Broberg 2020). Natural hazards lead to a halting of development, as national budgets are redirected to cover these losses incurred. Following Tropical Cyclone Winston in 2016, a disaster recovery framework was developed by Fiji's Ministry of Economy. This framework outlined a F$731 million rehabilitation programme over two years, with extra funding provided for housing (F$184 million), restoring livelihoods (F$170 million), infrastructure (F$353 million) and resilience (F$24 million) (ADB 2019), which was financed by the Fijian government, donors and World Bank lending. Article 8 of the Paris Agreement unambiguously recognises 'the importance of averting, minimizing and addressing loss and damage associated with the adverse effects of climate change' (Broberg 2020).

Insurance can therefore play a major role in offsetting the negative financial impacts of natural disasters, aiding in recovery by reducing risk exposure and increasing an individual's level of financial resilience (Sandland et al. 2019). Approximately 70 per cent of all losses from natural disasters are unrecorded. This disconnect between the ability of insurance to alleviate these impacts and the current lack of coverage is known as the 'protection gap' (IAIS 2018). When climate disasters hit countries with low insurance penetration, it leads to a decline in economic output and increasing levels of poverty (Sandland et al. 2019). The protection gap can be expected to grow in line with the forecasted increase in the frequency and severity of climate disasters.

Tropical Cyclone Winston highlighted the protection gap in Fiji, during which 94 per cent of households were uninsured against tropical cyclones; the insured represented a mere 15,000 out of 240,000 residential homes (GFDDR 2016). This shortfall was, in part, due to insurers only being able to supply property catastrophe insurance for houses of a high construction standard certified by an engineer. Many low-income households do not meet this standard, and therefore cannot currently be insured. This protection gap highlights a market failure, putting the onus on the Government of Fiji to provide post-disaster financial assistance (GFDDR 2016).

The proliferation of insurance products in Pacific countries such as Fiji is limited by several factors. On the supply side, these include high transaction costs, the inability to spread risk over a large territory, and the relatively small size of the local economies, which keep insurance penetration to a minimum (Mahul et al. 2015). In addition, to limited awareness about risk and insurance, combined with a lack of willingness to mitigate risk through insurance (Prabhakar et al. 2013). The high cost and small-scale premiums for insurers mean it is currently not economically viable to insure smallholder farmers. This discourages insurers from investing in products that could reduce the protection gap (Sandland et al. 2019).

A study by the Pacific Catastrophe Risk Assessment and Financing Initiative (PCRAFI) in 2018 into the demand for household insurance against tropical cyclones in Fiji, found that while 93 per cent of respondents felt insurance could play a role in cyclone response, only 2 per cent felt it actually did. This figure demonstrates that, unlike many other countries, there is a significant level of distrust in insurance, highlighting the potential need for awareness raising on such products. For home insurance policies to be issued, the building needs to be certified by an Engineer confirming its resilience to a cyclone[2]. Engineer certificates were found to be a barrier to 31 per cent of respondents, representing a cost barrier to much of the population. Furthermore, the limited of understanding or access contributed 28 per cent and 13 per cent respectively.

Fiji is ranked as the 12th most hazardous country in the world by the World Risk Index, on the basis of high exposure to natural hazards and its relatively low coping capacity (Hilft et al. 2020). In Fiji, most middle- and low-income households have no insurance protection against natural hazards. The Agriculture Insurance National Working Committee (AINWC), comprising representatives from the government, the insurance industry, international development agencies and the private sector, was re-established in 2018. The committee was tasked with engaging relevant stakeholders to explore opportunities to introduce insurance to the agriculture sector in Fiji (Government of Fiji 2018b). Fiji's insurance penetration rate was 2.4 per cent in 2018, with only about 6 per cent of the households and 17 per cent of commercial properties having any type of property insurance. Those with insurance policies were offered only basic cover, which did not necessarily cover any major natural disasters. Cyclone insurance, alongside earthquake and tsunami coverage, is only available as an extension or optional extras to the basic property coverage and requires certification by a qualified engineer. This barrier makes many homes simply uninsurable. In addition, Fiji does not have any kind of crop, livestock or fisheries insurance. The ability for farmers to cope with the multiplicity and complexity of the risks to which they are exposed is quite limited.

2 Further information can be found here: https://www.rbf.gov.fj/wp-content/uploads/2019/05/Fiji-Sun_Cyclone-Insurance-Do-you-have-it-Are-you-protected_311016.pdf

The different kinds of insurance products currently preferred in Fiji are:

a. Bundled microinsurance products by FijiCare — combining funeral, term life insurance, personal accident and fire insurance into one product. The product aims to boost the resilience of policy-holders, allowing them to cope with a range of events that cause financial shocks.

b. Mobile insurance by BIMA — a mobile-platform offering microinsurance that is easy to use, fast and affordable.

c. Microlife by Life Insurance Corporation of India — providing death, disability, accident and funeral expenses to low-income customers, who previously had been underserved, so promoting greater financial inclusion.

The delicate nature of the agricultural sector in Fiji, coupled with the natural hazards faced by the country, necessitates a comprehensive discussion on the protection of agriculture through risk-transfer mechanisms. In this context, the Pacific Insurance and Climate Adaptation Programme (PICAP) was launched jointly by the United Nations Capital Development Fund (UNCDF), the United Nations University Institute for Environment and Human Security (UNU-EHS), and the United Nations Development Programme (UNDP), with an objective to improve the financial preparedness of 'Pacific households, communities, small businesses, organisations, and government towards climate change and natural hazards' (PICAP 2020).

Agricultural insurance has an important role to play in managing disaster risks, pertaining to extreme weather events. This should include insurance at different levels, starting from the farmlands. This would support the communities at the local level and protect the business at the meso level, as a business interruption cover to offset the agricultural loan portfolios of financial institutions and input suppliers. The focus on covering for natural hazards with a high covariate risk and individual loss assessment, is expensive and time consuming, especially when the actual amounts are limited to relatively low sums. Hence, it would be prudent to consider parametric insurance based on the categorisation of the cyclones, or some other variables. The major challenge, in this case, would be 'basis risk'. Thus, consideration should be given to including other datasets in the validation of parametric insurance, rather than pegging only one variable to one event like the categorisation of the cyclone. Necessary weight would need to be given for the associated indices like rainfall, wind speed, volumes of precipitation, etc.

The study by the Asian Development Bank (ADB), entitled *The Enabling Environment for Disaster Risk Financing in Fiji Country Diagnostics Assessment* (ADB 2019), identifies that the lack of product development is hindering disaster risk transfer to the insurance and capital markets in Fiji. Parametric products become attractive for individual exposure units when the premium-to-pay-out ratio is above a certain threshold, say more than 1:10. Henceforth, efforts for deploying innovative and new technology-driven solutions would address the challenge of designing products that take into consideration the above factors.

The issues surrounding blockchain as a new technology prove a major roadblock in the adoption of blockchain within the insurance industry. These issues surround slow transaction speeds, lack of standards and interoperability between different blockchain platforms, coupled with legal and regulatory concerns (Deloitte 2018). However, the development of new consensus mechanisms is improving performance and interoperability, while reducing complexity, cost and energy requirements (Sandland et al. 2019). Over time, such development will lower the cost and risk of deploying blockchain technology.

As this technology is in its infancy, blockchain encounters several barriers to adopting blockchain-based climate catastrophe insurance. First, there exists a technological barrier in the availability of comprehensive data insurers need to accurately estimate risks in order to price premiums (Frankze 2017). In addition to this, there also needs to be a high level of confidence in the fidelity of payment triggers (Sandland et al. 2019). At present, data are only available at the national level, inhibiting the provision of local-level protection in disaster-prone areas currently unaccounted for in insurance offerings. Developing robust data sources is therefore pivotal to increasing insurance penetration in vulnerable communities.

Furthermore, for small states, these issues are compounded, with increased difficulty in accessing reliable data. Small states' lower resilience means post-disaster infrastructure, such as telecommunications, could greatly jeopardise the functionality of a blockchain-based climate catastrophe insurance, with the platform inaccessible when most needed (Ibid.).

Uptake is a key challenge for the introduction of any insurance product. The deployment of blockchain-based climate catastrophe insurance requires consumer education about insurance value, and information technology (IT) literacy in order to address any social or cultural barriers.

1.3.1 Blockchain-based parametric insurance

Parametric insurance is an emerging financial product mitigating socio-economic impacts following climate disasters, with the potential to amplify coverage among climate-vulnerable households (Sandland et al. 2019). In contrast to traditional insurance, parametric insurance does not require on-the-ground inspections, as settlements are based on predetermined triggers that are linked to independent, objective measures that are correlated with damages (Sandland et al. 2018). For disaster risk insurance, this triggering event could be rainfall or wind speed. Removing the need for on-the-ground inspection of damages as a means of settlement can be based on predetermined triggers, which are linked to objective measures that are correlated with damages, speeding up the payment of claims. Payments would therefore be approximately proportional to the losses expected to be incurred post-disaster (World Bank 2007). Central to this, is the availability of data to ensure metric thresholds represent real damage. This will be examined in the subsequent chapter on the technical feasibility assessment.

What is blockchain?

Blockchain is a distributed ledger technology in which transactions are recorded chronologically and publicly. It emerged to address the pitfalls of centralised databases, such as data manipulation, fraud, embezzlement and theft (Nakamoto 2008). Although the first major use-case was the cryptocurrency, Bitcoin, the blockchain technology that underpins its transaction system extends far beyond this cryptocurrency. Blockchain enables a near friction-free, inexpensive and transparent mechanism for peers to transact without an intermediary, and to monitor, report on and verify the validity of the transaction between members of complex networks. This facet ensures transparency and consistency in data channels, which is fundamental to providing transparent reporting of disaster aid and claims pay-outs.

Trust is established using a distributed consensus mechanism to check the validity of transactions, independent of intermediaries. For example, Proof of Work is used in the Ethereum blockchain[3]. With blockchain technology, insurance data, including policies, pay-outs, know-your-customer and anti-money laundering, can be recorded digitally on secure, incorruptible digital ledgers across a dispersed network of nodes. As the blockchain is open to writing and inspection, actors within the disaster aid landscape and insurance providers can be held accountable for their actions (Observer 2017). Further, the transfer of data is handled independently and automatically on-chain, removing manual, routine and paper-based procedures.

Smart contracts can further streamline this process, by codifying traditional insurance policies. Blockchain removes the need for a central authority, legal system or external enforcement mechanism by permitting a seamless and constant contract execution environment that renders transactions to be traceable, transparent and irreversible. Blockchain-enabled smart contracts, therefore, help build trust between policy-holders and the broader ecosystem of insurance providers, regulators and other players, since the risk of data tampering (fraud, theft and hacking) is considerably mitigated (Clyde and Co LLP 2018). Research suggests that the automatic handling of data also removes 30 days of administration time from the insurance/reinsurance cycle (ibid.), providing efficiency gains to the industry.

Unlike traditional database operations, with the blockchain, individual-level data can be attached and processed in real-time – at a significantly greater speed and volume than what is currently possible. This allows insurers to offer customised pricing to individuals, based on frequent risk assessments. This acts to tailor long-term risk reduction strategies for different groups and thus, enhance the effectiveness of distribution through building trusted relationships and transparent, timely post-disaster claim processing (OECD 2018a). Decentralisation has the potential to disrupt the traditional insurance model, enabling new peer-to-peer models of insurance. Friendsurance, an InsurTech start-up in Germany, for example, allows customers with the same type of insurance to connect and share premiums, assess risks and claims, with reduced costs (Clyde and Co LLP 2018).

Currently, insurers are experimenting and modelling policies through the use of different blockchains. Ethereum is the most diffuse blockchain offering smart contract solutions, while others exist such as NEO, NEM, EOS and Cardano. The most notable blockchain consortium in insurance is the Blockchain Industry Insurance Initiative (B3i), operating R3 Corda – a permissioned-private blockchain. AXA, on the other hand, is experimenting with the platform-agnostic Hyperledger Fabric, a permissionless open-source blockchain. The use of different blockchains highlights the fact that InsurTech is still maturing and the market consolidating. Thus, it is important to maintain interoperability and flexibility based on minimum standards, to ensure a collaborative environment to build capacity, develop partnerships and share best practices as to optimising policies or driving a revolution in accessing and scaling such policies to address the 'protection gap' (ibid.).

Blockchain-based climate catastrophe insurance (BBCCI)

Blockchain-based parametric insurance (BBPI), sometimes known as blockchain-based climate catastrophe insurance (BBCCI), benefits the insurer and policy-holder by automating claims, enhancing trust, increasing transparency and ensuring immutability in the securely distributed ledgers (Cohn et al. 2017). Instant verification, coupled with the ability of blockchain to consolidate data points from third-party providers, supports making the premiums affordable, as the corresponding risks are reduced (Davis 2018). The terms of the agreement are pre-programmed, with the ability to self-execute and self-enforce without intermediaries, so streamlining the insurance process to 'if/then' statements. When the premium is paid, the contract details are entered into immutable blockchain software via a smart contract, to ensure the processing of claims when a pre-specified weather event is triggered. A smart contract is a virtual contract written in code governing a step-by-step transaction (Knezevic 2018). As policies exist on the distributed ledger,

3 A type of decentralised blockchain platform that establishes a peer-to-peer network that securely executes and verifies smart contracts. Further information can be found here: https://aws.amazon.com/blockchain/what-is-ethereum/

BBCCI ensures transparency of cash pay-outs for all stakeholders, without the need for a central financial authority. The transparency afforded by BBCCI instils confidence, by providing a layer of transparency through access to data, to improve inter-organisational co-operation between insurers and reinsurers (Sandland et al. 2018). Blockchain integration with parametric insurance can therefore provide trust via transparency over whether the policy was taken out and if premiums are paid; thus, BBCCI increases insurance uptake as trust is built.

An 'oracle' is used to determine whether the threshold for a pay-out metric has been exceeded. An oracle is a third-party data source, supplying data on the blockchain for the creation and execution of automated smart contracts held on a computer program, such as Ethereum, and recorded on a distributed ledger technology (Lamberti et al. 2017). By bringing external data onto the blockchain via a weather index database or satellite imagery, the smart contract will determine whether a pay-out should be executed, or not. For example, if a weather index database notes wind speeds exceeding 90 miles per hour (mph) in Tavua, the smart contract then initiates a pay-out based on the expected damage caused by 90mph wind speeds.

The application of blockchain-based parametric insurance is supported by the proliferation of smartphones and associated mobile wallets, allowing finance to reach previously untenable locations. In Fiji, the number of people who own a mobile phone outnumbers those with a bank account (Cave 2012), with 84 per cent of Fijians with a mobile phone (GSMA 2019) compared with 76.8 per cent subscribed to financial services (NFIT 2019). The proliferation of mobile phones can facilitate insurance providers to service claims via mobile payment channels, increasing the uptake of insurance products and therefore insurance penetration.

Blockchain-based parametric insurance can, at least in theory, change how insurance works and how we protect against climate risk. It fundamentally alters insurance offerings by lowering transaction costs of simple policies in favour of lower-premium policies, coupled with the reduced costs of not requiring on-the-ground inspection (Cohn et al. 2017), which is even more profitable for insurance companies. BBCCI can circumnavigate the challenges previously limiting the penetration of insurance in climate-vulnerable communities, such as lack of reliable data, cost, high premiums, claim disputes and delays in payments (UNDP 2017). This means that previously unprofitable insurance cases could be covered alongside improved payment speeds and channelling to previously inaccessible areas (Greatrex et al. 2015).

2. Objectives and Methodology of the Technical Feasibility Study

This study provides background information, a brief description as well as recommendations that could support the Government of Fiji to implement a favourable policy and regulatory environment for the adoption of blockchain-based parametric insurance. Methodologically, for both the technical and economic feasibility assessment, the study employed desktop review and limited stakeholder consultations due to COVID-19 restrictions. These are detailed in the following sections.

2.1 Desktop review

A review of policies, institutional arrangements, and gaps in the structural process via desk research of country needs was necessary to discover any apparent opportunities for the deployment of blockchain-based products that minimise the exposure of vulnerable communities to climate risks. Successful and unsuccessful examples are cited herein to create a foundational background for the feasibility assessment. The desktop review reduced redundancy in the process by highlighting the information, case studies and challenges that had already been tried, tested and published.

2.2 Technical and economic feasibility assessments with primary data sources

The desktop review also confirmed that BBCCI had been adopted in other countries. However, in-person stakeholder engagement, which was required for this feasibility study, could not take place in Fiji due to the prevailing COVID-19 conditions that restricted travel. Additionally, electronic stakeholder engagements could not be conducted either, due to logistical challenges. Apart from the criteria extracted from the initial work plan in the Terms of Reference (ToR) of this study, additional information was considered to increase the credibility of the feasibility assessment. By examining both the technical and economic feasibility of the blockchain-based climate catastrophe project, with Fiji as a case study, this report also proposes an implementation roadmap for multistakeholder consideration.

Technical feasibility assessment

CRITERION 1: Climate risk and frequency as primary data sources underpinning the necessary digital infrastructure

- A brief assessment of the availability of data measuring the frequencies and magnitude of climate-related disasters and their financial impacts based on locality (damage from cyclones, flooding [from rivers], storm surge flooding [from the ocean], landslides, excess rainfall and drought).
- An assessment of categories of climate-specific disasters and associated potential technological solutions.

CRITERION 2: Market barriers and infrastructure

- Is the current policy and regulatory landscape favourable for such projects in the locality?
- Is the correct type of infrastructure available for the execution of these projects?
- What is the trade-off for adopting blockchain-based climate insurance projects?

Economic feasibility assessment

In this chapter, the economic rationale for adopting blockchain-based climate catastrophe insurance (BBCCI) is analysed with a special focus on the agriculture sector and its vulnerability to natural disasters in Fiji. The economic analysis of the agricultural sector and the economic impact of environmental risk are examined and presented in subsequent paragraphs. The affordability metrics and the methodology are presented to assess the willingness of farmers to opt for BBCCI. However, stakeholder consultations that were planned as part of the initial approach for this study were not undertaken due to logistical challenges posed by the prevailing COVID-19 situation.

CRITERION 3: Customer demand

- To assess the locals' willingness and ability-to-pay for BBCCI.
- To examine any competitive advantage (unique selling points) of BBCCI product in the market.
- To assess the understanding of farmers towards climate risks and their perception towards risk mitigation.
- To assess the key permanent and temporary crops of farmers and incomes generated from these crops.
- To assess the awareness of consumers towards BBCCI and IT skills in order to address any social and cultural barriers.

CRITERION 4: Economic viability

- To conduct a market analysis and estimate the cost structure for a crop insurance product.
- To undertake econometric analysis on primary data and/or secondary data.
- To assess the insurance industry landscape in target areas in Fiji.
- To examine the experience of similar products introduced in other countries to identify lessons learnt.

A roadmap for implementation

Based on the results of the technical and economic feasibility assessment, a high-level implementation roadmap is recommended for the Government of Fiji to support roll out of BBCCI products in the country. However, due to insufficient primary survey data from Fiji during the coronavirus pandemic, this study was unable to produce complete localised analysis as intended. The replicability of the BBCCI product structure and business model in other Commonwealth states with similar geographical and socio-economic characteristics needs to be studied further, based on the above parameters.

3. Technical Feasibility Assessment

The technical feasibility assessment explores the case for deploying blockchain and other emerging technologies when offering parametric insurance solutions in Fiji. This assessment presents the different datasets available for consideration, the granularity, and the existing legal and governance policies relating to the adoption of blockchain-based parametric insurance solutions.

CRITERION 1: Climate risk and the frequency of localised climate data underpinning the necessary digital infrastructure

3.1 The severity of climate-related catastrophic events

Climate change and its effect on weather patterns pose several risks for Fiji and its population. Extreme weather events, such as the floods and Tropical Cyclone Evan in 2012, threaten Fiji's safety and security. And the frequency of these events is likely to increase in the future. Estimates suggest that by 2050, 1 in 20 year rainfall events will have risen from 245mm to 300mm in a single day. And if global warming reaches 2.5°C, as predicted, tropical cyclones will occur twice as frequently as they have in the past (Kuleshov et al. 2014). The Fijian government recognises these risks and the consequences for a country with a high percentage of its people relying on agriculture for their income and livelihoods (Thomas et al. 2018). It also understands that rising sea levels will compound the situation, as saltwater intrusion affects land arability and its suitability for livestock (USAID 2018).

3.2 Availability of localised climate data and associated technological solutions

Localised climate data are essential for the technical viability of any parametric insurance solution. The data from breached parameters form the 'oracles' that activate the smart contract to issue cash pay-outs. The available data vary in granularity (from one national data point right down to individual property-level data points). For the programme, availability is more relevant than granularity; however, granularity will significantly impact the structure and complexity of the delivered scheme.

The datasets described below are collected by government agencies and cover large areas of the Earth, and their quality has undergone detailed vetting. The data have long been available in academia and are used widely for climate studies, which validates their use for weather and catastrophic parametric insurance.

ERA5 weather data

For data requirements relating to temperature, rainfall and other major weather parameters, it is common to use ERA5[1]. The dataset contains hourly estimates on a range of atmospheric, land-surface and sea-state parameters on a 30km grid. Information about uncertainties for all variables at reduced spatial and temporal resolutions are also included. Preliminary daily updates of the dataset are available within five days of real-time, allowing pay-outs within two weeks of data release. ERA5 publishes quality-assured monthly updates within three months of real-time. ERA5 covers the period from 1950 to the present.

