



UNIVERSITY OF CAPE TOWN

MINOR DISSERTATION

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**A decentralised asset registry to expand  
access to finance for the agricultural sector  
in South Africa**

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*A thesis submitted in fulfillment of the requirements  
for the degree of Master of Philosophy*

*in the*

**Financial Technology (FinTech)  
African Institute of Financial Markets and Risk Management**

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UNIVERSITY OF CAPE TOWN

## *Abstract*

Commerce Faculty

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Master of Philosophy

### **A decentralised asset registry to expand access to finance for the agricultural sector in South Africa**

by Kungela MZUKU

Over 61 percent of Africans are involved in agriculture; of this, only a few have access to financial services catered for their business. To get financial assistance, farmers have to provide sufficient collateral in the form of land, machinery and other large assets, many of which they do not own. Instead, farmers own mostly agricultural assets such as cattle, pigs and crop trees. The aim of this study is to make use of the agricultural resources available to farmers as collateral for financial loans. This was achieved through the development of a decentralised agricultural registry between farmers and the financial sector. Through an exploratory study, it was found many African countries introduced Movable Property laws to help increase acceptable collateral for financial loans. Unfortunately, many limitations were encountered which resulted in the adoption of the laws to be extremely low. As a result, this paper looks to blockchain technology as a solution as it would allow for transparency between farmers, government and financial sector. By creating a decentralised agricultural registry, farmers can register their biological assets and financiers can verify that the assets exists, are healthy and are currently not being used as collateral in another loan agreement. It is hoped that the registry can be used as a tool when financial agreements between farmers and banks are conducted.

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## Chapter 1

# Introduction

### 1.1 Introduction

Over 61% of Africans are involved in Agriculture while less than 1% of formal credit facilities are given to the sector (Africa, 2017). Acquiring financial help from a formal financial institution, such as a bank, is a strenuous task for emerging farmers in South Africa. Farmers who own their land are regularly granted loans by banks, and farmers who lease their land are rejected due to insufficient collateral. Rejected farmers often then turn to government grants for assistance. Although the service is available to all, funding is limited and should their application be approved; it will take years for the funds to be received by the farmer.

Collateral is an important topic to explore when it comes to expanding access to finances for businesses in emerging markets. Many African countries have introduced laws that broaden the list of acceptable collateral for loans (Desmond, 2017). Before individuals had to own land to be considered eligible for a loan. With these new laws, vehicles, cattle and crops can be used instead of a land. However, the practical implementation of the laws has introduced challenges. Consumers have found it hard to register their new assets as multiple parties are needed to verify that indeed the asset exists and is in good health. Furthermore, finance providers lacked trust in the process as consumers could use one the same cattle in multiple loan agreements without them knowing.

Blockchain technology has been a popular buzzword in the financial industry. Apart from cryptocurrencies, many use cases have implemented blockchain as a "decentralised database" to store valuable information in an encrypted and trustless environment (Kamanashis and Vallipuram, 2016). Ethereum, the second largest cryptocurrency, introduced a programmable blockchain which allows developers to create decentralised applications called "dapps" and "smart contracts", which are contractual agreements that can be executed autonomously between a buyer and a seller (Konstantinos and Michael, 2016).

The Ethereum Blockchain is fast becoming a key instrument in innovation, particularly within the agriculture space. Successful use cases include using blockchain to track produce from Farm-to-Fork and the creation of marketplaces where cattle and crops can be traded easily among users (Andreas, Francesc, and Agusti, 2018).

The increase of availability data within the agricultural industry has allowed for agricultural assets to be increasingly recognized as an emerging asset class. In recent years, the financial services industry has taken an interest in agriculture due to it's ability to provide attractive returns on investments made, uncorrelated returns to the stock market, and the ability to be hedged against inflation (Ducastel and Ward, 2017).

The aim of this thesis is to use blockchain technology as asset registry in order to expand access to finance in emerging markets. The asset registry will help facilitate the use of alternative assets as collateral for financial loans.

This thesis will focus on the Macadamia Nut industry in South Africa as a use case. The reason for this selection is invigorated by the large amount of Macadamia Farmers are making use of precision agriculture technology. Many farmers are making use of the (*Aerobotics*) platform. Aerobotics is an agricultural management platform that warns farmers of pests and diseases before they happen.

This research is worth doing because for the first time in history, farmers are able to precisely track the health of their crops. The tracking of crops (using Aerobotics) has created a historical database of crop health and farming practices of the farmer. This means that farmers have a digital history of agricultural business which they can use to lower insurance premiums or to get better interest rates on loan.

Together with the rise of Blockchain technology, agricultural data can now be made available to third parties such as banks, insurers and government entities. This thesis hopes to create interest in the agricultural, finance and technology industry so that all three sectors can work together on one solution.