CHIRPS data

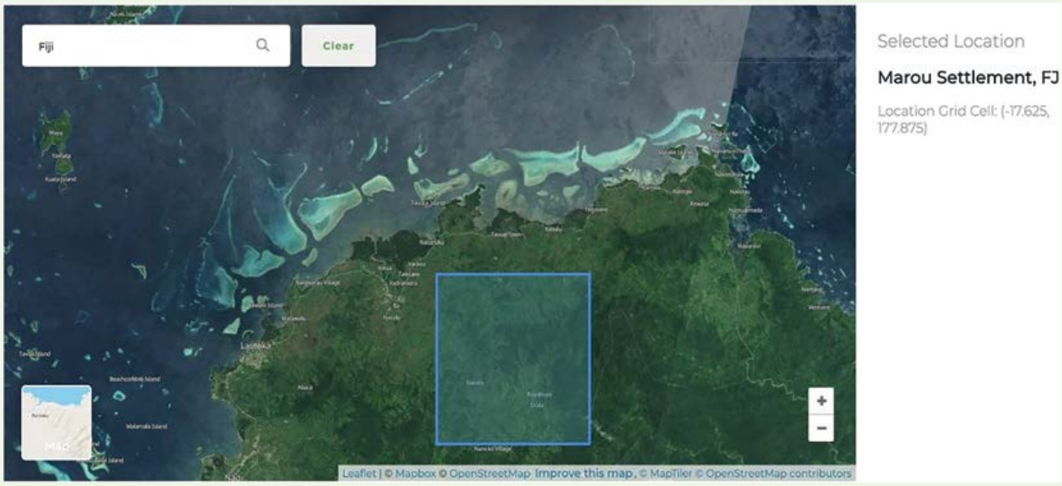
In terms of rainfall, the ERA5 dataset has a 30km resolution, which could be too coarse for small areas like Fiji. In that case, Climate Hazards Group InfraRed Precipitation with Station data (CHIRPS)[2] should be a more suitable dataset, as it has rainfall data at 5km. CHIRPS is a 35+ year quasi-global rainfall dataset. Spanning 50°S–50°N (and all

1 Further details are available at: https://www.ecmwf.int/en/forecasts/datasets/reanalysis-datasets/era5.
2 Further details about CHIRPS are available at: https://www.chc.ucsb.edu/data/chirps.

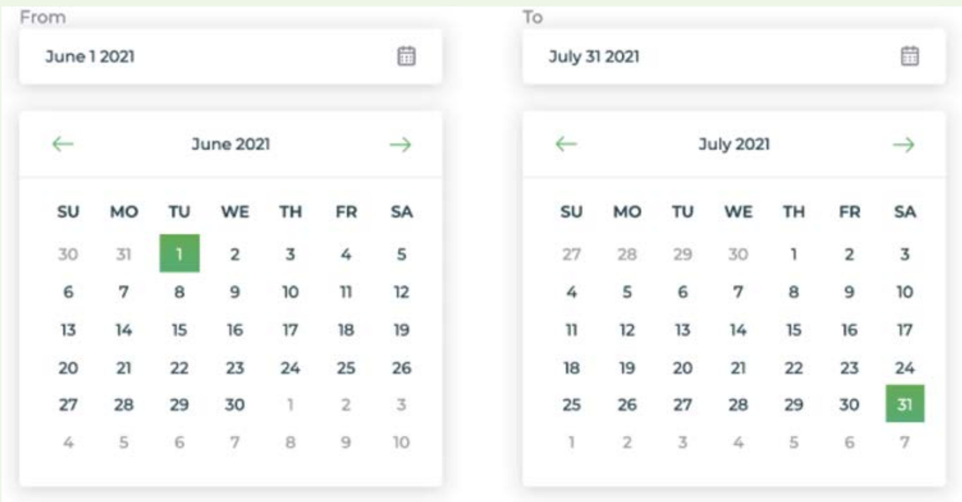
Example 3.1 CHIRPS application to compensate Fijian farmers in a drought

Below is an example of a CHIRPS rainfall product (using Fiji) to pay farmers if rainfall over a summer period is too low.

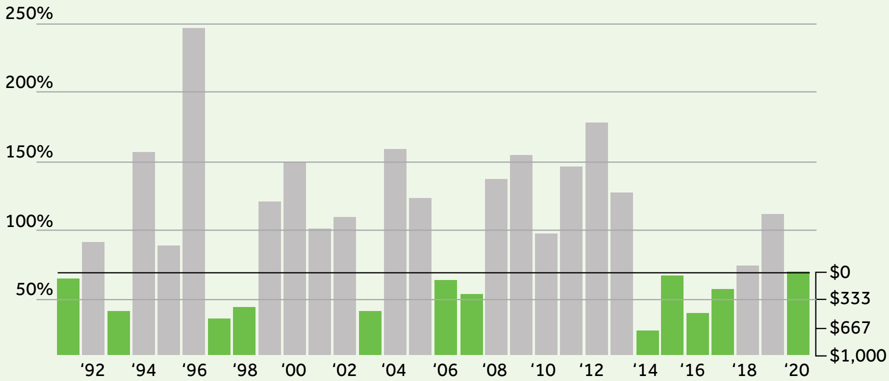
First, an insurer selects the location over which they want the measured rainfall to determine the pay-out. The location chosen below is for a square grid around the Marou Settlement in Fiji, with the grid cell centre at –17.625 latitude and 177.875 longitude.



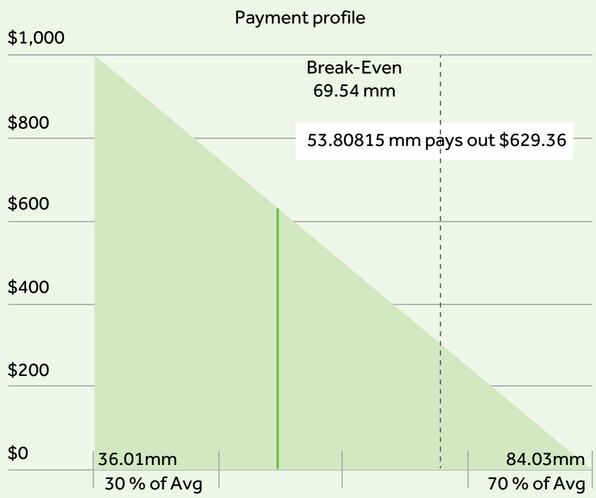
The insurer then selects the time period over which rainfall is needed. Here, the date range is 1 June 2021 to 31 July 2021. The policy will pay based on total rainfall measured for the location above between these two dates.



Historical rainfall data for the above Fiji location between 1 June and 31 July is shown as a percentage of the 30-year average rainfall. For example, 100 per cent is the 30-year average rainfall, while 80 per cent would be the level of 80 per cent of the 30-year average rainfall. The bar graph shows rainfall from 1991 to 2020, with the green bars showing years with positive pay-outs with low rainfall, while the grey bars show years with no pay-outs since the rainfall amounts are high enough (for there to be no drought) in those years.



The pay-out would be higher as rainfall is lower. The total pay-out would be maximised at US$1000 in this example.



The payment here will compensate the farmers in drought-like conditions.

Source: Arbol Inc.

longitudes) and ranging from 1981 to near-present, CHIRPS incorporates satellite and weather station information for seasonal drought monitoring.

Where station density is low, such as the tropics, the CHIRPS dataset blends station and satellite data. For Fiji, around 17 weather stations are used, along with satellite estimation of rainfall to generate higher resolution rainfall data.

IBTrACs

For cyclones, national agencies around the world release track and intensity data going back to at least 1950. These datasets capture the track of each cyclone's location in the form of latitude and longitude updated every few hours, along with other parameters, such as wind speed and pressure.

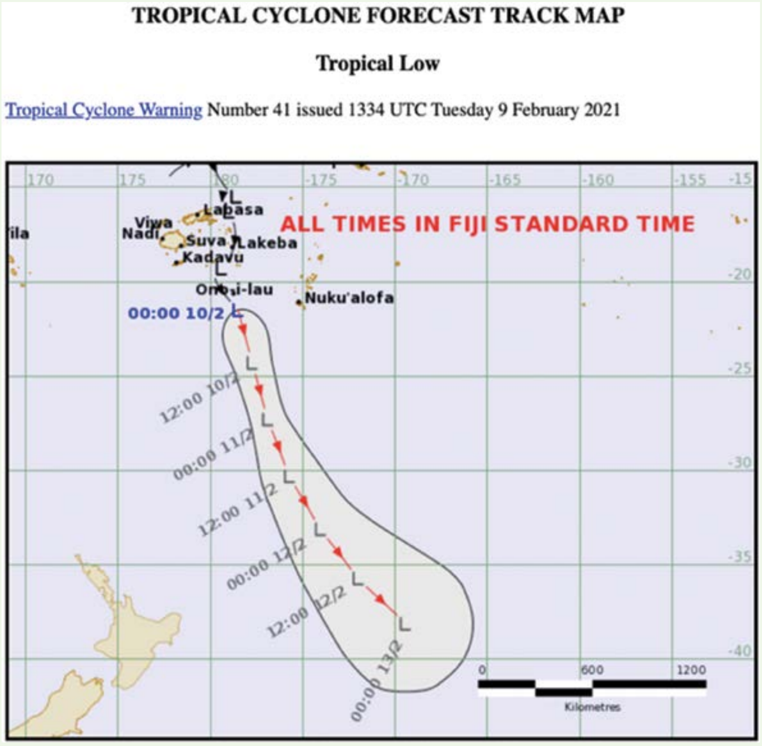
International Best Track Archive for Climate Stewardship (IBtrACs) is a dataset that combines data from these national agencies; it collects cyclone track data in a single repository to aid understanding of the distribution, frequency and intensity of tropical cyclones worldwide[3]. The World Meteorological Organization (WMO) Tropical Cyclone Programme has endorsed IBTrACS as an official archiving and distribution resource for tropical cyclone best track data. The data are available in many formats. The IBTrACS–

3 A full description of IBTrACs data is available at: https://catalog.data.gov/dataset/ncdc-international-best-track-archive-for-climate-stewardship-ibtracs-project-version-3.

WMO version of the dataset uses data from the WMO.

With data from 12 different agencies or historical databases, the Fiji Meteorological Service (Regional Specialised Meteorological Centre [RSMC] Nadi–Tropical Cyclone Center), the data are available for all the major basins, including the Pacific. In contrast to traditional insurance methods, which are very slow to cover claims, the granular dataset enables rapid and fair pay-outs after cyclones hit.

Example 3.2 Cyclone track visual and data table for Fiji



Details:

	Time (UTC)	Intersity Category	Latitude (decimal deg.)	Longitude (decimal deg.)	Estimated Position Accuracy (km)
0hr	12 pm February 9	tropical low	21.5S	178.5W	[! No value and no default value for observed_uncertainty element !]
+6hr	6 pm February 9	tropical low	22.9S	178.1W	30
+12hr	12 pm February 9	tropical low	24.3S	177.7W	55
+18hr	6 pm February 10	tropical low	25.8S	177.3W	85
+24hr	12 pm February 10	tropical low	27.3S	176.9W	110
+36hr	12 pm February 11	tropical low	30.3S	175.7W	170
+48hr	12 pm February 11	tropical low	33.1S	174.0W	230
+60hr	12 pm February 12	tropical low	35.7S	172.0W	320
+72hr	12 pm February 12	tropical low	38.1S	169.4W	405

Cyclone intensity is defined by the correlation between maximum sustained wind speed and the damage caused.

Category	Sustained winds	Gusts
Five	>107 kt >198 km/h	>151 kt >280 km/h
Four	86–107 kt 158–198 km/h	122–151 kt 226–280 km/h
Three	64–85 kt 118–157 km/h	90–121 kt 167–227 km/h
Two	48–63 kt 89–117 km/h	68–89 kt 126–166 km/h
One	34–47 kt 63–88 km/h	49–67 kt 91–125 km/h

An example parametric cyclone product for a given location would pay based on nearest track data (as in table above) and on intensity category.

Example details for a parametric cyclone risk policy for a single property location:

Sample latitude / longitude location of property in Suva, Fiji: -18.14, 178.44 (Suva)

Radius: 10km

Intensity	Pay-out
CAT 1	0
CAT 2	0
CAT 3	US$250
CAT 4	US$500
CAT 5	US$1,000

The policy above details the pay-out structure for a possible parametric hurricane pay-out. The location of the chosen property and its radius denotes the spatial area in which pay-outs are made. Therefore, a radius of 10km implies that a cyclone passing within 10km of the location point will possibly trigger a pay-out.

The actual pay-outs are determined by the intensity category and the maximum sustained wind speed within the defined radius. Pay-outs increase in line with the intensity category, and in the case of the hypothetical policy above, a Category 3 cyclone would pay US$250, a Category 4 would pay US$500, and Category 5 would pay US$1000. These amounts and thresholds are customisable based on historical damage analysis or coverage required by the policy-buyers. The above policy is for a single location point. Similar policies would need to be repeated across many locations to cover the country.

Source: Arbol Inc.

3.3 Availability of data on theoretical loss exposure, average indemnity costs and aggregation risk

A disaster risk insurance product should not be commercially viable unless there are available data on theoretical loss exposure, average indemnity costs (aligned to parametric pay-outs) and, where relevant, aggregation risk (e.g., for flooding, landslides etc.).

With parametric insurance, several factors drive exposure to catastrophic weather events. For agriculture, the effect of weather on crop yields, such as sugar, can be estimated using various open-source models. These models use historical data and biological characteristics to evaluate the likely impact of different weather variables on crop output. This information provides the input for estimating exposure from various weather perils, such as excessive rain or high temperatures.

When a building age increases, the accuracy of the assessment and the building materials (e.g., concrete or glass) indicate the likely loss for different wind speeds. Fragile structures are more likely to suffer damage from wind speeds above certain thresholds.

If the property data are insufficiently granular, coverage amounts can be estimated using damage suffered in previous seasons. By using machine learning to target affordable premium levels, parametric insurance can provide coverage for partial exposure and a financial cushion that is lacking currently. In a parametric insurance context, combining property data with machine learning methods reduces the need for expensive modelling services, such as AIR Worldwide and RMS (Risk Management Solutions). We can price and reinsure the risk without needing external input. All the historical cyclone data and ongoing data required to make pay-outs, such as IBTrACs detailed above, are available free of charge.

Additionally, the national, state and academic institutions that maintain global catastrophe data should ensure it is relevant for insurance providers.

3.4 Assessment of the optimal level of granularity in location, peril coverage and 'sums insured'

In addition to the availability of data relating to climate and loss exposure, it is also essential to assess the optimal level of granularity in location, peril coverage, 'sums insured' etc. that can: (a) be built into a technical solution; and (b) be clearly understood, communicated and sold by local agents administering the insurance service.

'Granularity' in this context refers to the space between gridlines. For example, a high granularity temperature dataset may refer to the average temperature measured across a $2km^2$ grid, while a low granularity temperature dataset could measure average temperatures on a $100km^2$ grid. So, granularity is a decisive factor for data accuracy. For data measured on a $100km^2$ grid, everyone living within a cell is assigned the same average data for a pay-out, even though individual experiences may vary considerably. In contrast, a $2km^2$ cell will have reduced variation between the average grid data and the experience for individuals living in that box.

Additionally, there are 'fairness trade-offs' to consider. At a macro-level, more granularities seem fairer because pay-outs are more aligned to individual experience. However, at a micro-level, more granularity means more policy-holders are treated differently and receive different outcomes. All parametric solutions have issues with fairness. There will be some policy-holders without damage who receive pay-outs and others with damage who do not. The excessive granularity of location could exacerbate this problem in some cases.

In the context of Fiji, depending on the granularity of the data, someone in Suva, the capital, could receive a different payment to someone else in a nearby area if the data outputs are distinct for the two places. On the other hand, a low granularity dataset may have the same data for most of Viti Levu island, which would mean everyone in a large area receives the same payment. There are trade-offs to both outcomes (discussed below). The damage from natural disasters varies even across small regions, and we need to ensure customers receive payments for the damage suffered.

A parametric programme aims to reduce basis risk by ensuring that the available data and the customer experience correlate as much as possible. At one end of the spectrum, we have policies where the data granularity is low. In this scenario, the cell in the data grid covers a large area, and every policy-holder in that area receives the same pay-out, even if the damage suffered varies considerably. While at the other end of the spectrum, we have high data granularity. In this scenario, the cell in the data grid covers a small area, and policy-holders living near each other would receive different pay-outs.

Differing pay-outs may cause issues, but it is essential to focus on the reduction of basis risk. Datasets should be of sufficient granularity to ensure that the damage suffered by policy-holders correlates with the pay-outs they receive. The weather datasets, CHIRPS and ERA5, discussed earlier, have a granularity of between 5 to 31km, depending on the variable, e.g., rainfall or temperature. This data resolution is typical in parametric contracts, as it balances the trade-off between differing pay-outs and the reduction of basis risk.

With parametric coverage for cyclones, resolution refers to how often the cyclone position, wind speed and other metrics are measured both temporally and spatially. The pay-out for losses to farm produce or property, such as the farmhouses, depends only on data metrics and is fine-tuned to region size and premium affordability. Parametric products for cyclones use cyclone track data, which show the exact location every six hours and an estimate of intermediate locations. The pay-out is determined when a policy-holder's location is within a certain distance of the cyclone track and wind speed exceeds a certain threshold. The distance from the cyclone determines the pay-out. The premium will be lower when there is a lower probability of the cyclone being close enough to the policy-holder's location. The resolution here is a product design choice that combines desired premium levels and historical policy pay-outs to ensure the policy-holder receives a payment when a disaster strikes.

It is imperative to examine the feasibility of implementing a solution that contains 100 different trigger locations, versus 10 or 1, within the country as a whole. Weather data can be fed into smart contracts using bridges known as 'oracles'. Using this method to cover disaster risks at multiple locations is not technically complex. Arbol Inc. manages insurance pay-outs for thousands of locations. In Fiji, smart contracts can manage pay-outs to policy-holders across the country. Pay-outs for each location are determined once underlying weather data are updated. However, assessing the optimal level of location and peril coverage and 'sums insured' is connected to the economic feasibility assessment, detailed in Chapter 4, because such granularities are some of the determining factors leading to a sustainably profitable insurance product.

CRITERION 2: Market barriers and infrastructure

3.5 Digital infrastructure for disbursing payments

Here we assess the capability to disburse the payments at the local level, i.e., to collect premiums from the policy-holder and send payments, upon a trigger event, to the policy-holder. This issue is key to customer satisfaction. In many parts of the world, banking services are not available to large segments of the population, and mobile payment systems are used instead. This method is already prevalent in Africa and Asia. An example is Project Arbol in Cambodia, which worked in partnership with a local microlender and utilised a payment app[4].

In Kenya, M-Pesa, a mobile telephone and payments operator, facilitates microinsurance for agricultural input buyers. For example, once an event such as a cyclone hits, the payment to each user can be calculated by the parametric insurance pay-out formula. This automation speeds up payment disbursement since, in traditional policies, there is a long wait time to estimate damage via on-the-ground surveys. After calculating the payment amount, the next step is to send the payment to the user.

This study has identified that mobile technology penetration is relatively high in the Fijian society and hence technological adoption is prevalent. The existence of mobile-based applications like 'PacFarmer' (GSMA 2019), which is a digital platform for farmers in Fiji, offers them access to information on government schemes, commodity prices and weather information, etc.

4 Further information can be found at: https://blog.chain.link/arbol-receives-chainlink-grant-to-build-parametric-crop-coverage-service/

The percentage of farmers who are using mobile phones in Fiji is reported to be 99 per cent; however, the percentage of farmers using the different applications on their mobile phones is reported to be around 36 per cent (Daunivalu 2018). Hence, it is important to enhance digital literacy and build the capacity of farmers to utilise the different data sources, so they can take part in the digital economy and make informed decisions. Given the impetus of the Reserve Bank of Fiji on the national payment system strategy, with an emphasis on digital innovation, capacity-building initiatives need to be undertaken to strengthen the participation of farmers in Fiji's digital economy.

Example 3.3 M-Pesa microinsurance programme in Kenya

The Kilimo Salama project in Kenya is a partnership between the insurer UAP and the Syngenta Foundation. The scheme has enlisted local agro-dealers to distribute the product. Farmers visit an agro-dealer, who offers insurance under the Kilimo Salama project, and purchase their farming inputs. The agro-dealer then offers the farmer insurance protection for their inputs. The cost of the insurance is related to the cost of inputs purchased. If the farmer decides to buy the agricultural insurance, the dealer scans the barcode on the bag of seeds or fertiliser using a mobile phone application. The application informs the dealer of the premium, and the farmer pays the dealer in cash for the goods as well as for the premium.

The dealer, in turn, captures the farmer's details, including name, mobile number and sum insured, on his or her mobile phone and transmits this information via the phone to the insurer through a central communications server. The farmer then receives a text message with the policy number and cover details. The premium amount is transferred through the dealer's mobile money account to the insurer. Payments are made through the widely used Safaricom M-Pesa mobile money service.

The Kilimo Salama process drives efficiency by omitting all paperwork.

Source: http://www.impactinsurance.org/sites/default/files/MP26%20v3.pdf

3.6 Assessment of the regulatory and commercial information requirements related to know-your-customer, reinsurance and swaps, claims processing etc.

Compliance with legal and regulatory requirements related to know-your-customer, reinsurance and swaps, claims processing, etc. against the specific value-add of BBCCI will be vital to the success of the insurance product. The insurance sector is highly regulated and subject to significant oversight, so BBCCI providers will need to follow detailed rules as licensed insurers and BBCCI contracts will need to be valid under Fijian insurance law. Further, agreements executed automatically using smart contracts must be legally binding. This platform may also raise competition law or data protection concerns. Legal barriers could significantly impede BBCCI implementation. So, the legal element of BBCCI is vital to the initiative's success.

Table 3.1 outlines seven steps within a parametric insurance use-case. For each question, the relevant legal research questions have been identified. The second column of the table provides an overview of legal issues, opportunities and ambiguities to guide further research and implementation in Fiji's jurisdiction.

3.7 Assessment of the trade-offs of blockchain design against the existing 'business-as-usual' scenario

To assess the trade-offs of blockchain design against the existing 'business-as-usual' (BAU) scenario, data on current practices in Fiji was required. Due to the prevailing the prevailing conditions of COVID-19 and other logistical challenges, the study team worked with secondary data from the Pacific Insurance and Climate Adaptation Programme (PICAP).

Table 3.1 Seven steps within a parametric insurance use-case

Steps	Legal research questions
(1) A householder types the website address into his/her browser in the same way as they would with any non-blockchain web application, and signs up to the quotation platform by entering their email address, password and details of his property.	• **Is there any difference in legal considerations (e.g., data privacy, e-commerce law) between a consumer using the blockchain platform, rather than another aggregator or insurance quotation platform?** Fiji's Electronic Transactions Act states that a transaction shall not be denied validity simply because it occurred electronically.[1] Though this Act was formulated before the advent of distributed ledger technology and smart contracts, it confirms that a transaction will not be rendered invalid because it occurs electronically and online. Utilising smart contracts poses separate legal issues, which are discussed under step (5) of this table. • **Are providers of BBCCI also subject to any existing specific regulation enforced by financial regulators?** Fiji's Insurance Act 1998 is the main piece of legislation that governs insurance in Fiji.[2] Providers of BBCCI as an insurer would be subject to several requirements under the Act as licensed insurers, including solvency,[3] registers[4] and reinsurance arrangements.[5] Insurers and intermediaries are subject to many information requirements. Insured people must be offered a 'reasonable' explanation of the contents of any insurance document signed, and intermediaries must disclose all information of which they were aware at the time of, or before, signing the contract which is likely to affect the contract.[6] Further, supporting documents and representations must not be misleading,[7] and policies must be expressed in Fiji dollars unless the Reserve Bank gives written permission otherwise.[8] When implementing BBCCI, it will be important to note which entities are serving as insurers, and which are serving as intermediaries or brokers.
(2) The householder who has signed up to the platform is issued with a public and private key, where the latter is stored securely on his/her device or browser.	

1 Section 5, Electronic Transactions Act 2008.
2 Insurance Act 1998.
3 Ibid. Section 31.
4 Ibid. Section 59.
5 Ibid. Section 39.
6 Ibid. Section 6.
7 Ibid. Section 128.
8 Ibid. Section 127.

(*Continued*)

Table 3.1 (*Continued*)

Steps	Legal research questions
	The Insurance Act, along with the Insurance Regulations 1998 and the Reserve Bank of Fiji (Amendment) Decree 2009, gives the Reserve Bank of Fiji the power to regulate the insurance industry and its actors. The Reserve Bank conducts on-site and off-site examinations of insurers and can compel several actions, including the generation of reports or returns (RBF 2020, p.17). Given the Reserve Bank's broad power in this regard, it will be an important body for BBCCI providers and may play a key role in regulating the implementation of parametric insurance. The Reserve Bank of Fiji has already shown some willingness to explore implementing parametric insurance (Elbourne 2020) and has expressed a desire to tackle climate risks and explore emerging technologies (RBF 2020, p.12). It should also be noted that Fiji's insurance laws are currently under review and may be updated in the near future (Ibid. p.2). Given the relative youth of parametric insurance and the rapid development of climate-related risk insurance, this reform may more clearly accommodate BBCCI or similar projects in the future. This could be by expressly addressing requirements for parametric insurance within its provisions or by confirming that smart contracts are suitable for insurance agreements. BBCCI providers should also be aware of Fiji's Financial Transaction Reporting Act 2004.[9] Insurance providers are 'financial institutions' subject to regulation under this Act.[10] As such, providers must follow specific provisions, or risk facing fines. Most importantly, financial institutions have a duty to verify the identity of each customer and keep a record of this identity and any transactions that occur.[11] Thus, BBCCI providers should obtain a record of the name, address and occupation of each customer. This must be verifiable with official documentation. Further, providers must report any transaction of over US$10,000 directly to the Financial Intelligence Unit, unless the recipient of this payment is carrying out banking activity under the Banking Act 1995.[12] • **Are the terms of a parametric insurance agreement consistent with existing insurance law?** BBCCI is dependent on the Insurance Act allowing a parametric insurance regime. Parametric insurance differs from traditional models in that it gives policy-holders pre-approved pay-outs if an event that has been agreed upon previously occurs, as opposed to making individual on-the-ground assessments of loss suffered.

9 Financial Transactions Reporting Act 2004.
10 Ibid. Schedule: Interpretation of 'Financial Institutions'.
11 Ibid. Section 4.
12 Ibid. Schedule: Interpretation of 'Financial Institutions'.

(*Continued*)

Table 3.1 (*Continued*)

Steps	Legal research questions
	Solicitors from Clyde & Co identify two key factors that can make legal regimes unsuitable for parametric insurance (Konsta 2018). The first is when insurance law requires an 'insurable interest' in a specific subject matter, which may not always be the case in parametric insurance regimes. Fijian law does not have such a requirement,[13] and indeed when defining 'insurance business', the Insurance Act 1998 describes insurance merely as the business of undertaking liability in respect of loss or damage contingent upon the happening of a specified event.[14] The second factor that can preclude parametric insurance is the 'indemnity principle', which requires that a pay-out must correspond to the actual loss suffered by the insured. No such principle is evident in Fijian law. Thus, at least on the surface, the Insurance Act does not contain any fundamental barriers to parametric insurance, which, if combined with a permissive legal environment for smart contracts, could be a precursor to a favourable regulatory environment for BBCCI adoption.
(3) The householder receives and installs a number of tamper-proof (wind speed/flood) detection devices in various locations at his/her home. Each of these devices has a hardware-secured private key of their own, a GPS locator, a built-in camera, and an ability to detect and send data signed by using their own private key. The encrypted copy of the data is stored across each node of the blockchain network.	• **Is the management of encrypted data considered a matter under the right to privacy, according to Fiji's Bill of Rights?** Fiji's constitution has enshrined a general right to privacy,[15] though the interaction between this right and data remains largely unexplored (Fiji Women's Rights Movement 2018). • **Who is the controller of (personal) data uploaded by the householder?** Fiji has no comprehensive data protection law.[16] Though Fiji has taken steps to establish an 'e-government', this largely concerns internal operations within the government itself and the broad diffusion of technology across the country. Several other acts touch on data protection, but this is largely in other sectors, including telecommunications and online safety.[17] • **How can the risks and responsibilities of the parties to these BBCCI contracts be managed?** Even in the absence of specific data protection laws, BBCCI should take steps to manage data risks and ensure security. Policy-holders should be made aware of the data they are providing when signing a contract for insurance. Further, insurers should not use personal data for any reason other than executing insurance arrangements.

13 Note that this requirement is explicitly excluded in Section 6(1) of the Insurance Law Reform Act 1996.
14 Section 2(1), Insurance Act 1998.
15 Constitution of the Republic of Fiji, Article 24.
16 Dataguidance (2020), 'Fiji', available at: www.dataguidance.com/jurisdiction/fiji
17 See, for example, the Online Safety Act 2018 and the Telecommunications Promulgations 2008.

(*Continued*)

Table 3.1 (*Continued*)

Steps	Legal research questions
(4) The householder decides to receive an offer from an insurer and requests a quote by permitting the insurers on the platform to access his/her detection devices and any personal information that may influence the quote to be received. A smart contract between the insurer and the customer enables all the relevant household's data to be provided and matched against the predefined risk criteria of the insurer, resulting in a perfectly tailored quote being automatically issued to the householder by the insurer.	• **Could a group of competing insurers agreeing to offer BBCCI together, on the face of it, raise concerns in the context of Fiji's competition and consumer law?** Offering BBCCI through a consortium of existing insurers raises certain competition concerns. Fiji's competition law is governed by the Competition and Consumer Commission Act, which establishes the Competition and Consumer Commission to oversee business practices and promote competitive markets.[18] Under the Act, the commission has fairly broad powers to review actions of businesses that stifle competition. For example, businesses cannot enter into contracts that would 'substantially lessen competition'.[19] The extent to which a consortium of providers might lessen competition likely depends on factors such as the legal structure of the organisation, the market share of the organisation and the possibility for other insurers to offer a similar service. • **Should there be a common structure to govern the relationships between the insurers in the consortium and to ensure the blockchain architecture design mitigates the risk of anti-competitive behaviour?** Engaging with the Competition and Consumer Commission is key to ensuring the BBCCI does not raise any competition concerns. The consortium should be structured in a way that does not breach the Act. Understanding how strictly the commission interprets certain provisions is also important.
(5) The householder either manually selects their preferred quote or, if the platform has been designed to do so, the best quote is automatically selected for the householder, based on his/her own preferences and pre-sets entered into their profile. The householder then confirms his/her acceptance of the offer by signing the transaction with his/her blockchain private key (e.g. through biometric authentication).	• **Is a smart contract (existing purely in code and not in natural language) legally binding and enforceable, according to the law on contracts in Fiji?** As a relatively small jurisdiction, Fiji has not had to reckon with many issues regarding smart contracts. Nonetheless, general principles of common law and broader examinations of smart contracts can help guide this discussion. Under common law, contracts are formed when there has been an agreement of reasonably clear terms, an intention to create legal relations, and when there is 'consideration', or payment. Smart contracts are no different. These basic elements of a contract can be fulfilled by the underlying transaction, but it is unclear whether the smart contract itself, in the absence of any other binding legal document, could constitute an agreement. Even though Fiji has not come to a clear conclusion on this issue, the UK's Jurisdiction Task Force noted that English common law does not traditionally require that contracts are in any particular form and suggests that smart contracts are compatible with current contract law (Herbert Smith Freehills LLP 2019). The Australian government has used smart contracts to enforce individual clauses within a contract (Barley 2018). These promising signs from abroad indicate that Fiji, as a common law jurisdiction, has no obvious barrier to smart contract implementation, but their exact legal status remains largely untested locally. • **What standard information should BBCCI providers give policy-holders in accordance with Fiji's Insurance Act, etc.?** Insurance intermediaries must offer a 'reasonable' explanation as to the terms within any insurance contract.[20] If BBCCI providers fill this role, they may need to explain more technical parts of the contract in clear natural language to policy-holders. It may therefore be important to avoid highly technical language in key agreements or correspondence when possible.

18 Fijian Competition and Consumer Commission Act 2010.
19 Ibid. Section 60.
20 Section 6, Insurance Act 1998.

(*Continued*)

Table 3.1 (*Continued*)

Steps	Legal research questions
(6) Six months later, the householder's home is damaged by a cyclone. The householder returns to the platform to retrieve the photos captured and wind speed data recorded in the blockchain by an 'internet of things' (IoT) device time-stamped at a certain time and date.	• **What should be the standard of clarity in the contract terms communicated via natural language in the context of BBCCI?** To align with basic common law rules of contractual interpretation, these terms should be communicated such that a reasonable person giving effect to the ordinary meaning of their words would reach the desired outcome.[21] Thus, policy-holders should be able to understand: (a) the conditions of payment; (b) the situations in which a pay-out will occur; and (c) the sum paid to policy-holders upon certain events. These issues should therefore be communicated in clear language that a reasonable policy-holder would understand. • **What happens if there is a dispute between the insurer and the policy-holder? That is, if the smart contract has not been written clearly or if design flaws cause the smart contract not to function as expected.** This is a realistic possibility, and if the contract exists purely in code with no other legal agreement, the implications are unclear.
(7) Automated image analysis, automated analysis of the wind speed/flood level detector devices, GPS location and public cyclone warning information confirm that the damage occurred in the area. The policy parameters are then processed by the smart contract to make an automated decision for an agreed payment to the householder, potentially through a mobile payment system.	There is no clear precedent in Fiji for dealing with this situation, so it may be best to allocate the risk of these malfunctions by prior agreement (Mik 2017, p.25). Customers should have this risk allocation and any dispute process communicated to them in clear language. (Refer to the section on compliance against service requirements and technical risks and mitigation actions, below.) **How are insurance pay-outs and the income of BBCCI providers taxed?** Any income from the insurance pay-out that is additional to the sum contributed by the policy-holder is taxed. When paying policy-holders, BBCCI providers must therefore withhold 10 per cent of the difference between the premium paid and total pay-out (Fiji Revenue and Custom's Service 2018). This money should be paid to Fiji's Revenue and Customs Service. BBCI insurers would also have to pay tax at a rate of 20 per cent on their chargeable income/net profit. Finally, insurance premiums are subject to a value-added tax at the rate of 9 per cent (Ibid.).

21 This would also help meet statutory requirements, such as Section 29(e) of the Insurance Law Reform Act 1996.

Existing microinsurance products in Fiji do not cover property damage arising from natural hazards. Covering natural hazards through microinsurance is considered uneconomic, because natural hazards generally impact a large populace, which requires significant capital reserves and has a high cost for assessing claims. At the time of this report, Fiji did not have any form of agriculture insurance. However, PICAP, one of the successors of the Pacific Financial Inclusion Programme (PFIP), has introduced the region's first bundled insurance product. The insurance product supports farmers by offering cover for life, personal accident and fire, but does not cover natural hazards. In 2020, a project was initiated to develop a 'climate disaster risk financing framework and parametric insurance' in Fiji.

In this context, drawing a comparison with the existing business-as-usual scenario would not be an option in the Fijian context.

Advantages of blockchain

The advantages of adopting blockchain technology over conventional digital technologies in climate catastrophe insurance are three-pronged:

- Rebuilding trust in the claims process: The tamper-proof nature of blockchain gives it the inherent advantage of being more trustworthy than previous technologies. When used to underpin insurance-as-a-service offerings, smallholder concerns are alleviated, and greater standardisation of insurance products is enabled.
- Increased standardisation: By basing insurance products on blockchain, templates can be created that give stakeholders (i.e., farmers, co-operatives, donors, buyers, etc.) the tools to customise insurance products more cost-effectively (Sprout 2018a). The infrastructure allows the claims process to be standardised and monitored by verifying real-time weather data across a range of policies. This removes the need for an intermediary to track policies on a company level and makes the process more trustworthy and reduces transaction costs. Moreover, it creates the possibility to launch index-based insurance products at scale for a range of products for 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 rainfall triggers a pay-out. Furthermore, since multiple parties share and update policy and weather data, blockchain technology makes the process secure and trustworthy (PWC 2017).
- Lower transaction costs: Using index insurance instead of indemnity-based insurance lowers the cost of processing claims. This also removes the need for an individual level loss assessment and makes the system data easier to verify. The potential for fraud is also lower (IFAD 2017). Proponents estimate that a reduction in transaction costs of 30 to 80 per cent is achievable through blockchain technology, mobile money and other digital platforms to automate the verification and payment processes.

The premium for the customer can be broken down into the following components:

$$\text{Cost of insurance} = \underbrace{\text{cost of the risk}}_{\substack{\text{Actuarially}\\ \text{fair premium}}} + \underbrace{\text{administrative costs}}_{\substack{\text{Information costs,}\\ \text{loss adjustment}\\ \text{and delivey costs}}} + \underbrace{\text{cost of ready access to capital}}_{\text{Cost of reinsurance}}$$

Table 3.2 Cost of Insurance (USD)

	BAU	Parametric insurance with conventional digital technologies	BBCCI
Cost of risk (actuarially fair premium)	US$40	US$40	US$40
Administrative costs (Information costs, loss of adjustment and delivery costs)	US$30	US$15	US$10
Cost of ready access to capital (cost of reinsurance)	US$30	US$30	US$30
Total cost of insurance	US$100	US$85	US$80

Each of these components includes complexities and variations, depending on the target market, type of insurance, regulations and technology.

Between traditional, digital and blockchain, all three forms will have the same actuarially fair premium (based on data and risk) and a similar cost of reinsurance. Also, all three will have similar costs to any external intermediaries, such as local regulators or local agents/brokers.

The main difference between traditional, digital and blockchain insurance is in the middle component, i.e. information costs, loss adjustments and delivery costs. For Project Arbol's blockchain-based parametric insurance, the premium is the cost of reinsurance + Arbol's fee (10% of the premium). There are no additional costs for claims or loss assessments because there is no claims process. For traditional non-parametric insurance, there are substantial costs of claims processing and damage assessment, which is not present in parametric insurance, either in digital or blockchain form.

Blockchain brings trust to the process that traditional digital insurance lacks. Over time, blockchain also promises to bring down capital costs by decentralising its use for reinsurance and insurance.

3.8 Defining the system and service architecture standard

3.8.1 Technical specifications of a smart insurance contract

Based on the technical concept and climate data requirements mentioned in the above sections, it is therefore recommended that the design of each smart contract underpinning the BBCCI system and service architecture should include the standard components to be outlined below.

In principle, the smart contract facing the customer and the insurer will be made up of the same terms, just mirroring each other. It should comprise the following:

01. Type of risk, such as rainfall or cyclone, covered

02. Dataset to call for the contract[5] (such as ERA5)

03. Back-up dataset in case main dataset fails

04. Maximal possible payment for a policy, also known as the 'limit'

05. Formula to determine payment to the policy-holder based on input data (e.g., $10 payment per mm of excess rainfall)

06. Time period of policy (e.g., 1 June to 30 November)

07. Premium payment by the policy-holder

3.8.2 The emergence of the 'smart legal contract' and new legal actors

Smart contracts can comprise the entire agreement among parties or simply express a subset of enforceable promises (or 'clauses'). While different jurisdictions have specific distinctions, the formation of a smart contract and its legally binding effect is the same as a written agreement. To agree to a smart contract, the parties must first negotiate the mechanics of the smart contract and come to a 'meeting of minds'. Once terms are settled and the related code deployed on a blockchain, the parties can manifest their assent to those terms through their interactions with the smart contract.

A 'smart legal contract' is a legal contract that is embodied in digital form and uses computation to automate some aspect of the performance, monitoring or administration of contract obligations and related operations (such as sending notice). This functionality is made possible because the smart legal contract can be connected to software systems. Examples of smart legal contracts include contracts that automatically execute electronic payments when data shows that performance (trigger event has happened) has taken place and payment is due; or a contract that automatically issues a service-level credit and an invoice when data indicate that a party's performance does not meet the agreed-upon service-level standards.

Effective regulation requires a right addressee against which to enforce the rules. There may be variances between legal rules implemented by humans and ones implemented through computer code. The self-executing elements of blockchain applications, as new legal elements designed by coders as new legal actors, may lead to the over-regulation of users. As a result, there may be new regulatory drawbacks, such as unintended biases and questions of access to redress faulty decisions. For example, if a blockchain financial network produced unintended outcomes due to a software bug or loophole (in a smart contract), all financial institution users would immediately face the same

5 The term infers that for the smart contract to be triggered, the underlying dataset that shall be used for triggering the smart contract

operational difficulties – because decentralised ledgers on a blockchain store data across interconnected nodes. There are no technical or legal options that can circumvent these difficulties. Therefore, Paech (2017) alludes that the material scope of regulation should extend to cover more/new legal elements and actors, such as coders, for blockchain-based transactions.

3.8.3 Potential technical risks and mitigation actions

Table 3.3 describes common risks for administering a parametric insurance programme and mitigation steps that minimise the risks.

3.8.4 New roles for regulators in the 'blockchain era'

Crypto-legal structures imply the possibility that Distributed Ledger Technology (DLT) leads to near-automatic compliance with regulatory requirements. This possibility offers both pros and cons: those of regulations closely mirroring socio-economic realities versus the risk of automatic restraint considerably eroding individual autonomy. For instance, blockchain is known for its security and prevention of fraud, such as payment scams. Smart contracts can protect buyers and sellers by ensuring payment is not sent until agreed goods/services get delivered. Blockchain thwarts scams by recording all transactions so that a coin/credit cannot be counterfeit or double-spent. Identity theft in the process of transactions is not possible because unique digital signatures (key pairs) authorise transactions. The roles of law enforcement agencies may have to evolve.

Deploying blockchain for the governance of insurance schemes would encompass a series of institutional and regulatory reforms. In the context of carbon markets, Convery (2001) suggests that, 'Economists tend to pay relatively little attention to institutional design – and associated legal and administrative frameworks – but they are central considerations if emissions trading is to be successfully mobilised.' Similar principles apply to other emerging uses of blockchain, including BBCCI. These legal and administrative frameworks should ensure simplicity, strict accountability and flexibility concurrently.

Table 3.3 Risks and mitigation steps for a parametric insurance programme

Risk	Illustration of risk/possible errors	Mitigation steps (using Arbol Inc.'s smart insurance contract as an example)
Data errors	If a rainfall insurance policy period is from 1 July to 30 September, the data will be needed until 30 September. The 30 September data would be released on 5 October, but we wait until 10 October to make sure the data are not revised.	Arbol Inc.'s data infrastructure is built on blockchain and designed to highlight errors and overwriting of past data. Blockchain data are immutable, so once data are added to the chain, any changes or errors are highlighted. Another mitigation step used against data errors is to have a standard waiting time after the final data are released, to see if any revisions have occurred. This tends to be five business days.
Calculation error	The amount paid out may be calculated incorrectly due to unforeseeable issues at the source(s) of data.	We can have code to check the original source data outside of the smart contract in case there are discrepancies. Calculation errors are checked by having redundant code to check the original data source.
Payment error	Correct cash pay-out may not reach the policy-holder on the mobile payment system at the speed as expected. This may be attributable to any technical issues with the local payment system provider.	Confirmation of pay-out calculation between Arbol Inc. and local payment vendor to ensure that both parties agree on what the payment needs to be. Mitigation steps will need to be examined on the local payment system provider's side to ensure the correct payment is furnished for a given customer. The total payment across all customers will be furnished by Arbol Inc. or the relevant reinsurer. Arbol or another reinsurer will calculate the payment that should be sent to each customer, and this can be verified with the local payment vendor that their payment matches for any customer.

4. Economic Feasibility Assessment

This chapter, focuses on the vulnerability of Fiji's agriculture sector to natural disasters, and analyses the economic rationale for adopting blockchain-based climate catastrophe insurance (BBCCI). This analysis and the impact assessment of environmental risk is presented in subsequent paragraphs. The affordability metrics assess the willingness of farmers to adopt BBCCI. However, the stakeholder consultations could not take place as widely as planned due to the logistical challenges posed by the prevailing COVID-19 situation.