### 1.1.1 Research Questions

To achieve the research aim, the following research question will be explored;

**How can decentralised technology assist in expanding access to finance for agricultural businesses in South Africa?**

In order to answer the research question above, this thesis will probe the following sub-questions;

- What financial challenges are faced by agricultural businesses?
- How have agricultural assets been used as collateral for loans?

- To what extent can blockchain technology be used to create an agricultural asset registry for farmers?

### 1.1.2 Research Objectives

The following research objectives were constructed in order to address the research questions (1.1.1);

1. Explore the South African Financial Landscape for small to medium enterprises
2. Examine past use cases where agricultural assets have been used as collateral for loans
3. Evaluate critically the use of blockchain technology as a solution
4. Explore the financial challenges faced by macadamia nut farming industry
5. Demonstrate an agricultural asset registry that uses blockchain technology
6. Discuss the limitations presented by a decentralised agricultural asset registry

### 1.1.3 Research Methodology

The research objectives are achieved through explanatory methods of research. This exploration includes an internship at an agricultural technology company, interviews, and multiple engagements with farmers throughout the country. The researcher chose to immerse themselves fully in the sector to gain domain knowledge into the agricultural landscape.

This thesis focuses mainly on the agricultural industry and the exploration of blockchain as a solution. The paper shows a snapshot in time, and it acknowledges that the findings may change.

This thesis will follow the Design Science Research (DSR) Methodology as developed by Vaishnavi and Kuechler (2004). The methodology was designed for "(1) the creation of new knowledge through the design of novel or innovative artifacts (things or processes) and (2) the analysis of the artifact's use and/or performance with reflection and abstraction" (Vaishnavi and Kuechler, 2004, p. 1). DSR contains five stages, and a summary of the process is shown by figure 1.1 below.

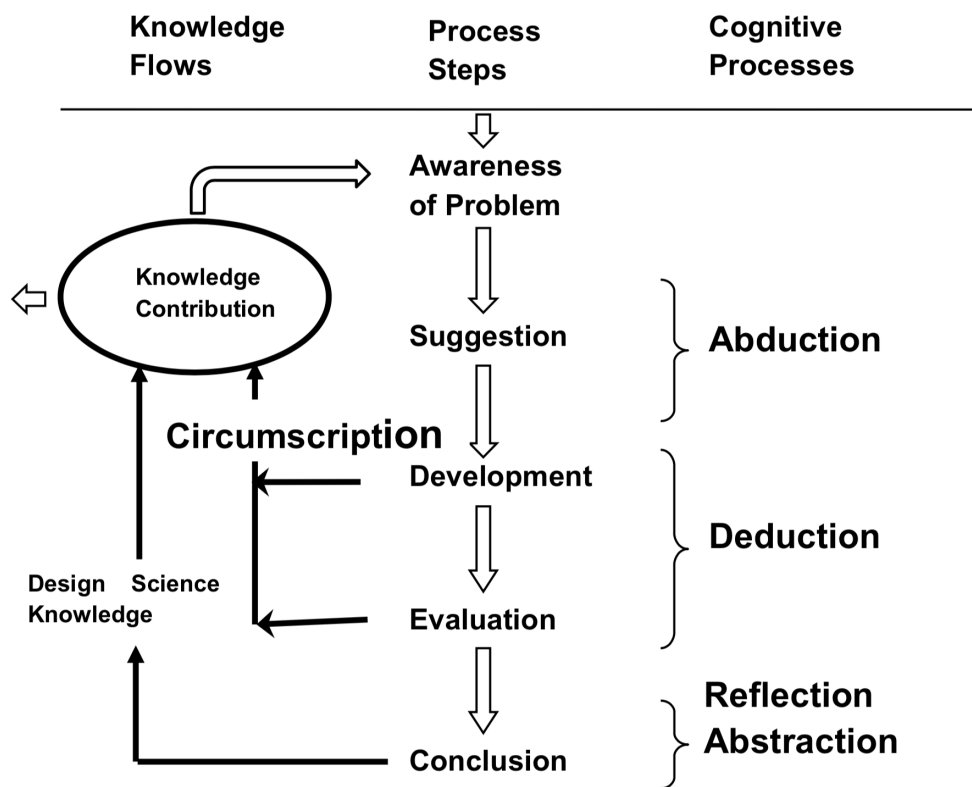


FIGURE 1.1: Design Science Methodology (Vaishnavi and Kuechler, 2004)

### Stage 1: Awareness of the problem

In this thesis, the problem is sparked by various challenges faced by farmers when applying for financial assistance. Farmers who do not own lands struggle to loans due to insufficient collateral. In the literature review we explore (1) access to finance small to medium businesses in South Africa, (2) the South African financial landscape and agriculture, (3) the current use of agricultural assets as collateral in African countries and, (4) blockchain technology. Simultaneously the research questions are developed within the literature review section, and they form the basis of the research objectives which are stated in section 1.1.1 above.