4.1 Background: Fiji's macroeconomic context

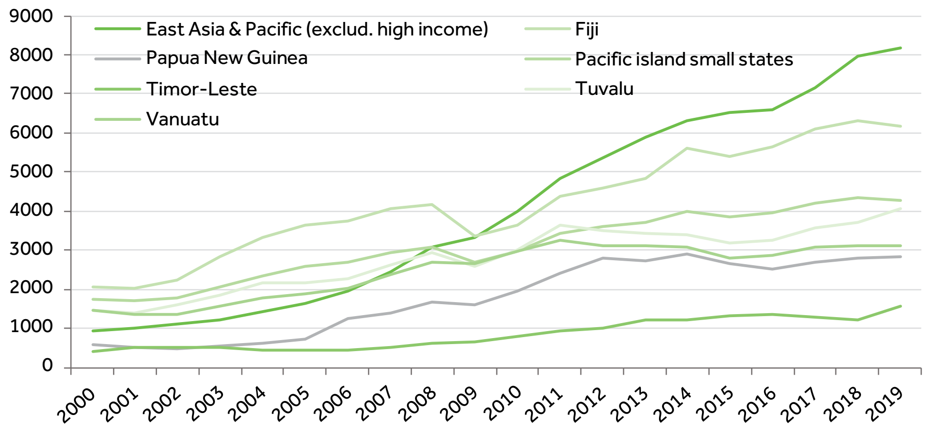
a. Key figures

Fiji is a middle-income developing island state. It is the second most populated Pacific small island developing state (PSIDS), following Papua New Guinea, and ranked the third richest among the PSIDS in terms of GDP per capita: US$6,176 in 2018 (see Figure 4.1). Fiji has a diversified economic structure relative to other PSIDS members, with historically robust economic growth, particularly since 2013, despite a slowdown in 2016 following the fallout from Tropical Cyclone Winston. Increased public expenditure and a stimulus package sustained growth potential in 2017. However, post-2017, Fiji underwent an economic slowdown, due to various risks, which led to decreased investor and business confidence. The slowdown was exacerbated during the coronavirus pandemic and its detrimental effects on tourism — which is the country's leading economic sector, accounting for more than 30 per cent of GDP. GDP declined sharply by approximately 19 per cent in 2020. A sluggish recovery was expected in 2021, before a return to strong growth in 2022 (see Figure 4.2).

b. The economic impact of environmental risk

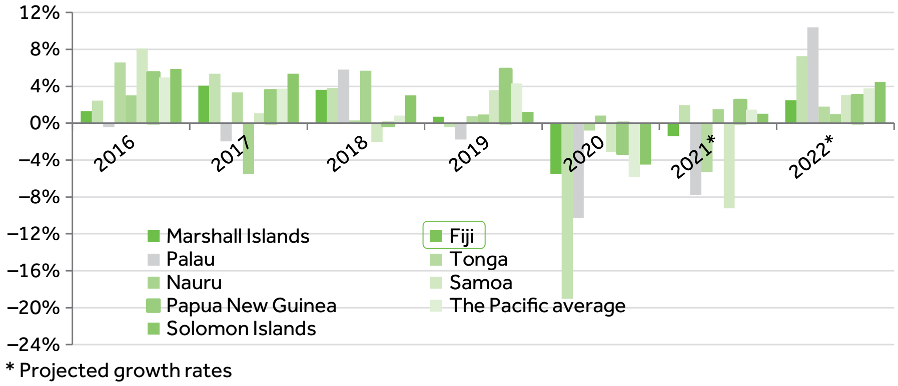
However, Fiji is highly vulnerable to natural disasters, being ranked tenth in terms of climate risk by the Global Climate Risk Index in 2018. The island is most susceptible to tropical cyclones and floods, suffering the effects of, most notably, Tropical Cyclone Winston in 2016. This caused damage amounting to approximately US$1 billion, which represented 20 per cent of GDP (Schimel 2020), consistent with damage from a 200-year event (Government of Fiji 2017b). Tropical Cyclone Winston had detrimental economic effects at the sectoral level, with agriculture, forestry, commerce, hotels and restaurants accounting for 87 per cent of total losses (WTO 2019). The International Monetary Fund estimates that Fiji has a 70 per cent chance of suffering from a significant natural hazard-related disaster each year, while the Government of Fiji projects an average annual loss close to 5.8 per cent of GDP due to cyclones and floods (Government of Fiji 2017b). In early 2018, Fiji suffered three cyclones in three months, including

Figure 4.1 GDP per capita for Pacific Islands states



Source: BCI from World Bank

Figure 4.2 GDP growth for key Pacific Islands states



Source: BCI from ADB

Cyclone Gita, which hit the south of Fiji, incurring economic damage of approximately US$1.23 million and the evacuation of 288 people (Fijian Broadcasting Corporation 2018). Cyclones Josie and Kenie followed, affecting 150,000 Fijians

(Government of Fiji 2018b). Fiji is hit by one cyclone per year on average, resulting in estimated asset losses of F$152 million (approximately US$73 million) per year (UNCDF 2020b).

For Fiji, the cost of climate risk is likely to multiply in the future. A study forecasts annual losses due to extreme weather events that could reach 6.5 per cent of GDP by 2050 (Government of Fiji 2017b). This cost is amplified by urbanisation trends, increased concentration along the coastline and the accelerated impact of climate change (UNDRR 2019). Climate change is expected to increase both the frequency and intensity of extreme rainfall events by the end of the century. These extreme rainfall events, currently occurring once in 20 years, could potentially increase in magnitude by 5–7mm by 2030 and by 6–36mm by 2090, depending on the country's CO_2 emission levels (Government of Fiji 2017b). Albeit climate change simulation models produce diverse projections of cyclone formation rates, the majority suggest a potential decline of 20–40 per cent in cyclone formation but an increase in intensity by the end of the century (Australian Bureau of Meteorology and CSIRO 2014).

In the absence of resilience-building measures, asset losses will only increase as damage from weather events rises. For instance, losses from floods increasingly stem from a rise in the frequency of smaller floods, rather than from the less frequent but larger floods (Government of Fiji 2017b). In addition to the loss of economic activity, Fiji is severely and frequently affected by floods that cause loss of life, and damage to housing and infrastructure. Inland flooding, whether pluvial or fluvial, is a regular occurrence during the monsoon season in Fiji, usually accompanied by high-intensity rainfall due to tropical cyclones and storms (UNDRR 2019b). On average, Fiji has suffered more than one flood per year in the last 40 years. A significant number are high-frequency, low-intensity floods, which incur significant losses on a cumulative basis (Government of Fiji 2017b). Average annual damage losses from floods are estimated at around F$400 million (US$192 million), or 4.2 per cent of GDP (ibid.).

On the other hand, droughts are rare in Fiji. Between 1970 and 2016, only six major droughts were recorded (ibid.). However, despite their infrequency, droughts have significant effects. When they occur, an average of 20 to 30 per cent of the country's land area is affected (ibid.). Droughts often lead to decreased agricultural production, shortages in potable water and forest fires.

Fiji is also highly exposed to catastrophic events like earthquakes and tsunamis, much like all countries in the Pacific region. Fiji has faced seven significant earthquakes since 1980, with some studies suggesting that Fiji has a 20 to 40 per cent probability of experiencing at least one significant earthquake in the next 50 years (UNDRR 2019b). Climate change can potentially increase the tsunami risk, primarily through rising sea levels.

Fiji's vulnerability to environmental risk is only aggravated by its relatively high poverty rate, where more than one-third of Fijians live below the national poverty line. According to the World Bank, 15.1 per cent of the population lives on less than US$3.10 per day (World Bank 2017), while 35 per cent of the population (26% in urban areas, 44% in rural areas) live below Fiji's basic needs poverty line (Government of Fiji 2016). A significant percentage of Fijians live in what is qualified as 'affluent subsistence', where they have enough resources to satisfy basic needs but no ability to grow beyond that level (Wehrhahn et al. 2019). In 2016, 54 per cent of the population participated in the labour market, but 60 per cent of the employed population (78% in rural areas, 37% in urban areas) were engaged in informal industries or subsistence activities (ILO 2017). Tropical Cyclone Winston is believed to have had a significant long-term effect on employment and poverty, whereby the vulnerable population (those who are non-salaried) may be forced into the informal sector, thereby increasing subsistence activities (Government of Fiji 2016).

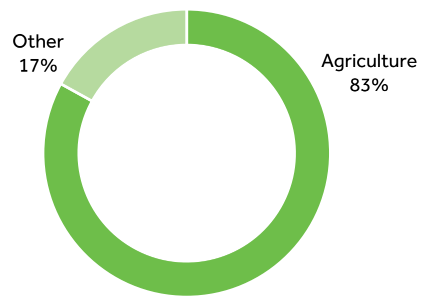
This analysis emphasises the mounting economic damage that continues to arise from the escalating climate risk, intensified by lack of adequate protection or adaptation mechanisms. Hence, the study's focus on the agricultural sector is of further importance, as it accounts for the 'lion's share' of Fiji's at-risk population.

4.1.1 Overview of Fiji's agricultural sector

a. Key figures

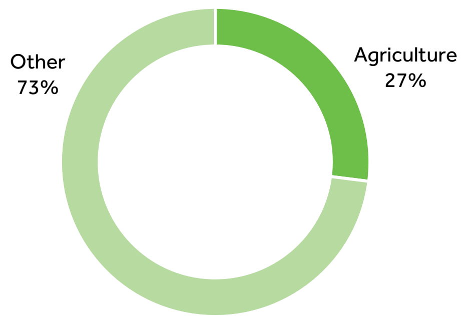
The Fijian economy relies strongly on three main sectors: tourism, agriculture and textiles. Fiji has a low unemployment rate, but a high rate of informal employment and a high level of dependency on subsistence activities (Government of Fiji 2016). Agriculture is a key sector for the Fijian economy, supporting the livelihoods of 27 per cent of the local population (Figure 4.3). The sector is a cornerstone to rural Fiji, as it represents the primary source of work for more than 83 per cent of the rural population (see Figure 4.4). This has particular importance, since 62 per cent of people living in poverty reside in rural areas in Fiji (Fiji Bureau of Statistics 2021). Despite its small share of total

Figure 4.3 Main source of work for rural population



Source: BCI from Export Gov

Figure 4.4 Source of livelihood of Fiji's population



Source: BCI from Export.gov

output, subsistence livestock production is critical for income generation and food security for the rural population (Government of Fiji 2016).

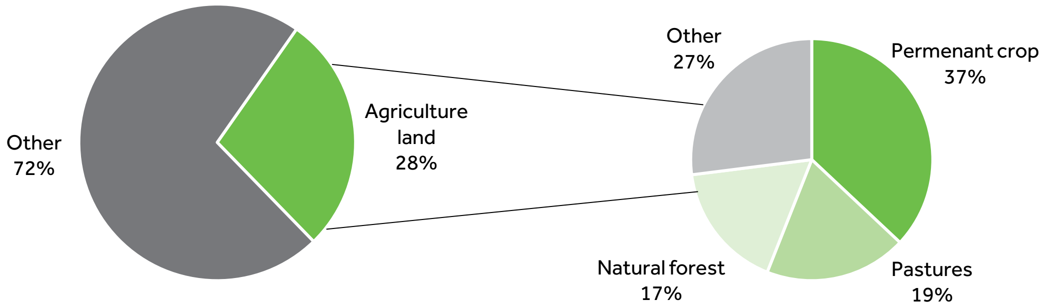
There were 70,991 agricultural households[1] in Fiji as of February 2020, only 12 per cent of which were headed by a female (Fiji Ministry of Agriculture 2021). The members of these agricultural households totalled 300,861 individuals, with only 28 per cent directly engaging in some type of farming activity qualifying them as 'farmers'. Approximately 40 per cent of Fijian farmers were either an employer or self-employed, while more than 63 per cent had a bank account, and well over half owned a mobile phone (Ibid.). Despite a relatively high financial penetration rate among farmers, only 2 per cent stated that they had taken out an agriculture loan/credit in the last 12 months. Where they did, this was primarily for the purpose of land purchase (34%), followed by machinery and tools purchasing (20.3%).

b. Land use and crop production

In Fiji, agriculture represents 27 per cent of total land use (Figure 4.5), which in turn is used mainly for permanent crop production (37%), followed by pastures (19%) and natural forests (17%). Despite the decline in agriculture's share of GDP, as both tourism and textiles continue to grow, the sector continues to play an extremely important role in both commercial and subsistence activities, providing 36 per cent of all employment in Fiji (World Bank 2020). According to the 'Fiji Agriculture Census 2020', released in July 2021, most farming households (65%) in Fiji live on farmland areas under 1 hectare (ha; 10,000 m^2) – see Table 4.1.

1 An 'agricultural household' is as a household where the main economic activity identified is farming activity (i.e., crops, livestock, fishing and forestry).

Figure 4.5 Agricultural land use by type



Source: BCI from Investment Fiji

The country produces varied cash crops, which include coconuts, bananas, yams and cassava; however, its dominant crop remains sugarcane, representing 8.3 per cent of agriculture GDP, despite the decline in production volumes in recent years. The cash crop sector, which represents 5.4 per cent of GDP, is a cornerstone to the livelihoods of many Fijians. Sugarcane accounts for approximately 18 per cent of the island's exports and is grown by some 13,700 farmers on small farms averaging 2.8 hectares in size (UNCDF 2020b). The sector has faced growing structural challenges over the past decade, including declining productivity, rising production costs, labour shortages and the removal of preferential prices by the European Union (Government of Fiji 2017b). Sugarcane is often grown in coastal areas, thereby exposing production to increased environmental risk stemming from cyclones and storm surges (PCRAFI 2015).

Coconut production also plays an important role in the agriculture sector, contributing to the economic and social welfare of the rural population, in particular. Although the sector has seen a continued decline in performance since the 1970s, it remains crucial to the subsistence of the rural population, as it supports the livelihood of some 100,000 farmers (Government of Fiji 2019). According to the International Coconut Community in Fiji, coconut-related exports (coconuts, coconut oil and copra meal[2]) stood at over 2 million tons and represented 0.55 per cent of national export earnings in 2019. Rice is also a crucial food crop in Fiji, with average per capita consumption reaching up to 75kg per year in 2016 (FAO 2017).

Table 4.1 Farmland area distribution by farming household

Number of households	Farmland area	Share of total households
44,475	Under 1 ha	65%
14,383	1–3 ha	21%
4,255	3–5 ha	6%
3,000	5–10 ha	4%
1,355	10–20 ha	2%
598	20–50 ha	1%
145	50–100 ha	0%
213	over 100 ha	0%

Source: BCI from the Fiji Agriculture Census 2020

According to the 'Fiji Agriculture Census 2020', Fijian farmers produced more than 3.06 thousand tons of temporary crops and 0.93 thousand tons of permanent crops, representing just under F$2.4 billion (US$1.1 billion) and F$0.163 billion (US$0.08 billion), respectively (see Tables 4.2 and 4.3).

4.1.2 Vulnerability and climate risk impact

Agriculture is the sector most vulnerable to climate change, due to its high dependence on climate and weather. Cyclones cause extensive damage to crops, trees, livestock and farming equipment (Government of Fiji 2017b). The failure to protect smallholder farmers from strong winds and temperature extremes, with low yields resulting in low incomes, impacts capacity for future yields (FAO 2016). Meanwhile, a largely poorer dependence base[3] means agriculture is highly vulnerable to

2 Copra meal is the by-product of oil extraction from dried coconut kernels (copra).

3 i.e. a relatively poorer base of farmers reliant on agriculture for income which renders them even more vulnerable to weather events as the impact on their livelihood and income is even more pronounced.

Table 4.2 Main indicators of key permanent crops in Fiji, 2020

Permanent crops	Number of HHs	Area planted		Area harvested		Volume harvested		Value of harvest	
		in ha	%	in ha	%	in mt	%	in F$ (k)	%
Pineapple	1,503	234	5%	716	13%	28,629	31%	46,332	28%
Coconuts	4,178	3,512	68%	3,548	63%	35,479	38%	42,426	26%
Banana	9,907	507	10%	132	2%	3,946	4%	8,512	5%
Pawpaw	1,393	120	2%	48	1%	3,877	4%	5,689	3%
Vudi	12,800	295	6%	74	1%	2,233	2%	5,278	3%
Voivoi	2,567	33	1%	114	2%	910	1%	4,379	3%
Masi	297	18	0%		0%	721	1%	2,885	2%
All crops		5,192	100%	5,598	100%	93,022	100%	163,612	100%

Source: BCI from the Fiji Agriculture Census 2020

natural hazards (Mahendra, et al 2011). Half of those living below the national poverty line rely on agriculture for at least part of their income (Government of Fiji 2017b), while over 80 per cent of Fiji's farms are categorised as subsistence farms (Ministry of Agriculture 2018). This population of small-scale farmers is extremely vulnerable to natural hazards. Given their limited resources, they are unable to cope with the aftermath of such hazards. Following an episode of widespread flooding in 2009, an estimated 40 per cent of the affected farmer population, dependent on sugar farming for their livelihoods, were thought to be unable to meet their subsistence food needs. These farmers had limited coping capacity, as they were prone to having prior debts, dwindling savings and reduced incomes due to unfavourable global market conditions (Lal 2011). Flooding can inundate crops and kill livestock, causing substantial damage to agricultural infrastructure (Government of Fiji 2017b). The risk of flooding is also becoming more common as a growing number of farms have expanded into areas that are prone to flooding (UNDRR 2019).

Tropical Cyclone Winston had a particularly critical impact on the agriculture sector, causing vast damage to food crops and consequently affecting household income, food security and nutrition. In some areas, agricultural production levels were not expected to recover to pre-cyclone levels for five to ten years (Government of Fiji 2016). The tropical cyclone was estimated to incur personal income damages of F$351.6 million (US$168.1 million), 85 per cent of which was in the agriculture sector (UNCDF 2020b). A vast majority of poor households lost their proper food security and suffered from rising market prices for vegetables and root crops. The sugarcane industry was particularly affected by the tropical storm, accounting for 62 per cent of total losses or approximately F$25.2 million (US$12.1 million) (Ibid.). The Fijian government, therefore, devised a relief plan valued at approximately F$10 million (US$4.78 million), aiming to help sugarcane farmers recover and pay back their loans to the Sugar Cane Growers Fund (UNCDF 2020c). The cyclone also impacted the copra industry, hitting the main

Table 4.3 Main indicators of key temporary crops in Fiji, 2020

Temporary crops	Number of HHs	Area planted		Area harvested		Volume harvested		Value of harvest	
		in ha	%	in ha	%	in mt	%	in F$ (k)	%
Yaqona	18,478	6,484	47%	12,305	42%	24,610	8%	1,990,546	83%
Dalo	26,169	2,144	16%	5,116	18%	102,324	33%	143,630	6%
Cassava	40,495	2,703	20%	5,878	20%	117,561	38%	117,542	5%
Okra	1,994	136	1%	765	3%	11,481	4%	44,174	2%
All crops		**13,722**	**100%**	**29,234**	**100%**	**306,035**	**100%**	**2,395,136**	**100%**

Source: BCI from the Fiji Agriculture Census 2020 coconut growing areas of Vanua Levu, southern Taveuni and Lau.

Similarly, when Tropical Cyclone Harold struck in 2020, it caused widespread destruction to agricultural infrastructure and farming when it passed by Fiji's fourth largest island, Kadavu. The cyclone affected a significant share of the island's vulnerable population, including farmers who lost the entirety of their crops (e.g., yaqona, dalo, cassava, plantain, breadfruits, coconuts and vegetables) and livestock. Following the cyclone, prices of food and agricultural products soared, threatening the food security of the affected population. Also, Fiji Rice Limited reported losses of approximately F$350,000 (US$168,000) in the Northern Division of Fiji due to both Tropical Cyclones Yasa in 2020 and Ana in 2021.

Given the high level of exposure of Fijian farmers to environmental risk and natural hazards, it is crucial to develop adequate insurance solutions to protect them – by improving their resilience and coping capacity in the face of such events.

5. The case for parametric insurance in climate risk mitigation

CRITERION 3: Customer demand

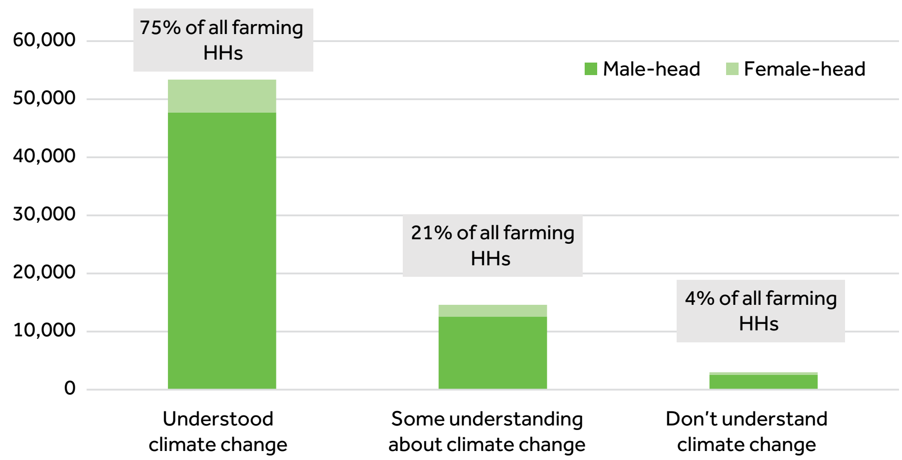
As highlighted previously in Chapter 3, the technical assessment section of this study report, the exposure and vulnerability of Fiji's agricultural sector to natural hazards require a serious analysis of viable risk insurance and mitigation solutions. Agricultural and crop insurance can play an important role in mitigating climate risk, providing direct relief and support to local communities. As discussed in Section 1.3, the extension of conventional insurance solutions to cover damages from natural hazards can be rather expensive and cause significant claim processing delays, especially when the claims pertain to relatively small sums. Hence parametric insurance presents a more suitable insurance solution.

Fiji's farmers showed a high degree of understanding about the threat of climate change, with 75 per cent of all agricultural households (see Figure 5.1) stating that they understood climate change (Fiji ministry of Agriculture 2021). Male-led households demonstrated a relatively higher awareness of climate change (76%) when compared to female-led households (69%). These results indicate that farmers are aware of the risk that climate change poses to agriculture and implies that, generally, they would be interested in mitigating those risks.

Parametric insurance products become attractive for individual policy holders when the premium-to-pay-out ratio is above a certain threshold, for instance, more than 1:10. Hence, efforts like deploying innovative and new technology-driven solutions would address the challenge of designing products that take into consideration the above factors. However, the development of new consensus mechanisms is improving and enhancing the performance and interoperability of technology-based insurance products, while reducing complexity, cost and energy requirements (Sandland et al. 2019). Over time, these developments will lower the cost and risk of deploying blockchain technology, for example. The study by the ADB (2019) cited in its Country Diagnostics Assessment that a lack of product development was hindering disaster risk transfer to the insurance and capital markets in Fiji.

This leads us to believe that the insurance industry has an important role in advancing the resilience of at-risk populations through the proliferation of parametric insurance solutions. Therefore, this chapter will showcase a brief analysis of the

Figure 5.1 Farming households' perception of climate change



Source: BCI from Fiji Agriculture Census 2020 insurance industry environment in Fiji and the case for developing parametric insurance.

5.1 Insurance industry landscape

5.1.1 Local industry performance

The insurance industry in Fiji witnessed continued growth in 2019, with premium income increasing for the fourth consecutive year to F$366.7 million (US$175.25 million) (Reserve Bank of Fiji 2020), up 5.4 per cent year-on-year, supported by the absence of major natural catastrophes. The industry showed robust performance despite the government-established scheme, the Accident Compensation Commission of Fiji (ACCF), which came into effect 1 January 2018, thereby overtaking certain insurance classes (i.e., Compulsory Third Party motor vehicle, employment and school accidents) from the general insurance industry.

The industry managed to post improved profitability and a strong solvency position, despite the impact of the reform establishing the ACCF, with insurers pushing business expansion by underwriting added exposures mostly in the motor, medical and fire classes. The market environment saw a few movements in 2019, with the exit of BIMA insurance[1] in April and the subsequent fall of 19,000 policy-holders out of coverage; this was, in turn, offset to some extent by the growth of bundled microinsurance products, which reportedly increased fourfold relative to 2018 (Reserve Bank of Fiji 2020). General insurance products continued to dominate the insurance sector, accounting for 59.1 per cent of the industry's total gross premium income, with income reaching F$216.8 million (US$104.1 million) in 2019, up from F$205.7 million (US$98.8 million) the previous year, mainly due to growth in the medical, fire and motor vehicle classes.