### Stage 2: Suggestion

Stage 2 analyses the macadamia nut industry and the financial constraints faced by farmers. The suggestion is to develop an agricultural asset registry which allows farmers to use macadamia trees as collateral for trees.

### Stage 3: Development

The agricultural asset registry is designed through an iterative approach. Three designs are created and evaluated to see if they fit the platform objectives. The third design is chosen as the final design which is developed. Blockchain technology is used to facilitate the back-end database, and the smart contracts facilitate the interaction between farmers and loan providers.

**Stage 4: Evaluation**

The benefits and limitations of the proposed system are discussed.

**Stage 5: Conclusion**

The thesis is concluded, and the research main research question is answered.

## Chapter 2

# Literature Review

### 2.1 Introduction

The following literature review will explore how decentralised technology can be used to improve access to finance for agricultural businesses in South Africa. The study conducted within this literature review will focus on research objectives 1, 2, and 3 as detailed in 1.1.2 of the Introduction chapter. Firstly, the South African financial landscape for small to medium enterprises (SMEs) will be explored to provide the context and environment for agricultural SMEs which are treated similar to any other business. It is hoped that by the end of this chapter, the reader would have gained a critical understanding of the financial challenges faced by agricultural businesses in South Africa.

The overall aim of the thesis is to build an agricultural asset registry platform which will be used by farmers in their applications for financial assistance. To build such a platform, the financial challenges experienced currently by farmers will be explored so that a wholesome solution is built. Secondly, past use cases where agricultural assets have been used as collateral will be examined as well as limitations experienced by parties who have taken part in the process. Lastly, the use of blockchain as a technological solution will be examined. Due to blockchain being an emerging technology, a cautious approach will be taken to assess whether or not the technology will fit the use case.

### 2.2 The Financial Landscape for Small to Medium Enterprises in South Africa

Small to Medium Enterprises (SMEs), play an essential role in the future economic prospects of African countries. The South African government classifies SMEs according to their annual turnover and the number of employees. SMEs are businesses that make less than R64 million turnover annually, have capital assets which are less than R10 million and employ less than 200 people (Research, 2016). There are a

significant proportion of individuals from previously disadvantaged communities who make up SMEs, and most rely on financial services to provide capital for their business (Amoako-Adu and Eshun, 2018).

The SME South African organisation conducted a survey, of the 1157 owners interviewed, 33% expressed they were unable to gain access to funding due to “operating history, inadequate cash flow and limited collateral” (Africa, 2018). Furthermore, of the small percentage of SMEs who have sufficient collateral, research shows that 50% of financial services struggle to define and register collateral, as more often than not, verification of ownership is costly to administer (Niinimaki, 2011). Many SME owners are new to entrepreneurship and many are forced to start small businesses due to little to no financial income. Taking into account the economic environment that the majority of entrepreneurs come from, one can argue that the lack of financial history, little to no cash flow and limited collateral is expected.

Literature paints a picture that Small to Medium Enterprise (SME) owners are struggling to gain access to finance. The environment is much more difficult for African nations as SME find themselves in a place where (1) Africa is considered riskier than other regions, (2) small businesses are considered a risky investment worldwide (Peter et al., 2017). The challenges are significantly worse for women and youth entrepreneurs because often, they do not meet the requirements. Title-Deeds and rights to land are mostly owned by heads of households and breadwinners, who are often the male figures of the family. This has been primarily caused by the socio-economic factors and cultural traditions that have influenced households for years. The broadening of assets has the potential to improve the businesses of women and youth entrepreneurs, particularly those in poverty-stricken nations.

The amount of individuals from previously disadvantaged communities is exceptionally high, and most rely on financial services to finance their business. Due to the high demand from the community for finance and low supply finance from providers, financiers are forced to be cautious when choosing who to provide finances to. Individuals and small business owners are required to have sufficient collateral to gain access to a lending facility. Although the amount of collateral deemed as "sufficient" is subjective to the financial institution, many make use of land as a deciding factor, and entrepreneurs who do not own land are rejected from formal lending institutions.

### **2.3 How biological assets are valued**

Agriculture within finance is seen as a sum of independent assets, and these assets include "title deeds, water rights and a biological asset" (Ducastel and Ward, 2017, p. 205). An asset is defined as anything that can generate positive cash flow in the future, and it is known to carry value today. The most important characteristic of

an asset is that its liquid. Should the owner of the asset wish to bequeath their ownership rights in exchange for profits, they should be able to do so easily.

For financial services to see South African farms as a viable investment option, they need to (1) have the ability to increase their cash flow on hand, today or in future, (2) increase the liquidity of the agricultural asset by creating a demand for the asset and, (3) be able to mitigate the risks which can range from natural risks such as hail storms, market risks (change in government), and economic risks (depreciation of the rand). (Ducastel and Ward, 2017).

In order to accept an asset as collateral, the financial sector has a formal infrastructure in place which is governed by international financial standards and regulation. To comply with international standards, a fair valuation of assets is needed. Scott, Wingard, and Biljon (2016) have identified a series of challenges faced by the public sector when valuing an agricultural assets, which in accounting standards is referred to as "biological assets". These challenges are;

(1) There is no active market available to determine the fair value of a biological asset. To value the assets, one has to rely on estimates and judgments from individuals who have experience in the space.

(2) There is no set guideline which states how one should value a biological asset. Agriculture has multiple different crops and animals which have different agricultural time frames and harvest periods. The difference in life cycles affects how each asset is valued and documented in the financial books.

(3) Many private companies in South Africa follow GRAP 101 which is the Generally Recognised Accounting Practices for Agriculture in order to comply with financial regulations and standards. It is common practice for community leaders or chiefs to sign community contracts with entities such as Asgi-SA, which helps communities to follow generally recognized standards and thus allowing communities to engage in financial markets easily. Not all communities have access to these services, and often contracts are canceled. This leaves a gap in the sector as many farm owners do not understand the financial regulations required.

(4) Valuing biological assets is costly. Agents with experience and specialisation of skills in the agricultural sector are needed. Collectively that has made the fair valuation of biological assets to be costly and challenging to conduct.

Many of the challenges listed above present paint a clear picture of why biological assets are not commonly used in financial services. The assets are costly to value and experienced professionals are needed to conduct a fair valuing process. Together with the high demand for finance, particularly among Small to Medium Enterprises, the current atmosphere does not make it easy for farmers to gain access to finance if they do not own land.

## 2.4 Current Use of Agricultural Assets as collateral for Loans

The ability to leverage of agricultural assets to gain access to financial services is a growing practice within various African countries, particularly those who have a large agricultural emerging market but little to no access to land. The following table 2.1 depicts the countries where movable assets such as crops and cattle are deemed acceptable collateral;

Country	
Zimbabwe	Between 2000 and 2008, Zimbabwe's formal sector shrunk by over 50% following the seizure of white-owned farms across the country. In response to this, then President Robert Mugabe introduced The Movable Property Security Interest Bill. The bill proposes the creation of a "collateral registry" which will be housed by the Zimbabwe Reserve Bank. The collateral registry will be available to small to medium businesses allowing them to use their movable assets as collateral. Since then, access to financial services increased by 8% on average (Banya, 2017).
Uganda	Uganda introduced the Movable Property Bill which is accompanied with The Uganda Registration Services Bureau, an electronic register available to all, which allows for the verification of information regarding an individuals' asset. The main use of the register is to see if the asset has been used before for collateral and mitigate the risk of an individual using one animal for multiple loans (Government, 2018, p. 1).
Kenya	Kenya introduced The Movable Property Security Rights Act which is a centralised registry of movable assets where individuals can verify the securities presented by loan creditors. ("Kenya's to use livestock as security against bank loans" 2017).
Malawi	Malawi introduced a Personal Property Registry system to allow lenders to register collateral and for third parties to check if the proposed asset has been previously used as collateral. Users are required to pay a fee to search and use the receipt to gain access to the search report. ( <i>Personal Property Security Registry</i> )

TABLE 2.1: Current use of agricultural assets as collateral in African countries

The acceptable assets according to the Movable Property bills are motor vehicles, stock for trade, shares, livestock and crops. To register the asset, one needs (1) unique identification number, (2) addresses of the grantor and creditor, (3) description of the asset, (4) the date, and (5) the period of perfection.

Kenya is the only country that introduced a movable assets bill but did not introduce

a central database for collateral. The absence of central database has been accompanied with an increased complaints from financiers that they unable to accept these assets due to the lack of a central database. The financiers would like to share information among each other in order to claim an asset attached to a loan should the creditor default, and to ensure that a specific asset is used for collateral only once. Uganda, Zimbabwe and Malawi have a central database for collateral and since its introduction, Zimbabwe has reported over 10 000 applications from cattle-owning young people seeking loans (Mwareya, 2017).

A study was conducted by Love et al. (2013) comparing 7 countries that introduced movable asset registries and 59 countries that did not have the registries . The results were as follows;

Variable	Effect
Access to finance	8% increase
Access to loan	7% increase
% of working capital financed by banks	10% increase
% of fixed assets financed by banks	20% increase
Interest rate	3% decrease
Maturity	6 months increase

TABLE 2.2: Summary of the results (Love et al., 2013).