Conversely, the insurance sector's net policy payments and claims totalled F$223.1 million (US$107 million), recording a marginal decrease of 0.1 per cent in 2019. Life insurance reported a 9.3 per cent increase in net policy payments to FJ$129.9 million (US$62.4 million), while general insurers had a decline in claims paid by 12.2 per cent to FJ$93.2 million (US$44.7 million) (Ibid.), due to the reduction in major insurance losses arising from the absence of major catastrophes in 2019.

The Reserve Bank of Fiji received 32 insurance-related complaints in 2019, representing a 33.3 per cent decrease year-on-year. Further analysis of the filed complaints demonstrated a lack of understanding of the terms and conditions of the purchased insurance cover among many policy-holders. Hence, disclosures provided by insurance companies may not be clear and adequate for the understanding of the average policy-holder in Fiji. Half of the settled complaints in 2019 resulted in the payment of F$0.07 million (US$0.033 million) by insurers to insured individuals, while the remainder were resolved without monetary settlement. Fiji mandates, through its industry regulations (i.e., Insurance Supervision Policy Statements [ISPS] No. 9), that complaints must be resolved in a period of no longer than 21 days. However, in 2019, the average period for addressing complaints stood at 60 days, mainly due to the complexity of the complaints, incomplete documentation by the plaintiffs, in addition to delays by the insurance companies in assessing and addressing the complaints (Reserve Bank of Fiji 2020).

In Fiji, the majority of middle- and low-income households have no insurance protection, with no insurance providers currently offering coverage against natural hazards. The Agriculture Insurance National Working Committee (AINWC), which comprises representatives from the government, the insurance industry, international development agencies and the private sector, was re-established in 2018. The committee engaged with relevant stakeholders to explore opportunities to introduce agriculture insurance to Fiji (Government of Fiji 2018). Fiji's insurance penetration rate stood at 3.4 per cent in 2018, with only 6 per cent of households and 17 per cent of commercial properties having any type of property insurance. Those insurance products there are often very simple, offering basic coverage not tailored to cover climate disasters. Insurance covering damage from cyclones is only available as an extension to basic property coverage and requires certification by a qualified engineer. At the same time, almost no crop, livestock or fisheries insurance is available in the Fijian market, diminishing farmers' capacity to cope with disaster risks.

1 BIMA insurance is an insurance provider that had been in operation in Fiji for four years prior to its exit in 2019. The company indicated at the time that it would not be transferring insurance policies to the principal underwriter, Dominion Insurance.

5.1.2 Parametric climate insurance

Despite having well-established conventional insurance schemes, there **were no climate-tailored insurance products in Fiji** at the time of this report. The insurance industry in Fiji does not presently offer property damage insurance cover against natural hazards nor any agriculture-specific climate risk insurance products. Natural hazards insurance is generally characterised by significant capital requirements and higher claim assessment costs, as it typically affects a larger population of policy-holders. In this context, the Pacific Insurance and Climate Adaptation Programme (PICAP) was launched jointly by United Nations Capital Development Fund (UNCDF), the United Nations University Institute for Environment and Human Security (UNU-EHS) and the United Nations Development Programme (UNDP), with an objective to improve the financial preparedness of: 'Pacific households, communities, small businesses, organisations, and government towards climate change and natural hazards' (PICAP 2020). The PICAP is the first initiative of its kind in the Pacific islands region. It entails providing the local population in Fiji and Vanuatu with market-based climate risk insurance solutions, before its progressive rollout to other island states in the region. The initiative specifically targets the agriculture, fisheries, retail and tourism sectors, with an emphasis on women and youth. The considerable impact of climate change-induced weather events has created a challenging environment of prolonged strained public expenditure. Thus, governments often resort to external aid assistance and reallocating budgets conceived for other economic development purposes (e.g., education, infrastructure, health... etc.).

PICAP's insurance products will be piloted, tested and scaled during an inception phase for two years, through the establishment of an Inclusive Insurance Innovation Lab set up by PICAP. The programme will capitalise on its founding parties' technical expertise and presence in the region to collaborate with the private sector (e.g., insurers, mobile network operators, financial service providers, etc.) to implement its digital-based solutions. The programme aims to enhance the financial resilience of Pacific populations and governments in the face of climate disaster risk. Parametric insurance will ensure faster post-disaster claim payments, by eliminating extensive claim assessments and streamlining payments through e-wallets and bank accounts.

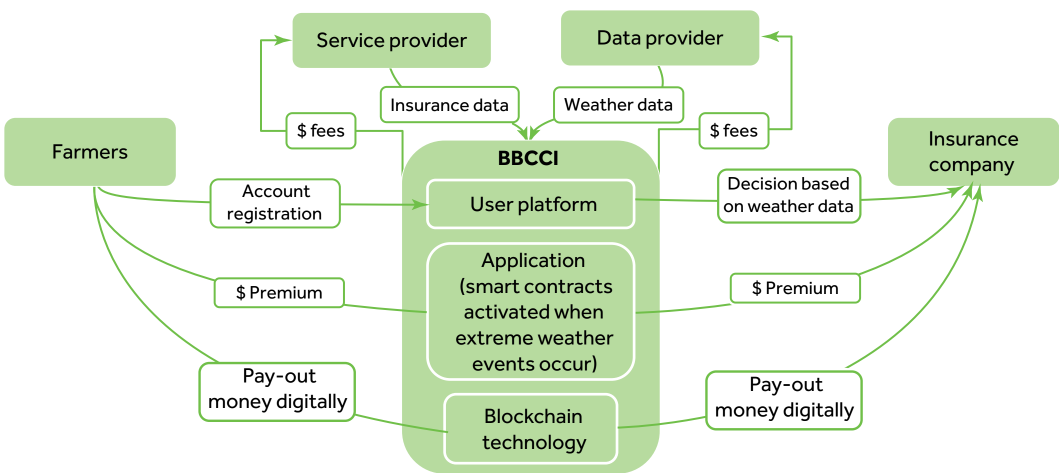
5.2 The BBCCI product structure

The proposed BBCCI product will eventually have a structure that will ensure maximum automatisation and digitisation of both the insurance and payment processes (see Figure 5.2).

The structure will involve the following parties and product elements:

- Service provider: An insurance service provider that will design the insurance product and devise a risk model in line with the Fijian context. The service provider will manage the marketing of the product and customer care.

Figure 5.2 BBCCI's initial product structure



Source: BCI

- An insurance company: The insurance company will manage the risk pool and perform pay-outs via mobile money. After verifying the pay-outs, the insurance company will reimburse the technology platform.
- A mobile money provider: This will facilitate financial transactions between end users and insurance products.
- A user interface: This is where insurance policies are registered as smart contracts on a blockchain, grouping payment processing, farmer data and policy information.
- An application layer: This links the smart contract infrastructure to the blockchain layer.
- Fiji government: The different line departments associated with the insurance sector will act as the regulator for this product.

According to this structure, the blockchain technology will assume a centralised role, gathering all parties (i.e., policy-holder, insurance company, weather data provider and policy data provider). The blockchain will manage all financial flows, ultimately through mobile money payments. Premium payments and automatic pay-outs will be managed through the underlying blockchain technology on behalf of the insurer. The underlying blockchain platform will be high-performing, triggering automatic payments once an extreme weather event is detected from the input weather data.

5.3 Blockchain-based climate catastrophe insurance (BBCCI) business model

Given the novelty of the use of blockchain technology in parametric risk insurance, there is a limited pool of available blockchain-based climate catastrophe insurance solutions in the market. Most BBCCI projects are in the early implementation phase, so it is difficult to accurately assess cost requirements, pricing and revenue generation for existing products.

BBCCI is typically characterised by time efficiency, cost-saving, and improved transparency and traceability compared to conventional insurance solutions. Automation significantly simplifies claims processing, eliminating the need for policy-holders to submit claims, as well as the need for the insurer to involve claims adjusters for inspection. This process reduces administration costs significantly, resulting in reallocating a higher percentage of premiums used for claims payment and immediate reimbursement. BBCCI is thus recognised for its potential role in eliminating barriers to insurance coverage for vulnerable populations: certain at-risk communities, such as farmers, are subject to major barriers that hinder their access to insurance solutions. These barriers include a lack of affordable and reliable insurance products, a lack of understanding of the benefits of insurance to increase resilience to shocks, and uncertainty around claim processing delays and payments (Van Anrooy, et al 2021). Based on the analysis in Section 4.1.1, with agriculture being a key sector of the Fijian economy and supporting the livelihoods of 27 per cent of the local population (Figure 4.3), it is important to mitigate the risk of such a large percentage of the population from weather-related damage in their farmland.

Commercial benefits from the use of BBCCI relative to other conventional insurance products can be summarised as follows:

- Improved customer trust (specifically in the claims process): By definition, the use of blockchain in insurance services eliminates the risk of tampering and fraud, making the service inherently more trustworthy by policy-holders.
- Increased standardisation: By mapping insurance products over blockchain technology, it creates templates that provide stakeholders with customisable tools to conceptualise insurance products more cost-effectively (Sprout 2018). The claim process becomes standardised and monitored through real-time weather data verification, thereby eliminating the need for an intermediary and increasing reliability, while reducing transaction costs.
- Reduced transaction costs: This stems from the elimination of individual/specific loss assessment and simplifying the data verification process, which lowers the claims processing costs considerably. Some reports estimate the potential reduction in transaction costs to be between 30 to 80 per cent by combining blockchain technology, e-wallets and other automation solutions in the verification and payment processes.
- Lower fraud risk and increased transparency: By basing insurance on blockchain technology, the potential risk of fraud is reduced (IFAD 2017) and reliability is increased significantly.

- Increased access to insurance coverage among vulnerable populations: Farmers are often faced with barriers that render access to insurance solutions quite challenging. BBCCI has the potential to eliminate such barriers by offering more affordable, reliable and transparent insurance products that increase policy-holders' resilience to weather shocks (FAO 2021).

Although BBCCI makes a compelling case for its aforementioned benefits, it can also involve certain costs affecting its implementation. The use of blockchain technology assumes the presence of technical prerequisites that may be challenging in the context of developing economies. These include mainly technical limitations, such as rates of internet usage and literacy among local populations, smartphones ownership, financial literacy and technology adaptation to fit the local context.

- As a nascent technology, blockchain faces various barriers to its application to parametric insurance. First, the technological barrier stems from the limited availability of comprehensive datasets, as insurers need to estimate the risk pool precisely in order to price premiums adequately (Frankze 2017).
- Small states' lower resilience in the case of climate hazards suggests that post-disaster damage to infrastructure, such as telecommunications, can put the functionality of blockchain-based climate catastrophe insurance at risk, rendering access to the platform impossible when most needed (Sandland et al. 2018).
- Uptake is a key challenge for the introduction of any insurance product. The deployment of blockchain-based climate catastrophe insurance requires consumer education, insurance value and IT literacy in order to address any social or cultural barriers.

A summary of the proposed blockchain-based climate catastrophe insurance (BBCCI) business model is provided in Figure 5.3.

Product marketing and commercialisation should involve well-recognised local organisations in the agricultural sector, which will guarantee reliability and trust with the local community. Going forward, as the product gains traction and expands,

Figure 5.3 BBCCI business model summary

Description	**Revenue streams**
Blockchain-based climate catastrophe insurance aiming to provide local populations with affordable, reliable and efficient insurance solutions to improve resilience against climate risk.	Revenue is generated from insurance premiums. As the project matures, further revenue can be generated by reinvesting profits into local community development (e.g., capacity building, human capital development,...etc.)

Customer targets	Customer challenges	Solutions	Value	Pricing
In its first phase of implementation, this project will target farmers in Fiji.	• Lack of understanding of the benefits of insurance in increasing resilience to shocks. • Access to direct communication channels to engage with customers.	These challenges will be addressed mainly by engaging local organisations in order to coordinate efforts to raise awareness and organise free consultation sessions/workshops on BBCCI	The key element of BBCCI success is customer engagement and trust. Hence, the presence of open communication channels with customer targets is essential.	Further targeted inspection of affordability and willingness to pay by customer targets is needed to better conceive an adapted pricing policy.

Key statement	Go-to-Market
BBCCI can offer affordable and reliable insurance coverage solutions to enhance resilience of vulnerable populations against increased climate change-induced risk and disasters.	This product can be launched through direct contact facilitated by local farmers associations (e.g., Fiji Crop & Livestock Council FCLC, Pacific Island Farmers Organisation Network PIFON, National Farmers Union NFU) and in collaboration with the Ministry of Agriculture.

Required capital	Growth potential
- Sizeable fixed capital requirement: equipment, product development, system integration - Limited variable cost element: maintenance and running costs	Following the initial pilot phase, through oversight and feedback, further adjustments can be drawn for product development and adaptation. This will enable the project to be easily scalable once launched, by growing the customer base through both vertical and horizontal expansion.

Source: BCI

the cost will benefit from economies of scale, which will improve margins and reinvestment in improving product quality. Once the product is well-established in the market, further revenue streams can be generated by reinvesting profits in the development of local communities (e.g., capacity building, vocational training, sustainable agricultural practices training, etc.).

The BBCCI product aims to provide the local population in Fiji with an affordable and reliable insurance solution to enhance their resilience against rising climate risk. In its early stages, the customer pool for the product will consist exclusively of farmers. Prior to launching the product, there will be a phase of market testing and raising customer awareness through workshops and information campaigns completed in collaboration with various local organisations working with farmers. One key element to ensuring the successful launch of a product of this nature is to engage the client base through clear messaging and open communication. Pricing will be determined based on a closer examination if the customer pool's capacity to pay; clear data are required to draw adequate insights, which will be crucial to fixing the product price. Alternatively, the product may be piloted through the PICAP initiative and BBCCI added as a layer to drive efficiencies and reduce the overhead costs associated with the traditional parametric insurance product.

5.4 Overview of the BBCCI global market

Table 5.1 provides a summary of BBCCI projects globally.

The Sri Lankan case

Among the projects in Table 5.1, the Sri Lankan one seems to be the most developed – following the expansion of its customer pool in 2020. The project, launched in 2019, aims to deliver micro-crop insurance solutions for farmers in Sri Lanka. The product consisted of developing a protocol for decentralised collaborative and automated insurance applications, using a weather data index as a trigger for smart contracts. After the co-ordinated launch earlier in 2019, with 200 farmers enrolled who were at risk of losing their crops due to extreme weather, the system made pay-outs to farmers in the initial operations phase. The programme then underwent a phase of enhancing the system's efficiency and scaling the number of policy-holders. The project in its first phase identified several gaps subject to improvement. First, many farmers in the area did not have access to electronic devices and internet access, which meant that the provider had to study alternative offline solutions through support from their local insurance partner, Sanasa, to facilitate registration in the group policy. Second, farmers managed transactions mainly

Table 5.1 Key BBCCI projects under development and/or launched

Insurance type	Provider	Country	Project phase	Start date	Description
Crop Insurance	Etherisc	India	N/A	N/A	Still in the development phase.
Crop Insurance	The Lab	Kenya	Testing phase	2017	The pilot was set to launch in April 2020 and will run for two to four years (four to eight seasons), targeting 1.2 million farmers in Kenya.
Crop Insurance	SmartCrop by Cornell University	China	The project status is unclear	N/A	A mobile platform aiming to help farmers hedge against crop volatility by using smart contracts and weather predictions. Farmers can initiate earlier pay-outs to mitigate risks from natural disasters.
Crop Insurance	Oxfam, Sanasa, Aon, and Etherisc.	Sri Lanka	Pilot launched	2019	Launched with 200 farmers in 2019 and expanded to 10,000 in 2020.

Source: BCI, from the various company and local sources through cash or cheques, thereby hindering the payment automation process and requiring further investigation of alternative mobile payment options in Sri Lanka.

CRITERION 4: Economic viability

5.5 Economic assessment of BBCCI in the Fijian case

This section was designed to assess and estimate metrics of willingness-to-pay by Fijian farmers for a blockchain-based climate catastrophe insurance product. This would require on-the-ground market surveys with the target customer pool (i.e., farmers), where they would be asked various questions to assess affordability and potential demand (e.g., farming business performance, income levels, costs, their assessment of climate risk, interest and willingness to purchase a parametric insurance product, etc.). Upon collecting and processing the survey data, an appropriate methodology (see below) would be applied to estimate willingness-to-pay (WTP). On the basis of their WTP, an adequate pricing scheme would be devised.

5.5.1 Methodology

ATP is the ability-to-pay – an affordability metric that assesses one's capacity to pay for a product and/or service based on relevant disposable income and personal expenses. As an individual's disposable income increases, their ability to pay more for a specific service also increases. On the other hand, the willingness-to-pay metric is a subjective parameter that takes into account the individual's perceived importance for a given service. This measure is typically calculated based on direct interviewee responses when asked about how much they would be willing to pay for said service and/or product. The methodology for calculating ATP and WTP are explained below.

A farmer's **ability-to-pay (ATP)** can be calculated from the following equation:

$$\sum \frac{\mathrm{ATP}_i}{m^2} = \frac{I_t \cdot P_i \cdot P_p}{T_f} \tag{1}$$

Where I_t is the respondent's total monthly income; P_i is the share of disposable monthly income allocated to insurance expenses; P_p is the theoretical share of insurance expenses assigned specifically to parametric insurance; and T_f is the total farmed area.

This equation will yield each farmers' ability to pay for a parametric insurance product, based on their individual characteristics, per square meter of farmland. This stipulates that a farmer's capacity to pay increases with the area of farmed land.

Moreover, **willingness-to-pay** can be calculated using the following equation:

$$\sum \frac{\mathrm{WTP}_i}{m^2} = \frac{P_e}{T_f} \tag{2}$$

Where P_e is the perceptive tariff that the respondent has stated in the survey data, which is then divided by the area of land farmed.

By comparing these two metrics, one can deduce that the product's end price should not exceed the calculated ATP.

- **If WTP > ATP, then WTP > BBCCI price > ATP:**
  - If the value of the WTP exceeds the value ATP, then the BBCCI product can be priced at a level that falls within the spread (WTP–ATP). This case is only viable if the relatively higher price can be justified by perceived higher quality and attributable comparative advantage.
- **If WTP < ATP, then BBCCI price <WTP < ATP:**
  - If the value of WTP falls below the ATP, it implies that despite being able to afford a higher price, the respondents do not perceive the product to be sufficiently important to warrant a higher price. The BBCCI product price in this case should not exceed the value of the stated WTP.

If the BBCCI product cannot be priced in accordance with the rules above, and therefore exceeds the WTP, then government intervention would be needed (through, for example, subsidies) so that the end-price can be attainable by the target customer pool.

5.5.2 Limitations

Given the whirlwind effect of the coronavirus pandemic, the intent to conduct on-the-ground surveys with local farmers in order to assess farmers' willingness-to-pay (WTP) for a potential BBCCI product was rendered impossible. Consequently, alternative datasets were used to enable the study to apply the aforementioned methodology and devise the appropriate WTP metrics and the product pricing schemes. The proximate information was derived based on the study conducted by PICAP and presented in this report.

Given the unavailability of the required micro-level data to fit the previous methodology, the study devised the following alternative methodology and turned to an empirical analysis of the ATP. Upon locating and sourcing farming household income survey data from the relevant government authorities in Fiji, a **cross-sectional regression analysis** was performed to estimate the ATP using the following equation:

$$\mathrm{ATP}_i = c + bX_i + u_i \tag{3}$$

Where X is a vector of relevant control variables (income, crop type, production volume, farmland area, etc.); c is the estimated constant; b is the vector of estimated coefficients of X; while u_i is the error term and (i) represents the respective farming household.

Based on the estimated results of the econometric model and their statistical significance, we would then be able to estimate an appropriate price scheme for the potential BBCCI product. Unfortunately, this approach was also rendered unfeasible due to the unavailability of any adequate micro-level income survey at the farming household level in Fiji. Although the recent release of the 'Fiji Agriculture Census 2020' offered valuable aggregate-level insights into Fiji's farming households' composition, crop production and geographic distribution, it did not provide sufficient income information. The underlying micro-level data from the census was also not made publicly available.

Top-level ATP estimate

Notwithstanding that producing accurate estimates of the ATP was not possible due to the unavailability of micro-level data (i.e., at the level of farmers or farming households), a **top-level estimate** could still be produced based on single data points from various sources. The estimation of this ATP measure was contingent on several key assumptions, as follows:

- farmers have comparable financial penetration and mobile phone ownership levels to the larger population in Fiji;
- farmers have a relatively well-established awareness of the growing natural hazard risk and demonstrate an interest in insurance solutions; and
- farmers would likely opt for an affordable parametric insurance product.

$$\frac{\mathrm{ATP}}{m^2} = \frac{I_t \cdot P_p}{T_f} \tag{4}$$

ATP/m^2 was calculated as the share of income that a farmer could potentially allocate to a parametric insurance product divided by the land area that they farm. Based on the recently released Fiji Agriculture Census 2020, there were 70,991 agricultural or farming households in Fiji as of February 2020, generating a total value of harvest of more than F$2.5 billion (US$1.2 billion) from both permanent and temporary crops in the 12 months ending February 2020. These two observations led to an estimated average annual income (I_t) of over F$36,043 (US$17,310) per household. Based on the farmland area distribution by agricultural household (see Table 4.1), we can estimate that an ordinary (median) household farms an estimated land area (T_f) of 0.77 hectares or 7,692.4 m^2. Assuming that the average agricultural household is willing to allocate no more than 1 per cent of its harvest income (P_p), at the most, **then the estimated average farming household's ability to pay is F$0.0469 (approximately US$0.0225) per square meter of farmland. Hence, for a small farm of 0.2 hectares (2,000 m^2), a household is likely to be able to afford to pay approximately F$94 (US$45.1) per year for a parametric insurance product.**

As indicated in Section 5.1.1, most of Fiji's rural population are engaged in agriculture, and around 27 per cent of the total land use is under agriculture. The country's agriculture is dominated by sugarcane, followed by varied cash crops like coconuts, bananas, yams and cassava. The agriculture sector is the most vulnerable sector to climate change due to its high dependence on the climate and weather. To address these vulnerabilities, PICAP undertook a demand survey to support the deployment of parametric insurance in Fiji. The study findings were used to analyse the interest of farmers to solicit BBCCI, with the findings presented in the subsequent sections of this report.