As shown in 2.2 above, the introduction of an assets registry has been accompanied with positive financial impacts. Moreover, smaller businesses with less than 20 employees were shown to benefit more from asset registries than bigger and more mature firms.

### 2.4.1 Current Limitations

This is how the process is currently implemented in Zimbabwe 2.1;



FIGURE 2.1: Collateral Registry Process (*Operationalising a Collateral Registry in Zimbabwe*)

The borrower, who is the business owner, will approach a bank and apply for a loan. The bank will grant the loan, using a movable property as collateral. It is the banks responsibility to register the collateral onto the asset registry platform, stipulating

who owns the asset. The bank that registers the asset has priority over the asset should the borrower default on their payment.

Individuals who have made use of the movable property laws in Kenya, Zimbabwe, and Uganda have expressed difficulty during the asset registration process. Currently, photographs are taken of the livestock record book, and third parties such as tribe leaders are required to determine and verify the owner of the cattle. In addition to ownership verification, the asset must be registered with a local veterinary office to make sure it is in good health. Individuals who have expressed the need for a digital database to smooth out the registration process. Currently the entire process is lengthy and costly (Mwareya, 2017).

A second limitation that was expressed, is that specialised services are needed to facilitate the registration, and the overall process up until the loan is repaid. The process requires a high level of trust between all parties involved which include farmers, financiers, community elders, and the government (Tshetlo, 2017). Literature shows that financial institutions find it costly to value biological assets due to financial regulations and requirements from internal compliance requirements.

## 2.5 When to Use Blockchain Technology as a Solution

A thesis titled "Bitcoin - A Peer-to-Peer Electronic Cash System" was released in 2008 by (Nakamoto, 2008), giving birth to Bitcoin, a digital currency that uses encryption techniques to secure and verify transactions. The financial services industry was one of the early adopters of blockchain technology. This interest was sparked by Distributed Ledger Technology (DLT), the underlying technology used for bitcoin payments. DLT has transformed payments, introduced the ability to clear payments in minutes and it increased the speed at which the settlement process is completed. DLT facilitates peer-to-peer transactions that do not require intermediaries to be completed. Once a user processes transactions, it is validated by a miner, and together with a group of other validated transactions, it is added to a chain of blocks (Michael, Cohn, and Butcher, 2018).

Blockchain can be classified into various categories namely permissionless and permissioned (Catalini and Gans, 2017). Permissioned blockchains require participants to request permission in order to interact with the blockchain. Often permissioned blockchains are private chains which are mostly used by corporations who want to reap the benefits that the blockchain provides with a restricted level of transparency. Permissionless blockchains, on the other hand, do not require the participants to be granted permission in order to interact with the blockchain. Permissionless blockchains are public, and examples include Bitcoin and Ethereum networks which can be used by all participants in the network.

Sections 2.3 and 2.4.1 reveal that the current methods of registering biological assets and using them as collateral presents some limitations. These challenges were;

1. Difficult to register assets as engagement is required from many third parties
2. A third trusted party, commonly a community agent, is required to verify the ownership and existent of the asset
3. Asset needs to be registered with the local veterinary office
4. Individuals with specialised skills are needed to facilitate the registration process
5. Trust is needed between all the parties involved
6. Valuing a biological asset is difficult and costly

Blockchain technology provides many benefits that can be exploited to solve the challenges listed above. (Wüst and Gervais, 2018) states the following benefits;

- Transparency allows for all parties to know the state of the data and any party has the ability to verify the data.
- Cryptography ensures that the integrity of the data is maintained and it is difficult to modify the data unless authorized to do so.
- Smart contracts can be used to create digital agreements between the parties involved. Once certain conditions are met, pre-determined functions can be executed. Thus making the system self-operating.

Blockchain offers many benefits which make it a good fit for the problem states in this thesis. Blockchain enables transactions between multiple parties to be conducted in a trusted environment even when one does not exist. The source of the transactions are verifiable, can easily be identified, stored and shared with no friction. Many in literature contend that blockchain is a bubble and it will struggle to get to a stage where the majority of people use it. Blockchain has been labeled as a foundational technology rather than a disruptive one. Instead of disrupting traditional business models that currently exist, it works better for the creation of systems. Looking at the innovation of TCP/IP which had similar expectations to revolutionize the business world, it took 30 years for the transformation to be realized, and Blockchain may take a similar route (Iansiti and Lakhani, 2017). (Godsiff, 2015) concludes that further development of the technology needs to be done in order to realise the full benefits and find use cases that fit its purpose.

To assess whether or not blockchain is the best solution for the case study between the agricultural and finance sector, we use the "Do you need Blockchain" model created by (Wüst and Gervais, 2018).

The model will be tested against the scenario shown in 2.1 which is currently being implemented in Zimbabwe. An asset registry platform exists. Any individual or

entity can add data(the asset) onto to the registry. Once data is added, any party can have access to it. Banks will then state publicly that a specific asset is being used as collateral. This will prevent the same asset from being used in future.

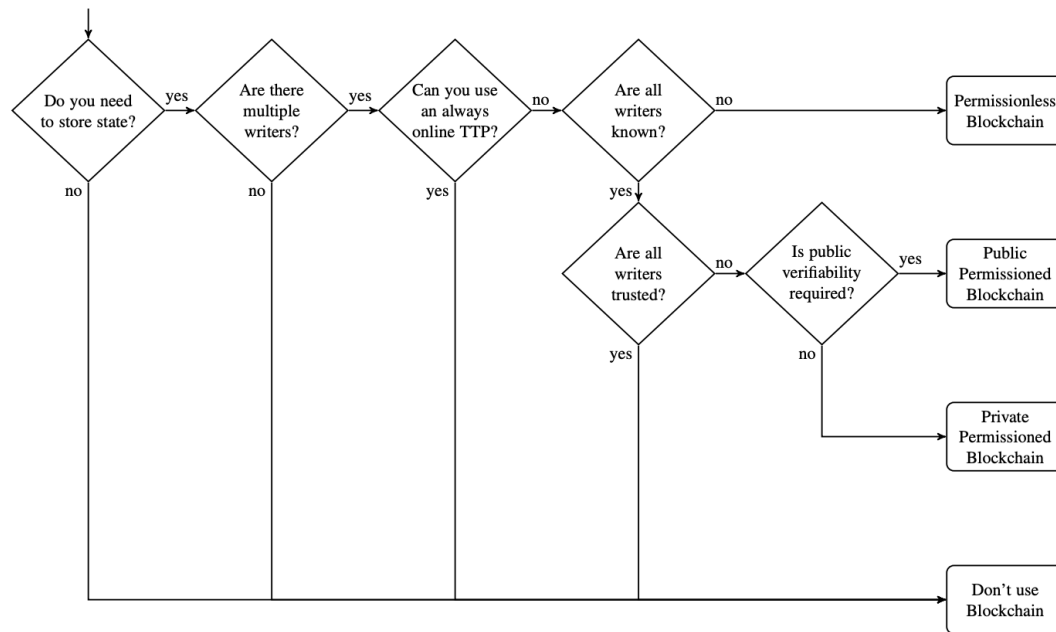


FIGURE 2.2: Do you need a blockchain?

**Do you need to store state?** Yes, the state of the data will need to be stored. When a financial institution registers an asset to be used as collateral, the data will need to be stored and available to asset owners and government officials.

**Are there multiple writers?** Yes, asset owners, community agents, financial providers will need to interact and add to the data. Blockchain Technology allows multiple parties to interact and coordinate with one another (Swan, 2015).

**Can you use an always online trusted third party?** No, using an online trusted third party will create a centralised system with one single point of failure. Should the asset registry database not be available, different parties would have multiple versions of the state of the data which would need to be verified with each other once the database is available. An online trusted third party would, therefore, make it hard for all the parties to verify the data which each other.

**Are all writers known?** Yes, all writers will have to register first before interacting with the data.

**Are all writers trusted?** No, not all writers are trusted. Even though an asset owner can add to the state of the data, banks may not trust the data provided. Thus, additional actions need to be done to prove that the information is indeed true.

**Is public verifiability required?** Yes, not all writers are trusted. Public verifiability allows the data to be transparent and verified publicly to all nodes. In our use

case, should a farmer register a cattle and a community agent verifies the ownership details, a third party bank will see the transaction.

According to 2.2, a public permissioned blockchain would be ideal. It can reduce costs involved with complying with regulation as well provide a secure environment within a trustless environment (Yermack, 2017). Public permissioned blockchain is the right solution for applications where "participants require some means of identifying each other while not necessarily fully trusting each other"(Vukolić, 2017, p. 3). In our scenario, financial institutions will have to identify other financial providers on the platform. If an asset owner makes a change to their profile and asset, it should be visible to all and immediately identifiable that they are the ones who made a change.

Although, making use of blockchain presents some limitations. Firstly, the time of recording of a transaction and the time the block is confirmed by a minor may be minutes apart, thus making it unreliable for timely transactions (Swan, 2015). This means asset verification will take time and potentially, two assets may be registered at the same time according to the blockchain time stamp.

Secondly, transactions on a public blockchain are costly (Marc, 2016). This is caused by the large amounts of nodes that are needed to process the transactions. Whereas private blockchains only need a few nodes to verify the transaction.