5.6 The PICAP's demand survey findings

A demand survey study in the context of the Pacific Insurance and Climate Adaptation Programme (PICAP) was conducted with Fijian farmers in August 2020 and yielded the following findings (see Table 5.2). The survey covered a population of 323 farmers overall across five crop categories (sugarcane, rice, copra, Kadavu and cash crops), predominantly farm owners (98%), with women representing approximately 60 per cent of total respondents. The survey findings offered useful insights into Fijian farmers' perception of climate risk and their response to recover from the damage from climate hazards. In line with expected results, cyclones represented the most common natural hazard impacting farming in Fiji, with 85 per cent of respondents being impacted by cyclones, followed by flooding (48%) and by droughts (25%) to a lesser extent. Results varied from one crop type to another; however, cyclones represented the most common threat facing all groups, with the exception of cash crops – which were more affected by flooding. The overwhelming majority of respondents (90%), across all crop groups, confirmed being impacted by natural hazards at least once a year, and all farmers expected to be affected by a weather event in the next five years. **These results reaffirm the understanding of climate risk as a key challenge facing farmers in Fiji, confirming the need for risk-mitigating solutions such as BBCCI.**

Table 5.2 Key findings from PICAP's farmers demand survey (August 2020)

Key variable	Crop type				
	Sugar cane	Rice	Copra	Kadavu	Cash crops
Population (number of farmers)	71	44	67	75	66
Women	70%	2%	40%	100%	61%
Farm owners	100%	100%	93%	96%	100%
	Climate hazards				
Impacted by cyclones	81%	100%	100%	100%	45%
Impacted by flooding	58%	53%	38%	20%	77%
Impacted by droughts	61%	62%	0%	0%	14%
Impacted by hazards at least once a year	100%	61%	100%	100%	77%
Somewhat or extremely likely to be impacted in the next five years	100%	100%	100%	100%	100%
	Financial risk mitigation and technical requirements				
Have a bank account	100%	100%	92%	73%	95%
Member of FNPF	25%	55%	48%	87%	44%
Access to mobile phone	97%	100%	100%	100%	82%
Access to mobile money	30%	100%	92%	80%	71%
Typically relies on loans after disasters	65%	0%	0%	0%	9%
Typically relies on savings after disasters	33%	75%	44%	76%	41%
Typically relies on family/friends after disasters	1%	25%	56%	24%	50%
	Interest in parametric insurance solutions				
Interested in more expensive insurance products or a combination of insurance, savings and loans to help manage climate risk	56%	100%	14%	100%	70%
Interested in more expensive insurance products that cover a variety of risks	56%	80%	100%	53%	92%
Interested in purchasing insurance through an association/co-operative	100%	66%	100%	32%	95%
Would be able to afford insurance products that cost more than F$/year	58%	25%	87%	47%	68%

Source: BCI from the Pacific Insurance and Climate Adaptation Programme (PICAP)

Regarding the technical requirements as a prerequisite for parametric insurance solutions, **the survey results confirmed the assumption that Fiji has a relatively well-established financial penetration and technology infrastructure.** In terms of financial penetration (or financial inclusiveness), 91 per cent of farmers confirmed having a bank account, while more than half were a member of the Fiji National Provident Fund[2] (FNPF), although results varied significantly across different crop groups. Almost all respondents (96%) had access to a mobile phone, while 72 per cent had access to mobile money, representing a relatively significant share. When asked about financial relief following an extreme weather event, more than half of the farmers relied on their own savings and less than one-third indicated their reliance on family and friends for support. Despite a high financial penetration rate, only 16 per cent of respondents revealed that they relied on loans. This may indicate a certain aversion to accumulating debt, specifically from financial institutions, or their incapacity to secure loan approvals. These findings substantiate the reality that farmers have a limited array of financial relief/support options available to them in the case of extreme weather events. This limited access to financial support constrains the farmers' financial resources and impedes their economic development opportunities, locking them in a vicious cycle of recovery.

Finally, the survey explored farmers' interest in parametric insurance solutions, demonstrating that interviewees were fairly receptive to insurance solutions covering climate risks. More than three-quarters of respondents were interested in relatively more expensive insurance products that covered a variety of risks, while two-thirds were interested in more expensive insurance products or a combination of insurance, savings and loans to help manage climate risk. Almost 79 per cent of respondents were interested in purchasing insurance through an association/co-operative. The survey indicated that group responses showed a **farmer's ability to afford an insurance product that costs F$100 per year**, with a modest share being able to afford a more costly product, at F$200, for example.

The outcomes of this survey helped reaffirm key assumptions about the target customer pool (i.e., farmers in Fiji):

- farmers in Fiji have a relatively high level of financial penetration and well-established access to mobile phones, and potentially e-money;
- farmers are aware of the growing natural hazard risk and are interested in insurance solutions;
- findings corroborate the lack of insurance and financial solutions allowing farmers' recovery following extreme weather events; and
- farmers are interested in parametric insurance solutions that are affordable, with demand more or less secured for a cost below the F$100 mark.

These conclusions affirm the viability and feasibility of a BBCCI product targeting farmers in Fiji, contingent on its affordability. Here we can look at a BCI fellow's experience regarding a BBCCI project launched in Cambodia, which offered crop insurance coverage for farmers. This currently confidential project, in its initial phase, ensured a US$150 insurance coverage for a premium fee of approximately US$13 a year for a pool of a few hundred farmers, with an average per capita annual income of roughly US$1,000. The crop insurance covered risk against drought and excess rainfall. This project showed that a possible price scheme would be dominated by the cost of the capital element, which in this instance represented 84 per cent of the total premium price paid by farmers (Figure 5.3). The remainder of the cost was equally split between fees for the local intermediary and the insurance premium fee.

The peculiarity of crop insurance against drought risk is that it tends to yield relatively more frequent disbursements, as drought occurs more regularly in the Cambodia region compared to tropical cyclones in Fiji (for instance). The high frequency of occurrence implies more regular disbursements and therefore a higher cost of capital, meaning that the cost of capital as a share of the total insurance premium price increases as the frequency of the

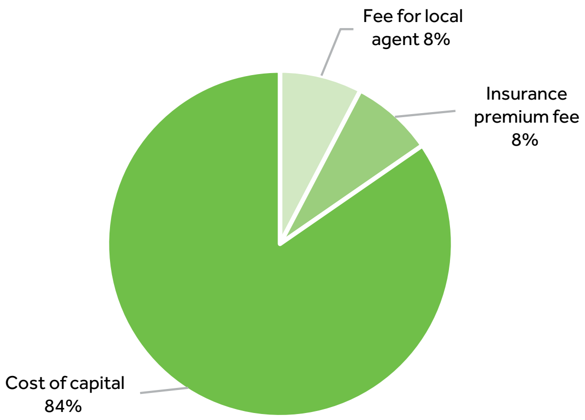
2 Fiji's largest financial institution, mandated by law to collect employment contributions towards the retirement savings of all workers in Fiji. In addition, the fund provides pre-retirement benefits such as housing, medical and education assistance. The fund represents a key source of support in the event of natural hazards.

Table 5.3 Summary of variables of interest

Variable name	Type of variable	Description
Percentage of women in the group	Continuous	Percentage of women in the group
Cumulative age of the group	Continuous	The sum of the age range of the group
Income sources	Categorical	Income sources (farming one crop, multiple crops, or from non-farm activities)
Hired labour	Categorical	Whether they hire farming labour (yes, no or family members)
Hazards	Categorical	Natural hazards/risks that impact productivity (cyclones, combination of cyclones and other hazards, or other hazards)
Impact frequency	Categorical	The frequency of these natural hazards/risks (once a year, twice a year, more than twice or once every two years)
Losses expressed in workdays	Continuous	The number of workdays lost due to these circumstances
Income loss	Continuous	Estimated income loss due to the damage
Bank account ownership	Binary	Whether they own a bank account
Members of FNPF	Binary	Whether they are members of the Fiji National Provident Fund
Financial products used	Categorical	The types of financial products that farmers are accustomed to using
Risk mitigation tools	Categorical	The tools that farmers use to manage the impacts of natural hazards (help from friends and family, savings or loans)
Preferred financial products	Categorical	Farmers' preferred financial instruments to mitigate risk (insurance, savings, loans or a combination)
Community trust in financial providers	Categorical	Whether the community trusts financial product providers (none, BSP bank, Baroda bank, Bank of the South Pacific, and insurance and savings)
Interest in insurance	Categorical	Whether they are interested in cheaper products (less coverage) or rather more expensive products (more coverage)
Preference for bundled products	Binary	Whether farmers are interested in bundled products (covering environmental risk, health and/or life insurance)
Purchase preference	Binary	Whether they prefer to purchase the insurance product through their farmer association or independently
Mobile access	Binary	Whether farmers have access to cell (mobile) phones
E-money access	Binary	Whether farmers have access to mobile money
Recovery amounts	Continuous	The amount of funding required to recover from these natural hazards
WTP (dependent)	Categorical	The amount of money they would be willing to spend for an insurance product

Source: BCI from the Pacific Insurance and Climate Adaptation Programme (PICAP)

Figure 5.4 Estimated cost structure for a crop insurance project in Cambodia



Source:BCI from internal sources.

weather event rises. Based on practical experience, ceteris paribus, a decline by 10 per cent in the probability of occurrence of the weather event per year, would decrease the cost of capital[3] as a share of the total premium by an estimated 2.3 per cent. This is rather important in the Fijian case, as tropical cyclones have a high occurrence rate, having suffered at least one cyclone per year in the last 30 years. Although the share of capital cost might be relatively lower in Fiji, compared to Cambodia, it is still a significant share. This would likely increase the cost of capital of a parametric insurance product.

One way to help keep the cost of capital from this element manageable is by cutting the cost elsewhere — adding a blockchain technology layer in this case would help decrease overall cost and ensure affordability for the local population. Alternatively, the implementation of a subsidy scheme for parametric insurance would be another effective measure to manage the affordability of the product and ensure a higher effective demand following the price reduction, compared to the otherwise lower potential demand based on the real price (i.e. higher price without subsidy).

5.6.1 Econometric analysis based on the PICAP demand survey data

The study was able to gain access to the underlying data from the farmers demand survey conducted in August 2020 by the Pacific Insurance and Climate Adaptation Programme (PICAP) (see earlier section for detailed description and findings from the survey). Upon examining the dataset, a similar empirical approach was devised to analyse the key determinants of the willingness-to-pay (WTP) of Fijian farmers who were asked about parametric insurance products. Upon sourcing the survey data from PICAP, a cross-sectional regression analysis was then performed to identify the key determinants of WTP through the following equation:

$$WTP_i = c + bX_i + u_i \tag{4}$$

Where *X* is a vector of relevant control variables (income source, income loss from natural hazards, etc.); *c* is the estimated constant; *b* is the vector of estimated coefficients of *X*; while u_i is the error term and (i) represents the interviewed farming group.

a. Regression analysis and findings

Given that the dependent variable is a categorical variable, where the interviewees were asked to choose an amount that they would be willing to pay for a parametric insurance product, this meant that the possible values of the dependent variable were limited to three ordered categories (F$100, F$200, or below F$100). This indicated that the appropriate regression model in this instance would be an ordered probit model. Ordered probit models are used to explain variation in an ordered categorical dependent variable as a function of one or more independent/control variables. This method requires the categories to be ordered, but does not require the distance between the categories to be equal. For dependent variables with more than seven categories, an ordinary least squares regression is preferred. Whereas if the dependent variable only has two categories, the ordered probit model reduces to simple probit.

Table 5.3 summarises all the possibly relevant control variables available in the survey. After assessing correlations and possible causality links, the choice of control variables was limited to a select number of 12 explanatory variables (shown in green in Table 5.3).

Table 5.4 summarises the regression results from the ordered probit model. The results indicate that although a large share of the specified explanatory variables showed no statistically significant coefficients, some key variables had statistically significant coefficients – at the 1 per cent and 5 per cent significance levels. The results of the model indicate that, on average, farmers that

3 The 'cost of capital' is the minimum rate of return required to cover the initial capital used to fund business operations, before generating profit. The cost depends on the debt and equity structure of a business, among other things.

Table 5.4 Ordered probit regression

WTP	Coef.[1]	St.Err.[2]	t-value	p-value	[95% Conf	Interval]	Sig[3]
Women	0.902	1.401	0.64	0.52	−1.845	3.649	
Age	0.002	0.014	0.17	0.867	−0.026	0.031	
Hazard type							
Cyclones	1.645	0.936	1.76	0.079	−0.189	3.48	*
Cyclones and other risks	−0.497	0.784	−0.63	0.526	−2.033	1.038	
Impact frequency							
Once a year	−0.711	1.448	−0.49	0.623	−3.549	2.127	
Twice a year	−1.764	1.656	−1.07	0.287	−5.01	1.482	
More than twice a year	−2.189	1.76	−1.24	0.213	−5.638	1.259	
Extremely likely to be impacted in the next 5 years	2.619	1.081	2.42	0.015	0.5	4.738	**
Income source							
Farming more than one crop	2.712	0.853	3.18	0.001	1.041	4.384	***
Farming and non-farming activities	0.141	0.851	0.17	0.868	−1.527	1.809	
Interested in cheaper insurance product	−3.28	1.096	−2.99	0.003	−5.429	−1.131	***
Interested in more expensive insurance product	0.657	1.032	0.64	0.524	−1.364	2.679	
Have access to e-money	1.171	0.739	1.58	0.113	−0.277	2.619	
Bank account owner	−0.704	1.261	−0.56	0.577	−3.175	1.767	
Community trust in financial institutions							
BSP bank	−3.468	1.598	−2.17	0.03	−6.6	−0.337	**
Baroda bank	4.334	510.16	0.01	0.993	−995.562	1004.23	
The Bank of the South Pacific	−0.892	890.06	−0.00	0.999	−1745.377	1743.594	
Savings products	2.194	333.575	0.01	0.995	−651.6	655.989	
SCGF	1.3	1.06	1.23	0.22	−0.777	3.376	
Workdays lost from hazard	0.005	0.004	1.10	0.273	−0.004	0.013	
Prefer to purchase through association	0.786	0.984	0.80	0.425	−1.143	2.715	
Prefer a bundled insurance product	−4.691	1.678	−2.80	0.005	−7.979	−1.403	***
Constant	−4.029	2.951	.b	.b	−9.813	1.756	
Constant	−0.58	2.88	.b	.b	−6.226	5.066	
Mean dependent var	1.154			SD dependent var			0.712
Pseudo r-squared	0.636			Number of obs			65
Chi-square	85.301			Prob > chi2			0.000
Akaike crit. (AIC)	96.819			Bayesian crit. (BIC)			149.004

*** *p<.01*, ** *p<.05*, * *p<.1*

[1] Coefficients

[2] Standard error

[3] Significance

face the risk of cyclones and farm more than one crop are more willing to pay more for a parametric insurance product. Moreover, those who believe that a major weather event is likely to occur in the next five years are in the higher category of the WTP for this type of product. On the other hand, farmers that prefer lower risk coverage for a lower cost naturally would be willing to pay less for an insurance product against environmental hazards. Similarly, farmers that prefer to pay for a bundled insurance product, which covers an additional risk (health or life insurance), would also be willing to pay less for a parametric insurance product. Surprisingly, other key variables such as the age and gender of respondents, access to mobile money, and the number of workdays lost from the onset of a weather event, were all found to be statistically insignificant.

b. Limitations of the regression analysis

The regression analysis unfortunately suffered from key limitations and drawbacks directly related to the nature and quality of the underlying survey data. These included:

- The small sample size (i.e., the limited number of observations): although the sourced survey data covered some 256 farmers in Fiji through group interviews, the data were collected on a group level rather than on an individual level. This meant that the total number of observations available was reduced to only 61. This represents a crucial drawback, as it increases the probability of bias in the results and decreases the representativity of the sample, which renders inference at a more general level (at the population level) impossible.
- The data collected in the survey covered more qualitative characteristics (e.g., perceptions, preferences etc.) rather than quantitative ones. This meant that most of the variables were either categorical or binary, which restricted the choice of regression models and made the interpretation of the findings more challenging.
- The absence of farming income-related data: the survey did not cover at any point any income-specific questions, leaving out a key and crucial determinant of individuals' willingness to pay for a given service. The data also did not cover the size of farmland owned by these farmers. Both elements are key differentiating characteristics that are imperative for assessing willingness to pay. Therefore, the absence of these characteristics implied the presence of an omitted variables problem, which could result in biased findings.

Although the survey covered key questions relative to Fijians' perception and trust in financial products and institutions, it left out some key interests, notably related to income levels and the financial performance of the farming business of the interviewed groups.

Given the lack of publicly-available income survey data in Fiji (on a household- or an individual level) for farmers in Fiji and the inability to conduct bespoke data collection from on-the-ground surveys, it was difficult to conduct a regression analysis that would yield rigorous and robust results.

6. Implementation Roadmap for Blockchain-Based Climate Catastrophe Insurance

In offering blockchain-based climate catastrophe insurance solutions and developing a roadmap of implementation, considerations have been given to ensuring that this application-level roadmap is compatible with the strategic goals of the Government of Fiji. Specific attention is drawn towards addressing the impacts of cyclones that are prevalent in the region. Accordingly, examples of storm monitoring and wind speed data were used as examples to highlight the impact in section 3.2 of this report.

Emerging digital technologies (including artificial intelligence [AI] and blockchain) should play an increasingly significant role in building disaster resilience for communities in general, and farmers in particular. Given its unique regulatory services (i.e., validity, consensus, immutability and authentication), blockchain (coupled with artificial intelligence) is capable of recording, securing and analysing the dynamic details of a colossal number of transactions, which could be a powerful tool for processing insurance pay-outs through the adoption of smart contracts.

The roadmap presented in this chapter aims to facilitate the rollout of BBCCI in the insurance sector. The implementation roadmap follows a three-step approach: **(1) Use-case; (2) Proof of concept;** and **(3) Scale** (Figure 6.1). A detailed step-wise blockchain roadmap for implementation is presented in the subsequent paragraphs of this report.

6.1 Step One: Use-case

Learn: Understanding blockchain benefits and the opportunity

Blockchain has been misconceived as a panacea to address every operational challenge. In reality, it can be a powerful instrument for certain use-cases *only*. To begin with, we can assess if blockchain would add real value to the status quo in Fiji's insurance sector in general and to parametric insurance in particular, by considering the seven criteria below:

1. Do multiple stakeholder parties along Fiji's insurance sector value chain need a shared database of insurance products?
2. Does that directory of insurance products require changes by multiple stakeholders?
3. Are there dependencies among the transactions by insurance providers, banks, government and retailers of insurance products?
4. Should insurance product data be recorded as tamper-proof or as immutable as possible?
5. Is there some consistency in the insurance product data?
6. Would disintermediation of the procurement, payment and/or monitoring process be meaningful for the insurance sector in Fiji?
7. Will the application result in economic (financial) incentives for all stakeholders along the insurance value chain in Fiji?

The technical and economic feasibility assessments in this report have already answered some of the questions above.

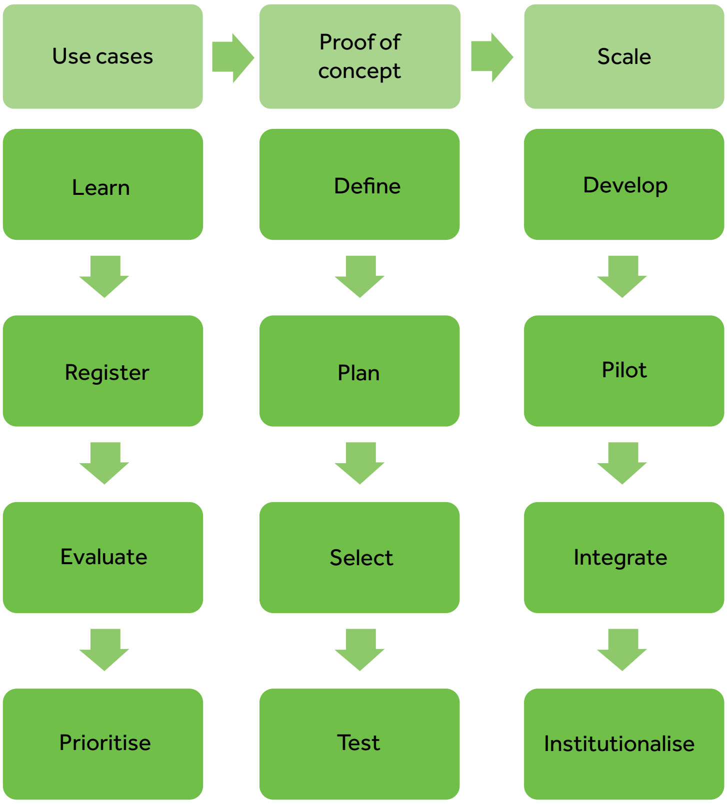
Register: Listing use-cases that adopt blockchain for parametric insurance in an inventory

Blockchain applications specifically designed to deploy blockchain-based parametric insurance have not been extensively adopted across the industry. However, use-cases from other countries can be used to develop customised solutions in the case of Fiji. Some relevant use-cases have already been 'registered' in Section 5.4 of this report.

Evaluate: Assessing how well use-cases leverage blockchain strengths

The main benefits of blockchain technology are transparency, trust, efficiency and auditability. To assess how well use-cases in other countries leverage blockchain's strengths, an evaluation of

Figure 6.1 A three-step approach to implementing BBCCI



Source: BCI

blockchain-based disaster risk insurance use-cases registered on an inventory would normally need to score against the following criteria:

1. Multiple parties share data: Multiple participants (including insurers, financial institutions, regulators, policy-holders) should view common information.
2. Multiple parties update data: Multiple participants (including insurers, financial institutions, regulators, policy-holders) should take actions (e.g., weather event monitoring) which are to be recorded and change the data.
3. Requirement for verification: Insurers and policy-holders need to trust that the recorded actions are valid.
4. Intermediaries add cost and complexity: Removal of central insurance policy record keeper intermediaries has the potential to reduce claim processing cost and the complexity of damage assessment.
5. Interactions are time-sensitive: Reducing delays has business benefits, such as the reduced risk of false claims and delayed pay-outs in the aftermath of the disasters.
6. Transaction interaction: Transactions on the BBCCI network created by insurers, banks, policy-holders and even telecommunications service providers depend on each other's data integrity.