In order for the information kept in the blockchain to be reliable and maintain its integrity, it will need to be verified by third parties who have the original data. An example of this is a government municipality verifying an ID number of a farmer. In the traditional setting, this is costly, and a third party is usually paid to carry out the verification. Blockchain will allow for this to happen without an intermediary, thus saving costs for the farmer. It allows for verification to happen a cheap cost to both parties (Catalini and Gans, 2017). Despite this decrease in costs, if data entered at the start of the transaction is faulty, it will not be modified.

Despite the limitations presented, blockchain is still an emerging technology that is yet to be developed. The blockchain, Ethereum, is a development environment that allows users to create decentralised applications that run on the blockchain through the use of Smart Contracts (Bartoletti and Pompianu, 2017, p. 1). Ethereum is also highly community driven and changes are made continuously to fit the needs and address limitations within the technology itself.

A more theoretical and practical analysis is required to explore the extent to which blockchain technology can be used to facilitate the interaction between multiple parties in an industry such as agriculture which relies on physical interactions. Till now, the processes have been manual with each party having their own data center which is not shared among everyone involved in the process. Blockchain would simplify operations in this sector tremendously.

## Chapter 3

# Macadamia Nut Industry Use Case

### 3.1 Introduction

The following chapter will explore the financial challenges faced by macadamia nut farming industry. The study conducted will focus on research objective 4 as detailed in 1.1.2 of the Introduction chapter. This chapter aims to create the context for which the proof of concept would operate and provide context to the design decisions that will follow in chapter 4. It is hoped that by the end of this chapter, the reader would have gained a critical understanding of the Macadamia nut industry and the precision agriculture solution, 3.6, dominating this market in South Africa.

### 3.2 Macadamia Nut Industry Use Case

This thesis proposes the introduction of a blockchain-based agricultural registry in order to improve access to financial services for the emerging market. In the literature review above, the study addressed the significant involvement of Africans in the Agricultural sector, and further demonstrated the interjection of governments to combat the financial gap experienced by farmers and those who owned movable assets such as cattle. Thus, to demonstrate the system, the scope was narrowed down to the Agricultural Sector.

For this thesis, Macadamia Nuts were chosen as the crop (asset) of choice. The reasons for this were;

- South Africa is the largest producer and processor of macadamia nuts in the world.
- Over 95% of Macadamia Nut farmers export their products to China and South America.
- Macadamia trees require high establishment costs which is a barrier for many small farmers, but they offer high returns in the long run.

### 3.2.1 Macadamia Nut Industry and Financial Constraints

To fully understand the financial constraints of a macadamia nut farmer, a diagram depicting the journey was constructed. The diagram aimed to map out fully the process the farmer goes through when farming Macadamia Nuts. It highlighted the various stages involved, starting with the pre-orchard establishment to the payment made by the processing/export company for services rendered. This payment includes the revenue that the farmer makes from selling the product.



FIGURE 3.1: Macadamia Nut Farmer Journey

The following financial constraints were identified;

- The orchard establishment period requires the most capital. Although there is government help, it takes about 2-3 years to receive a grant. Nurseries have long waiting lists as Macadamia Nut trees are in high demand. This list can span years, and thus when farmers reach the front of the list, they need to act quickly.
- During the first three years of the crop's lifecycle, no nuts are being produced. This means the farmer cannot take part in the yearly harvest for three years while still paying for production costs associated with the crops.
- From year four upwards, when the trees start bearing nuts, farmers need to take the relevant measures to harvest the nuts. Extra labour is needed to pick up the nuts that have fallen from trees. Once nuts have been collected and sent to the packing house, the nuts are weighed, and the packing house presents a price.
- The export company then delivers the nuts to the relevant buyers, and at the end of the harvest period, the farmer is paid the revenue. Over 95% of the South African Macadamia nut farmers export their fruit.

Overall, there are many areas for financial investment within the macadamia farmer's journey. The financial constraints faced by farmers, (1) farmers struggle with establishment costs, (2) no revenue is generated by the trees for the first three years of the orchard's lifecycle, (3) farmers who export their produce receive payment only once the harvest period is over.

To address the problems listed above, the following is proposed;

During January each year, Macadamia Farmers are preparing for the harvest season beginning in March. Figure 3.2 below depicts the export season for Macadamia Nuts in South Africa.