Prioritise: Ranking use-cases based on the impact evaluation criteria

Taking into account the score of each registered use-case against each of the six criteria in the preceding step, BBCCI use-cases in other countries can be ranked and prioritised so that the limited resources of the Fijian government can be used to develop the product and business model that offers the highest value to the country. That is, the lessons learnt from these inventoried BBCCI use-cases could inform the customisation of BBCCI products for use by Fijian populations.

For example, efforts should be made to explore how the BBCCI product structure could be made more efficient through a more sophisticated IoT-supported system of automated meteorological data collection and AI-supported validation through remote sensing devices installed in different geographical communities. Materials presented in Sections 1.3.1, 3.2 and 3.4 of this report could provide a direction for further technical studies.

Although use-cases in other countries were presented in Section 5.4 of this report, most cannot be thoroughly evaluated until operational or commercial data is made publicly available. However, evaluation and prioritisation are not necessary if the Government of Fiji wishes to play a pioneering role in promoting BBCCI in the Pacific region, regardless of the performance of use-cases in other countries, each of which has unique geographical and socio-economic factors that determine its viability.

6.2 Step Two: Development of proof of concept

Define: Identification of the minimum viable ecosystem (MVE)

Generally, a minimum viable ecosystem (MVE) is the least complex ecosystem that allows participants to learn about a more complex, future ecosystem with the least effort. This entails learning about the interdependencies and interactions between ecosystem participants, including customers, partners and governments and, specifically, how value should be shared.

In the case of developing BBCCI for Fiji, attention should be drawn to multiple players in the ecosystem who are offering their services already, to support the adoption of parametric insurance. Examples include:

- local insurance providers – FijiCare, BIMA, Microlife (mentioned in Section 1.3);
- relevant ministries – the Ministry of Agriculture, Ministry of Finance, Ministry of Economy (Climate Change and International Cooperation Division), Ministry of Commerce, Trade, Tourism and Transport, Ministry of Communications, Fiji National Disaster Management Office, etc.;
- banking/insurance regulators – the Reserve Bank of Fiji, the Association of Banks in Fiji;
- telecommunications service providers – Amalgamated Telecom Holdings (ATH), Telecom Fiji (TFL), Fiji International Telecommunications (FINTEL), Kacific Broadband Satellites, Southern Cross Cable Network (SCCN), Vodafone Fiji (VFL), Digicel Fiji, Inkk Mobile, Unwired Fiji, Fintel Internet Services (Kidanet), etc.; and
- selected farmer groups / civil society organisations – Fiji Crop and Livestock Council (FCLC), Pacific Island Farmers Organisation Network (PIFON), National Farmers' Union (NFU), etc.

Plan: The development of proof of concept (PoC)

The next step is to develop the appropriate insurance products that can be piloted locally. The pilots can be undertaken based on the prioritised areas, crops, cover, etc., which can be **integrated** into existing insurance products, including the digital prototype being developed by PICAP in due course. In the medium to long term, the details of pilots and areas of integration can be expanded and scaled up to another level, where BBCCI can integrate with the legacy insurance products across the country.

The design of the proof of concept or prototype for BBCCI in Fiji should consider the following factors:

- **Transaction rate**: Monitoring the parametric insurance value chain should not need high transaction rates, because the sector's stakeholders may not need to process enormous numbers of transactions every minute of every day. Setting a throughput of fewer than 2,000 transactions per second on a relatively basic blockchain would be sufficient for this purpose.
- **Consensus model:** It is essential to determine the consensus algorithms for this blockchain network, to ensure that it achieves the intended outcomes without favouritism. One of the prime concerns is the energy consumption of the 'mining' process. Therefore, a proof-of-stake (POS) mechanism that keeps the energy consumption rate extremely low is recommended. The selection of smart contract-integrated edge devices, such as edge terminals (web/mobile) and radio-frequency identification (RFID) devices, may have implications on the choice of the consensus mechanism. Moreover, stakeholders in the MVE also need to determine the organisation's consensus algorithm, since it is an 'entity' that is a user on the blockchain network and not every member of the entity should be allowed to access the same level of transaction data.

- **Privacy:** In consideration of the confidentiality of some transaction data in the parametric insurance procurement process, privacy options and authentication processes should be installed on the blockchain network, meaning that a 'permissioned' or multi-layered (governance) blockchain is recommended to satisfy privacy-related regulatory requirements.
- **Scalability**: A successful blockchain network must be scalable to ensure fast output (e.g., verification of enrolment of farmers, their land records, etc.,) even when an increasing number of users are joining the network. The proof of concept (PoC) must be built on extendable architecture to offer new functionality and modules to replace certain 'outdated' elements when necessary. A new module may be related to the handling of exceptional cases that require external human or machine interactions via decentralised apps (DApps), based on smart contracts and application programming interfaces (APIs) together.

Developing a minimum viable product (MVP), which is a product with a minimal set of features to be deployed in the long term, is a vital part of the PoC development. The developer of an MVP based on the prioritised use-cases should aim at:

- ensuring the parametric insurance blockchain design is compliant with relevant international standards (e.g., ISO 22739); and
- cost efficiency; as the product is expected to deliver cost efficiency in the range of 5–10 per cent, the same needs to be analysed based on the minimum composition that can deliver this result.

At this stage, it would be prudent to collaborate with PICAP and deploy BBCCI as an 'additional' layer in its ongoing parametric insurance product.

Select: Choosing the most suitable blockchain platform

Upon the development of PoC, considerations should be given to selecting the most suitable blockchain platform or provider of blockchain-as-a-service (BaaS), which serves as the digital infrastructure for BBCCI projects tailored for Fiji. (Note: The choice between using a blockchain platform or BaaS for BBCCI project development in Fiji depends on whether the local insurer has easy access to qualified blockchain engineers locally.) In fact, there are some major blockchain technology stacks/platforms for PoC development, each with its 'pros' and 'cons'.

These major platforms include Quorum, R3 Corda, Hyperledger Fabric and Ethereum. Some criteria to consider include the platform's industry focus, governance model, ledger type, consensus algorithm and smart contract functionality. Table 6.1 presents a simple comparison among these four blockchain platforms for reference only.

Test: Building and piloting PoC

The proof of concept for the BBCCI product will be subject to iterative and robust testing and end-user feedback within the MVE, before mass production. MVE participants will need to discuss and define the key metrics for PoC testing. As it is a proof of concept, these metrics will have to include:

- **Determination of whether the BBCCI proof of concept can be made commercially viable for the local insurer(s):** Once the PoC stage is complete, insurers need to decide

Table 6.1 Comparison between blockchain platforms

	Quorum	R3 Corda	Hyperledger Fabric	Ethereum
Industry focus	Cross-industry	Financial services	Cross-industry	Cross-industry
Governance	Developers	Permissioned	Permissioned	Developers
Ledger type	Permissioned	Permissioned	Permissioned	Permissionless
Consensus algorithm	Majority voting	Pluggable framework	Pluggable framework	Proof of work
Smart contract functionality	Yes	Yes	Yes	Yes

whether they will allow the PoC to proceed to production level or not. Local insurer(s) will also need to measure the possible returns if they choose to proceed.

- **Insurers need to ascertain whether their teams have a technical understanding of this blockchain product:** The design of the PoC or MVP tends to be contracted out to an external group of blockchain engineers. It is essential that actors along the BBCCI insurance value chain, including actuaries, brokers, marketers, underwriters, claims administrators and servicing professionals, have acquired an adequate level of technical capacity to understand and operate the BBCCI product before it goes into a live environment. Even if local insurers or RBF decide that the Fijian market is not suitable for deploying the BBCCI product yet, the PoC development experience gained will help stakeholders explore the transferability of this product concept to other sectors in Fiji.

6.3 Step Three: Scale

Develop: Developing operating models and governance

It is necessary that the MVE agrees on the operating model and governance of the BBCCI pilot consortium. All participating parties should have:

- clearly defined roles, liabilities and responsibilities; and
- an unambiguous process of joining and leaving the consortium, in accordance with a prescriptive operative and governance model.

In the case of BBCCI for Fiji, multiple parties (including insurers, banks, regulators and policy-holders) must agree on a set of rules that address liability and participant responsibilities, in order to make subsequent group decisions about technology, strategy and ongoing operations. These decisions may involve the following questions:

- Which types of households should be eligible for BBCCI to avoid the maladaptation phenomenon?
- Which common format, data standard and level of granularity should community meteorological data follow?
- Who should be the data steward, responsible for monitoring data quality and compliance with the standards agreed?
- How will the community meteorological data be shared if more than one insurer intends to participate in the pilot?
- What is the arbitration process in case of any irregularities arising from the smart contract codes?
- What will happen if all the data collection devices are also destroyed by a tropical cyclone?

Pilot: Blockchain solution in a live production environment

Unlike an enterprise-level blockchain system, the BBCCI is an industry-level application that requires a cross-sector live production environment where the solution will be tested. The BCI recommends a 'sandbox programme' to pilot the blockchain application, with live disaster risk insurance programmes, especially parametric insurance projects, being developed by PICAP.

The real-world data generated through BBCCI will inform the refinement of Fiji's disaster risk insurance policy and legal frameworks for the adoption of blockchain technologies in the country. Blockchain-based solutions should be viewed holistically, as the technology has wider application in other sectors – for example, peer-to-peer energy solutions, traceability of agriculture produce and associated certification activities, the circular economy, monitoring of forest conservation finance, mobilisation of private climate finance, adaptation infrastructure project procurement monitoring, etc. Hence, it would be necessary to build the capacity of stakeholders on the potential of blockchain as a differentiator to increase efficiency in e-governance and foster innovations in climate policy implementation. The potential role of these emerging digital technologies (including artificial intelligence and blockchain) in tackling corruption and fraud at various stages of climate policy implementation, through structured monitoring and verification protocols as well as precise project management, should be studied further and in depth.

Integrate: Interoperating with legacy systems and crafting a roll-out strategy

In general, organisations that adopt blockchain technology are similarly exposed to common risks concerning business processes, including regulatory, strategic and supplier risks. The supplier risks, in this context, involve the selection of underlying blockchain platforms, as mentioned in Step Two, as well as external vendors of other complementary technology services (e.g., IoT devices, cloud infrastructure), both at present and in the future. To ensure the interoperability of the blockchain product with legacy systems and hence, minimise the resistance of stakeholders, it is advisable that developers of PoC should integrate it seamlessly with back-end legacy systems being used across the industry.

Given that PICAP has already developed a prototype for disaster risk insurance with conventional digital technologies, an integrable design renders it viable for the BBCCI product to be piloted as a layer onto the existing PICAP insurance product. This approach would ensure that the underlying PICAP insurance product, which has already been tested, continues and the new layer of BBCCI can be validated for adoption in Fiji. Based on the results of this pilot, further steps towards the large-scale adoption of BBCCI may be considered. It should be emphasised that this is not a competitive product, but a complementary one – aiming to enhance the reach of parametric insurance and strengthen the resilience of farmers in Fiji.

Institutionalise: The operating structure

At the enterprise level, companies that aim to adopt blockchain technology and have undertaken the steps described above should institutionalise the new blockchain-based product structure and business model by growing their technical capacity through proper human resource planning (e.g., recruiting those with blockchain skills, internal training for employees) and accumulating systematic knowledge about the emerging digital technology sectors beyond the minimum viable ecosystem identified.

In the case of institutionalising BBCCI in Fiji, other than institutional capacity building programmes for participants in the MVE to begin with, the Government of Fiji should engage in legislative research to remove the legal and regulatory barriers to the extensive adoption of blockchain technology across the insurance industry, as discussed in Section 3.6 of this report. This could be the new 'operating structure' for the insurance sector in Fiji.

Subject to further stakeholder consultation and capacity gap analysis, the Fijian government may request technical assistance for institutional capacity building from the international community, to fully operationalise this model of blockchain use-cases across all insurance products in the country.

6.4 Further studies

Based on the technical and economic feasibility assessment, as well as the steps in the implementation roadmap in all the preceding sections, the BCI recommends the following further studies be undertaken:

a. **Capacity building needs assessment:** Following institutional capacity building programmes for MVE participants (especially relevant government officials), as described in Section 3.5 of this report, where farmers' capability to use smartphone applications was discussed, a community training needs assessment should be conducted prior to the roll out of the BBCCI product.

b. **Legislative study:** As indicated in Section 3.6, the Cabinet Office may start studying new legal solutions to the relevant legal questions or uncertainties around the introduction of BBCCI and the new responsibilities of relevant regulators (e.g., RBF) in Fiji's jurisdiction. This study will inform the new legislative bills, which will be drafted by the government to better regulate the new insurance product and business model. The BCI has experience in developing similar legislation in other Commonwealth jurisdictions.

c. **Disaster- or crop-specific databases:** BBCCI should not only cover cyclone-induced damage, but also other natural hazards such as landslides, droughts or floods. Further (agricultural) research may be developed to create differentiated databases or product structures that are specific to common crop types, livestock and fisheries in Fiji, since these insurance covers are not available in the country yet (as mentioned in Section 1.3).

Examples of these common crop types include pineapple, coconuts, banana and pawpaw (as listed in Table 4.2), each of which may have a different level of resilience to different natural hazards.

d. **The amalgamation of the BBCCI model with the wider adaptation finance agenda:** The roll out of BBCCI should be considered only the first step towards enhancing adaptation finance flows to Fiji. The BBCCI business model will increase the trust and confidence of stakeholders in this market and potentially, expand the profit margins of disaster risk insurance products in the long term. Further studies should be considered to link the BBCCI product with climate finance instruments (e.g., resilience bonds) or property disaster risk measurement tools for financial institutions to substantially increase private adaptation finance flows from foreign investors to the Fijian market.

e. **Complementarity of other emerging digital technologies:** This BBCCI product should be perceived as 'version 1.0'. Upon the roll out of this product in Fiji, further feasibility studies should be performed regarding the interaction among other emerging digital technologies (including artificial intelligence, the internet of things, unmanned aerial vehicles, satellite imagery, remote sensing, etc.) and their complementarity with the BBCCI 1.0. These complementary technologies may be able to automate field data monitoring and analysis of more granular data, to offer customised climate catastrophe insurance to smallholder farmers. The new technical knowledge that will have been created will inform the development of BBCCI 2.0 and above.

7. Conclusion and the Way Forward

This study aimed at understanding the potential value of deploying blockchain-based climate catastrophe insurance in addressing the different challenges faced by Fiji, especially due to tropical cyclone storms. The initial plan was to undertake a key stakeholder consultation with different actors in the insurance and related sectors, like agriculture and finance. However, due to the prevailing COVID-19 pandemic conditions and other logistical challenges, local stakeholder consultation was not feasible. Hence, the study had to rely on secondary data provided by PICAP to extract the potential interest and willingness of consumers to opt for this innovative solution in the Fijian context. The limitations of the study are explained in Section 5.5.2 of this report.

Based on the results of the technical and economic feasibility assessments, this study concludes that BBCCI solutions represent a viable and feasible measure, both economically and technically, in building adaptation capacities to climate risk in Fiji. The technical feasibility assessment analysed the availability of localised data and associated technological solutions. These were mapped to different internationally accepted datasets, with examples for the Fijian context presented. The existence of mobile networks, usage of mobile payments and the presence of internet-based apps like PacFarmer were reviewed, along with the penetration of mobile networks and usage of IT in the farming community.

The next step was to identify existing regulatory and commercial information in the Fijian context. At least on the surface, the Insurance Act does not contain any fundamental barriers to parametric insurance, which, if combined with a permissive legal environment for smart contracts, could be a precursor to a favourable regulatory environment for BBCCI adoption. In addition, taxation on pay-outs were reviewed and identified that any income from the insurance pay-out that is additional to the sum contributed by the policy-holder is taxed. When paying policy-holders, BBCCI providers must therefore withhold 10 per cent of the difference between the premium paid and total pay-out. This money should be paid to Fiji's Revenue and Customs Service. BBCCI insurers would also have to pay tax at a rate of 20 per cent on their chargeable income/net profit. Finally, insurance premiums are subject to a value-added tax at the rate of 9 per cent. The Government of Fiji may consider tax concession measures in favour of the introduction of a BBCCI product during its early stages.

The BBCCI product structure and the different stakeholders required for deployment were analysed and presented in the report. **The advantages of BBCCI in terms of increased customer engagement, increased standardisation, reduced transaction costs, lower fraud risk and increased transparency, and finally the penetration of insurance coverage among vulnerable communities were also identified.**

The top-level ability-to-pay estimate for the average Fijian farming household indicates that the pricing of a parametric insurance product should not exceed F$0.0469 (approximately US$0.0225) per square meter of farmland. Given that most Fijian agricultural households operate in small- to medium-sized farmlands, a farm area of 0.2 hectares (2000 m^2) would imply an ATP of approximately F$94 (US$45.1) per year. This conclusion is in line with results derived from the PICAP farmers' demand survey, which referred to F$100 (approximately US$48) as the fee that all interviewees were willing to pay for an insurance product covering extreme weather events. It is noted that a BCI fellow's blockchain-based parametric crop insurance product launched in Cambodia charges farmers only US$13 a year. **Thus, the view from this study is that farming households will usefully benefit from a parametric insurance product to mitigate growing environmental risks that challenge the survival of their agricultural activity.**

These findings represent a useful precursor for preparing the ground for the BBCCI business model detailed in Section 5.3. Further examination of micro-level studies has identified that blockchain-based climate catastrophe insurance can reduce the cost of issuing a policy by 40 per cent and in turn reduce farmer premiums by 30 per cent (Global Innovation Lab for Climate Finance 2019). However, taking account of the risk profile and inherent technological challenges that are prevalent in the Fijian context, and also the lack of primary data on consumers, **this study on a conservative approach projects a potential cost reduction in the range of 5–10 per cent from the existing premiums if blockchain-based agriculture insurance programmes are adopted in the country.**

One way to help keep the cost of capital manageable is by cutting the cost elsewhere — adding a blockchain technology layer. The implementation of a subsidy scheme for parametric insurance could be another effective measure to roll the product out with an efficient cost structure.

Following further examination into micro-level affordability and cost structure, BBCCI could be launched first targeting the next tranche of farmers that are expected to be onboarded through the PICAP programme in Fiji. The product will generate revenue primarily from the insurance premiums, but could then progressively target reinvesting profits into local community development opportunities. Public intervention and collaboration with associations and co-operatives are crucial to ensure an effective and efficient roll-out of products of this nature. This can be achieved by engaging with local farmers associations (e.g., the Fiji Crop and Livestock Council [FCLC], Pacific Island Farmers Organisation Network [PIFON], National Farmers' Union [NFU]) and the Fijian Ministry of Agriculture.

In deploying blockchain-based climate catastrophe insurance solutions and developing a roadmap for implementation, due consideration must be given to ensuring that the application-level roadmap is compatible with the existing infrastructure and also aligns with the strategic goals of Fiji in adapting to climate change. Blockchain-based solutions should be viewed holistically, as the technology has wider application in other sectors – such as in peer-to-peer energy solutions, traceability of agriculture produce and associated certification activities, the circular economy, monitoring of climate finance, etc. Hence, it would be necessary to build the capacity of stakeholders on the potential of blockchain as a differentiator to increase efficiency in e-governance and foster innovations. The role of emerging digital technologies (including artificial intelligence and blockchain) in tackling corruption and fraud through structured monitoring and verification protocols and project management need to be developed to benefit from this immutable technology.

The study has identified that mobile technology penetration is relatively high in the Fijian society and, hence, technological adoption should not be a huge challenge. Given the progress of the Reserve Bank of Fiji on deploying a national payment system strategy, with an emphasis on digital innovation, the development of BBCCI products should have passed the stage of 'learning' and be at the stage of 'use-case registration' in the implementation roadmap presented. The 'prioritisation' exercise can be based on different parameters such as geographic locations, agro-ecological conditions, types of crops, and/or types of cover (cyclone, drought, etc.). BBCCI may be deployed on existing parametric insurance products in Fiji, to evaluate its performance and identify priority areas that need to be incorporated into BBCCI.

The recommended way forward and an implementation roadmap was discussed in Section 6 of the report, where a three-step approach was presented. The way forward would be to pilot a BBCCI product as an additional layer onto the existing PICAP insurance product in Fiji. This approach would ensure cost-effectiveness and time efficiency, as the underlying PICAP insurance product is being tested and validated, while the BBCCI does not necessitate any reinvention of the research and development wheel in Fiji. Based on the results of this pilot, the replicability of the BBCCI product and business models for other economic sectors in Fiji – and even other Commonwealth countries – may be the subject of further studies in the future.

References

Asian Development Bank (ADB) (2019), 'Enabling Environment for Disaster Risk Financing in Fiji: Country Diagnostics Assessment', available at: https://www.adb.org/publications/fiji-environment-disaster-risk-financing

Australian Bureau of Meteorology and CSIRO (2014), 'Climate Variability, Extremes and Change in the Western Tropical Pacific: New Science and Updated Country Reports 2014', available at: https://www.pacificclimatechangescience.org/wp-content/uploads/2014/07/PACCSAP_CountryReports2014_WEB_140710.pdf

Barley, M (2018), 'Australia Developing National Blockchain for Legal Contracts', Ledger Insights, available at: www.ledgerinsights.com/australian-national-blockchain-smart-legal-contracts/

Barnes, D.P. (Ed.). (2020). 'A Pacific Disaster Prevention Review'. Australian Strategic Policy Institute.

Bird, J (2018), '"Smart" insurance helps poor farmers to cut risk', *Financial Times*, available at: https://www.ft.com/content/3a8c7746-d886-11e8-aa22-36538487e3d0

Bogdan, O, CC McPherlain and S Yoon (2019), 'Gendered Impacts of Weather and Climate: Evidence from Asia, Pacific and Africa', World Meteorological Organization, available at: https://library.wmo.int/ doc_num.php?explnum_id=10106

Boila, S (2018), 'TC Gita damage cost stands at $1.23m', Fiji Broadcasting Corporation, 19 March, available at: https://www.fbcnews.com.fj/news/tc-gita-damage-cost-stands-at-1-23m/

Broberg, M (2020), 'Parametric loss and damage insurance schemes as a means to enhance climate change resilience in developing countries', *Climate Policy* 20(6), 693–703.

Buhr, B., U. Volz, C. Donovan, G. Kling, Y. Lo, V. Murinde and N. Pullin (2018). 'Climate Change and the Cost of Capital in Developing Countries'. Imperial College London; SOAS University of London; UN Environment. https://unepinquiry.org/publication/climate-change-and-the-cost-of-capital-in-developing-countries/

Caribbean Catastrophe Risk Insurance Facility (CCRIF) (2017), 'CCRIF Reaches US$100 million Milestone in Pay-outs, available at: https://www.ccrif.org/node/11915?language_content_entity=en

Cave, D. (2012). Digital islands: How the Pacific's ICT revolution is transforming the region. *Lowy Institute for International Policy*, *21*, 1–24.

Chand, SS and KJ Walsh (2009), 'Tropical cyclone activity in the Fiji region: Spatial patterns and relationship to large-scale circulation', *Journal of Climate* 22(14), 3877–3893.

Charan, D, M Kaur and P Singh (2016), 'Indigenous Fijian Women's Role in Disaster Risk Management and Climate Change Adaptation', *Pacific Asia Inquiry* 7(1), 106–122, available at: https://www.uog.edu/schoolsand-colleges/college-of-liberal-arts-and-social-sciences/pacific-asia-inquiry/V7.php

Clyde and Co LLP (2018), 'Closing the protection gap through inclusive insurance', Clyde and Co LLP, London, 7–44.

Cohn, A, T West and C Parker (2017), 'Smart after all: blockchain, smart contracts, parametric insurance, and smart energy grids', *Georgia Law Tech Review*, 273, 273–303.

Convery, F. (2001). 'Emissions Trading and Environmental Policy in Europe'. Paper presented at the pre-summit conference - Knowledge and Learning for a Sustainable Society (Climate and Global Justice Session), Göteborg University, Sweden 12-14 June, 2001. http://www.emissionstradingnetwork.com

Dafermos, Y, M Nikolaidi and G Galanis (2018), 'Climate change, financial stability and monetary policy', *Ecological Economics*, 152, 219–234.

Daunivalu, J (2018), 'Empowering Fijian Farmers with Mobile Apps', available at: https://cgspace.cgiar.org/bitstream/handle/10568/98979/Exp_Cap7_Daunivalu.pdf?sequence=1&isAllowed=y

Davis, J (2018), 'Peer-to-Peer Insurance on an Ethereum Blockchain: General Consideration of the Fundamentals of Peer-to-Peer Insurance', *Dynamis Project White Paper*, 1–8.

Day, S, T Forster, J Himmelsbach, L Korte, P Mucke, K Radtke, P Theilbörger and D Weller (2019) 'World Risk Report 2019 – focus: water supply', Bündnis Entwicklung Hilft and Ruhr University Bochum – Institute for International Law of Peace and Armed Conflict (IFHV).

Delavallade, C., F. Dizon, R.V. Hill and J.P. Petraud (2015). 'Managing risk with insurance and savings: Experimental evidence for male and female farm managers in West Africa'. Available at: https://www.poverty-action.org/sites/default/files/publications/129282.pdf

Deloitte (2018), 'Blockchain and Five Vectors of progress', available at: https://www2.deloitte.com/us/en/insights/focus/signals-for-strategists/value-of-blockchain-applications-interoperability.html

Elbourne, F (2020), 'Parametric Insurance for Informal Workplace: RBF Governor', *Fiji Sun*, 20 January, available at: https://fijisun.com.fj/2020/01/20/parametric-insurance-for-informal-workforce-rbf-governor/

Fernandez, R and L Schäfer (2018), 'Impact Evaluation of Climate Risk Insurance Approaches: Status Quo and Way Forward', *Discussion Paper Series APR, Munich Climate Insurance Initiative*, 1–15.

Food and Agriculture Organization (FAO) (2015), 'Climate change and food security: risks and response', Food and Agricultural Organization of the United Nations, available at: https://www.fao.org/3/i5188e/i5188e.pdf

Food and Agriculture Organization (FAO) (2016), Fiji Tropical Cyclone Winston Situation Report – 16 March 2016, Available at: https://www.fao.org/resilience/resources/resources-detail/en/c/396283/

Food and Agriculture Organization (FAO) (2017), Review of the development of the rice industry in Fiji, available at: https://www.fao.org/3/i7106e/i7106e.pdf

Fiji Ministry of Agriculture (2018), 'Fiji Agriculture & Rural Statistics', available at: https://www.unsiap.or.jp/e-learning/el_material/5_Agri/1808_Sampling_FJI/P_FIJI.pdf

Fiji Ministry of Agriculture (2021), 'Fiji Agriculture Census 2020: Key Findings', available at: https://www.agriculture.gov.fj/documents/census/2020FACINFOGRAPHICSOFMAJORFINDINGS.pdf

Fiji Bureau of Statistics (2021), '2019-20 household income and expenditure survey preliminary release', 8 February 2021, available at: https://www.statsfiji.gov.fj/

Fiji Revenue and Custom's Service (2018), 'Talk Tax: Tax of Insurance', available at: www.frcs.org.fj/wp-content/uploads/2018/02/89.Talk-Tax-Insurance-FT.pdf

Fiji Women's Rights Movement (2018), 'The Right to Privacy in the Digital Age', available at: https://www.ohchr.org/sites/default/files/Documents/Issues/DigitalAge/ReportPrivacyinDigitalAge/FWRM.pdf

Franzke, C.L. (2017). 'Impacts of a changing climate on economic damages and insurance'. *Economics of Disasters and Climate Change*, *1*(1), 95–110.

GFDDR (2016), 'Post-Disaster Needs Assessment, Tropical Cyclone Winston', February 20, 2016. Available at: https://www.gfdrr.org/sites/default/files/publication/Post%20Disaster%20Needs%20Assessments%20CYCLONE%20WINSTON%20Fiji%202016%20(Online%20Version).pdf

Global Innovation Lab for Climate Finance (2019), 'Blockchain Climate Risk Crop Insurance: Lab Instrument Analysis', September, available at: www.climatepolicyinitiative.org/wp-content/uploads/2020/08/Blockchain-Climate-Risk-Crop-Insurance_instrument-analysis.pdf

Government of Fiji (2016), 'Fiji Post-Disaster Needs Assessment: Tropical Cyclone Winston, February 20, 2016', Government of Fiji, available at: https://www.gfdrr.org/sites/default/files/publication/Post Disaster Needs Assessments CYCLONE WINSTON Fiji 2016 (Online Version).pdf

Government of Fiji. (2017a), '5-Year and 20-Year National Development Plan', Ministry of Economy, Republic of Fiji, available at: https://www.fiji.gov.fj/getattachment/15b0ba03-825e-47f7-bf69-094ad33004dd/5-Year---20-Year-NATIONAL-DEVELOPMENT-PLAN.aspx

Government of Fiji (2017b), 'Climate Vulnerability Assessment: Making Fiji Climate Resilient', Government of Fiji, World Bank, and Global Facility for Disaster Reduction and Recovery, available at: http://documents.worldbank.org/curated/en/163081509454340771/pdf/120756-WP-PUBLIC-nov-9-12p-WB-Report-FA01-SP.pdf

Government of Fiji (2018a), 'Planned Relocation Guidelines: A framework to undertake climate change related relocation', Ministry of Economy, Government of Fiji, available at: http://fijiclimatechangeportal.gov.fj/document/

planned-relocation-guidelines-framework-undertake-climate-change-relatedrelocation

Government of Fiji (2018b), 'Republic of Fiji National Adaptation Plan: A pathway towards climate resilience', Government of Fiji, available at: https://www4.unfccc.int/sites/NAPC/Documents/Parties/NationalAdaptation Plan_Fiji.pdf

Government of Fiji 2019, 'Minister Reddy's speech for the whole nut processing training coconut-nutrition, health and wealth', available at: https://www.fiji.gov.fj/Media-Centre/Speeches/English/MINISTER-REDDY-S-SPEECH-FOR-THE-WHOLE-NUT-PROCESSI

GSMA (2019), 'The Mobile Economy: Pacific Islands', available at: www.gsma.com/mobileeconomy/wp-content/uploads/2020/03/GSMA_MobileEconomy2020_Pacific_Islands.pdf

Greatrex, H, J Hansen, S Garvin, R Diro, S Blakeley, M Le Guen, K Rao and D Osgood (2015), 'Scaling up index insurance for smallholder farmers: Recent evidence and insights', *CCAFS Report* 14, 1–32

Herbert Smith Freehills LLP (2019), 'UKJT Legal Statement on Cryptoassets and Smart Contracts Aims to Give Market Confidence That England and Wales Is a Crypto-Friendly Jurisdiction', available at: https://hsfnotes.com/tmt/2019/12/16/ukjt-legal-statement-on-cryptoassets-and-smart-contracts-aims-to-give-market-confidence-that-england-wales-is-a-crypto-friendly-jurisdiction/

Hilft, B.E., P. Mucke and L. Kirch (2020). 'Fisheries at Risk: Vulnerability of Fisheries to Climate Change', available at: https://www.nature.org/content/dam/tnc/nature/en/documents/Fisheries-at-Risk-Technical-Report.pdf

Hillier, D (2018), 'Facing Risk: Options and challenges in ensuring that climate/disaster risk finance and insurance deliver for poor people', Oxfam. Oxford Available at: https://oxfamilibrary.openrepository.com/bitstream/handle/10546/620457/bp-facing-risk-climate-disaster-insurance-160418-en.pdf?sequence=13

International Association of Insurance Supervisors (IAIS) (2018), 'Climate change risks to the insurance sector', Issues Paper, International Association of Insurance Supervisors, available at: https://www.insurancejournal.com/research/app/uploads/2018/08/IAIS_and_SIF_Issues_Paper_on_Climate_Change_Risks_to_the_Insurance_Sector_-1.pdf

International Fund for Agriculture Development (IFAD) (2017), 'Exploring the Advantages of Blockchain Technology for Smallholder Farming', available at: https://www.ifad.org/documents/38714170/39135645/blockchain_smallholders.pdf/d4506af0-79d1-04df-7800-98b380f80dfa

International Labour Organization (2017), 'A study of the Future of Work in the Pacific', ILO Office for Pacific Island Countries, available at: https://www.ilo.org/wcmsp5/groups/public/---asia/---ro-bangkok/---ilo-suva/documents/publication/wcms_553880.pdf

IPCC, 2018: Summary for Policymakers. In: *Global Warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty* [Masson-Delmotte, V., P. Zhai, H.-O. Pörtner, *et al.* (eds.)]. World Meteorological Organization, Geneva, Switzerland, 32 pp.

Kharin, V.V., G.M. Flato, X. Zhang, N.P. Gillett, F. Zwiers and K.J. Anderson (2018). 'Risks from climate extremes change differently from 1.5 C to 2.0 C depending on rarity'. *Earth's Future*, *6*(5), 704–715.

Knezevic, D (2018), 'Impact of Blockchain Technology Platform in Changing the Financial Sector and Other Industries', *Montenegrin Journal of Economics*, 14(1), 109–120.

Konsta, S (2018), 'Parametric Insurance: Closing the Protection Gap - Legal Considerations', available at: https://www.unisdr.org/preventionweb/files/56544_clydecoresilienceparametricinsuranc.pdf

Kreft, S., D. Eckstein and I. Melchior (2016). Global climate risk index 2017. 'Who suffers most from extreme weather events? Weather-related loss events in 2015 and 1996 to 2015'. *Germanwatch*. Available at https://policycommons.net/artifacts/1555054/global-climate-risk-index-2017/2244863/

Kuleshov, Y, S McGree, D Jones, A Charles, A Cottrill, B Prakash and FLSK Seuseu (2014), 'Extreme weather and climate events and their impacts on island countries in the Western Pacific: cyclones, floods and droughts', *Atmospheric and Climate Sciences* 4(05), 803.

V Lal, B. (2011). *A Vision for Change: AD Patrel and the Politics of Fiji*. ANU Press.

Lamberti, F, V Gatteschi, C Demartini, C Pranteda and V Santamaria (2017), 'Blockchain or not blockchain, that is the question of the insurance and other sectors', *IT Professional*, 1–1.104Strengthening Disaster Resilience in Small States

Mahendra Dev, S (2012), 'Climate change, rural livelihoods and agriculture (focus on food security) in Asia-Pacific region'. *Indira Gandhi Institute of Development Research*, Available at: http://oii.igidr.ac.in:8080/xmlui/bitstream/handle/2275/141/WP-2011-014.pdf?sequence=1

Mahendra, RS, PC Mohanty, H Bisoyi, TS Kumar and S Nayak (2011), 'Assessment and management of coastal multi-hazard vulnerability along the Cuddalore–Villupuram, east coast of India using geospatial techniques', *Ocean & Coastal Management*, *54*(4), 302–311.

Mahul, O, S Cook and B Bailey (2015), 'Advancing Disaster Risk Financing and Insurance in the Pacific', Washington DC, World Bank.

Mik, E (2017), 'Smart Contracts: Terminology, Technical Limitations and Real World Complexity', 9 *Law, Innovation and Technology* 269, available at: https://doi.org/10.1080/17579961.2017.1378468

Miles, KS and M Wiedmaier-Pfister (2018), 'Applying a gender lens to climate risk finance and insurance', InsuResilience Global Partnership, available at: https://www.insuresilience.org/wp-content/uploads/2018/11/insuresilience_applygender_181128_web.pdf

Nakamoto, S. (2008). 'Bitcoin: A peer-to-peer electronic cash system'. *Decentralized Business Review*, 21260.

NFIT (2019), '2019 Financial Inclusion Report, National Financial Inclusion Taskforce, Reserve Bank of Fiji'. Available at: http://www.nfitfiji.com/wp-content/uploads/Fiji-Financial-Inclusion-Annual-report-2019_final.pdf

Observer (2017), 'How Blockchain Technology Can Help Poor People Around the World'. Observer, available at: https://observer.com/2017/05/how-blockchain-technology-can-help-poor-people-around-the-world-banking-emerging-markets/

Organisation for Economic Co-operation and Development (OECD) (2018a), 'Financial inclusion and consumer empower in Southeast Asia', available at: https://www.oecd.org/finance/Financial-inclusion-and-consumer-empowerment-in-Southeast-Asia.pdf

OECD (2018b), 'Assessing the Real Cost of Disaster: The Need for Better Evidence'. OECD Reviews of Risk Management Policies. OECD Publishing, Paris, 17–64.

Pacific Catastrophe Risk Assessment and Financing Initiative (PCRAFI) (2011), 'Country Risk Profile: Fiji. Pacific Catastrophe Risk Assessment and Financing', available at: https://pcric.org/wp-content/uploads/2022/03/Fiji.pdf

PCRAFI in collaboration with Pacific-Australia Climate Change Science and Adaptation Planning Program (2013), 'Current and Future Tropical Cyclone Risk in the South Pacific, Country Risk Profile: Fiji', available at: https://www.pacificclimatechange.net/sites/default/files/PCRAFI_country-risk-profile_Fiji.pdf

PCRAFI (2015), 'Country Note: Fiji', World Bank, available at: http://pcrafi.spc.int/documents/193

PICAP (2020), Pacific Insurance and Climate Adaptation Programme, United Nations Capital Development Fund, available at: https://www.uncdf.org/pacific-insurance-and-climate-adaptation-programme

Paech, P. (2017). 'The governance of blockchain financial networks'. *The Modern Law Review*, *80*(6), 1073–1110.

Prabhakar, S, GS Rao, K Fukuda and S Hayashi (2013), 'Promoting Risk Insurance in the Asia-Pacific Region: Lessons from the Ground for the Future Climate Regime under UNFCCC', in Philipp Schmidt-Thome and Johannes Klein (eds.), *Climate Change Adaptation in Practice: From Strategy Development to Implementation,* John Wiley & Sons, Ltd., Oxford.

PWC. (2017). 'Blockchain, a catalyst for new approaches in insurance'. Available at: https://www.pwc.com/gx/en/insurance/assets/blockchain-a-catalyst.pdf

Reserve Bank of Fiji (2020), *Insurance Annual Report 2019*, Reserve Bank of Fiji, available at: https://www.rbf.gov.fj/insurance-annual-report-2019/

RNZ (2021) 'Fiji's cyclone Yasa damage bill climbs to $345 million', *Stuff*, 16 February, available at: https://www.stuff.co.nz/world/south-pacific/300231865/fijis-cyclone-yasa-damage-bill-climbs-to-345-million

Sandland, C, D Schilling and A Marke (2019), 'A critical analysis on the capacity of blockchain-based parametric insurance in tackling the financial impact of climatic disasters', *Strengthening Disaster Resilience in Small States: Commonwealth Perspectives*, 87.

Schimel, A (2020), 'Fiji', in Barnes, P (ed.), *A Pacific disaster prevention review*, Australian Strategic Policy Institute Limited, available at: https://www.aspi.org.au/report/pacific-disaster-prevention-review

Seager, J (2014), 'Disasters Are Gendered: What's New?', in *Reducing disaster: Early warning systems for climate change*, Springer, Dordrecht, 265–281.

Singh-Peterson, L and M Iranacolaivalu (2018), 'Barriers to market for subsistence farmers in Fiji – A gendered perspective', *Journal of Rural Studies*, 60, 11–20, available at: https://doi.org/10.1016/j.jrurstud.2018.03.001

Sloan, J (2019), 'Migrant workers: legal and other challenges for Fiji and the Pacific', available at: https://www.sas.com.fj/commercial-law-updates/regulation-of-migrant-workers-in-fiji-and-the-pacific

Sprout. (2018). 'Climate risk Insurance Solution: Productizing Blockchain to Reach the 99% of Uninsured Farmers with a Novel Microinsurance Infrastructure'. Available at: www.sproutinsure.com

Thirumalai, K., P.N. DiNezio, Y. Okumura and C. Deser (2017). Extreme temperatures in Southeast Asia caused by El Niño and worsened by global warming. *Nature communications*, 8(1), 1–8. Available at: https://www.nature.com/articles/ncomms15531

Thomas, A, P Pringle, P Pfleiderer and CF Schleussner (2018), 'Tropical cyclones: impacts, the link to climate change and adaptation'. Available at: https://climateanalytics.org/publications/2017/tropical-cyclones-impacts-the-link-to-climate-change-and-adaptation/

Tol, R (2018), 'Economic Impacts of Climate Change', *Review of Environmental Economics and Policy*, 12(1), 4–25. Available at: https://www.journals.uchicago.edu/doi/abs/10.1093/reep/rex027

United Nations Capital Development Fund (UNCDF) (2020a), 'Economic Impacts of Natural Hazards on Vulnerable Populations in Fiji', UNCDF, available at: https://climate-insurance.org/wp-content/uploads/2021/01/Fiji-Economic-Impacts-Report-27Nov2020.pdf

UNCDF (2020b), 'Economic Impacts of Natural Hazards on Vulnerable Populations in FIJI', available at: https://climate-insurance.org/wp-content/uploads/2021/01/Fiji-Economic-Impacts-Report-27Nov2020.pdf

UNCDF (2020c), 'Economic Impacts of Natural Hazards on Vulnerable Populations in Fiji, Papua New Guinea, Samoa, Solomon Islands, Tonga, and Vanuatu', available at: https://www.uncdf.org/Download/AdminFileWithFilename?id=14103&cultureId=127&filename=economic-impact-of-natural-hazards-on-vulnerable-populations-reportpdf

UN Development Programme (UNDP) (2017), 'Financing Solutions for Sustainable Development: Disaster Risk Insurance'. UNDP, available at: https://www.undp.org/content/dam/sdfinance/doc/Disaster%20Risk%20Insurance%20_%20UNDP.pdf, 1–3.

UN Office for Disaster Risk Reduction (UNDRR) and Asian Disaster Preparedness Center (2019), Disaster Risk Reduction in the Republic of Fiji: Status Report 2019. UNDRR and Asian Disaster Preparedness Center, available at: https://reliefweb.int/report/fiji/disaster-risk-reduction-republic-fiji-status-report-july-2019

UNISDR (2015) 'Sendai Framework for Disaster Risk Reduction 2015-2030', UNISDR, Geneva, 10–23. Available at: https://www.undrr.org/publication/sendai-framework-disaster-risk-reduction-2015-2030

UNISDR, (2018). Economic Losses, Poverty, & Disasters 1998-2017. CRED-UNISDR. Available at: https://www.preventionweb.net/files/61119_credeconomiclosses.pdf

US Agency for International Development (USAID) (2018), 'Climate Risk Profile: Pacific Islands'. USAID Available at: https://www.climatelinks.org/sites/default/files/asset/document/2018-26-Feb_CadmusCISF_Climate-Risk-Profile-Pacific-Islands.pdf

Van Anrooy, R., F. Espinoza Córdova, D. Japp, D. *et al*. (2022). World review of capture fisheries and aquaculture insurance 2022. FAO Fisheries and Aquaculture Technical Paper No. 682. Rome, FAO. https://doi.org/10.4060/cb9491en

Vuki, VC and A Vunisea (2016), 'Gender issues in culture, agriculture and fisheries in Fiji', *SPC Women in Fisheries Information Bulletin*, 27, 15–18.

Vulnerable Twenty (V20) (2015), 'Communiqué of the Inaugural V20 Ministerial Meeting', in Vulnerable Twenty Group of Ministers of Finance, Lima, Peru, 8 October 2015, 1–4.

ADB (2019), 'Assessment, Country Diagnostics. "THE ENABLING ENVIRONMENT FOR DISASTER RISK FINANCING IN FIJI.", available at: https://www.adb.org/sites/default/files/publication/485561/fiji-environment-disaster-risk-financing.pdf

World Bank (2007), Caribbean Catastrophe Risk Insurance Facility: A solution to the short-term liquidity needs of small island states in the aftermath of natural disasters, World Bank, Washington, DC, 1–4.

World Bank (2010), A Review of CCRIF's Operation After its Second Season, The Caribbean Catastrophe Risk Insurance Initiative, available at: https://documents1.worldbank.org/curated/en/164301468225617268/pdf/846360WP0Box380CCRIFReview200802009.pdf

World Bank (2017), *Pacific Possible: Long-term Economic Opportunities and Challenges for Pacific Island Countries*, World Bank, available at: http://documents1.worldbank.org/curated/en/168951503668157320/ pdf/ACS22308-PUBLIC-P154324-ADD-SERIES-PPFullReportFINALscreen.pdf

World Bank Group. 2020. Country Partnership Framework for the Republic of Fiji FY2021-FY2024. World Bank, Washington, DC. World Bank. https://openknowledge.worldbank.org/handle/10986/35099 License: CC BY 3.0 IGO.

World Trade Organization (2019), 'Pacific study (focusing on Fiji, Tonga and Vanuatu)', in *Third Symposium on Natural Disasters and Trade*, WTO, available at: https://www.wto.org/english/tratop_e/devel_e/ study_1_pacific_country_annex_18_april_draft_final.pdf

Yamineva, Y. (2016). Climate Finance in the Paris Outcome: Why Do Today What You Can Put Off Till Tomorrow?. *Review of European, Comparative & International Environmental Law*, 25(2), 174–185.

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