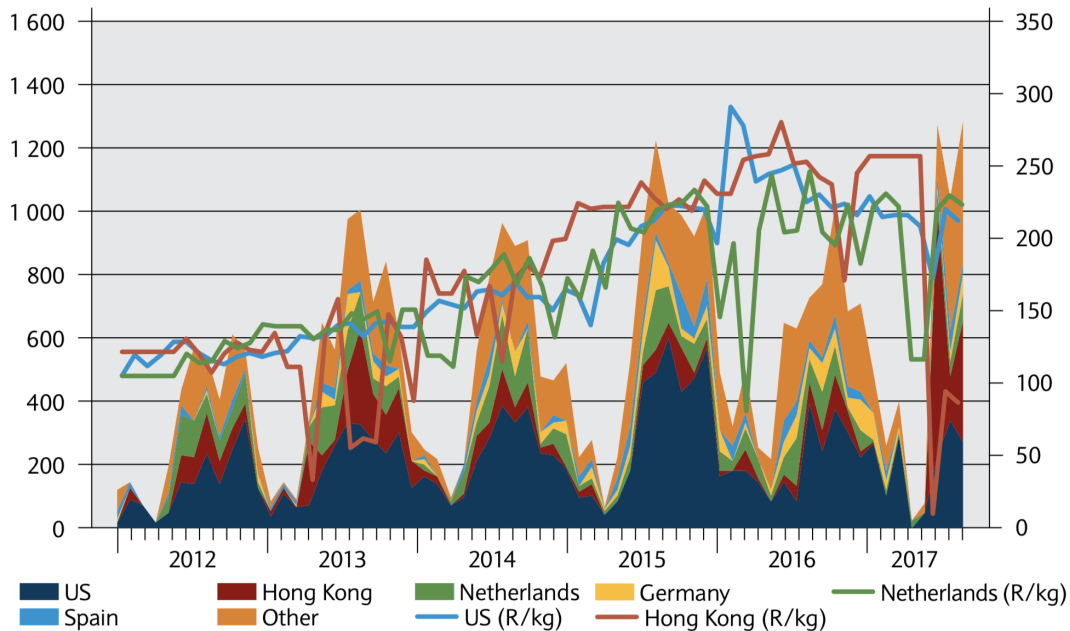


FIGURE 3.2: SA Macadamia Nut Kernel exports (t) and Price Trends (RHS) (*Agricultural Outlook Spring Edition 2017/2018*).

In preparation for the harvest period, the farmer has to find additional casualties who will help pack the nuts and prepare them for the packing house. Once harvest period begins, the nuts will start falling from the tree, to speed up the process, the farmer may shake the tree. The nuts are then picked up every week until all the nuts in the tree have fallen. The following image depicts the annual harvest period experienced by macadamia nut farmers.

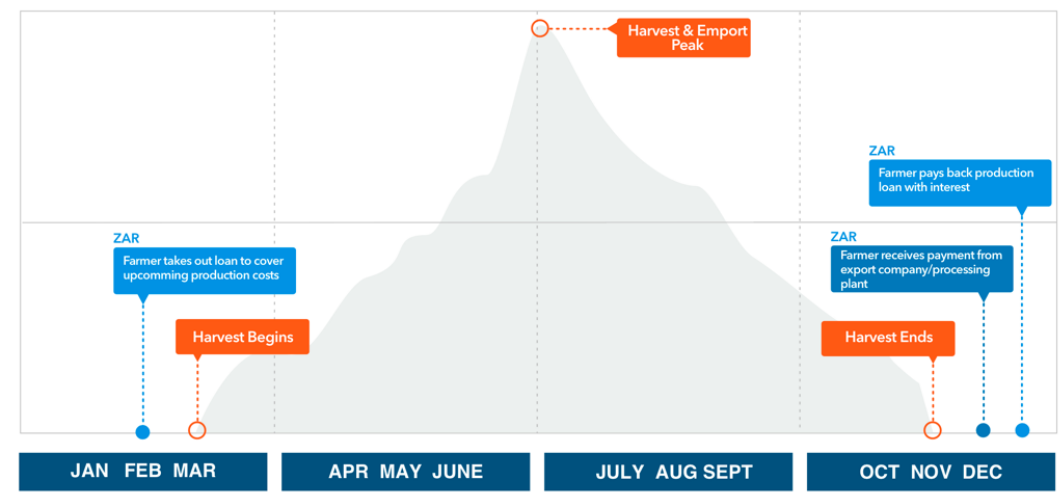


FIGURE 3.3: Macadamia Nut Harvest Period

Due to the costs involved during the harvest period, additional finance can be offered to the farmer before the harvest period begins. The Farmer may take out a production loan to pay for costs during the period of March-November each year. This means that farmers will not have to take out credit agreements with their suppliers in order to survive the busy harvest period.

To get a better understanding of the loan requirements for macadamia nut farmers, an interview was conducted (Appendix A), with an agricultural consultant from an agricultural business and the following financial challenges were mentioned;

- Management found it hard to start business without additional finance from a third party
- Management entered into a loan agreement with an export company in exchange for distributing their produce (at a discounted distribution fee in future) through the export company
- Once the business was profitable, management applied for a bank loan and was rejected due to unacceptable security

Appendix A is an example of a common case, as stated by the interviewee, among profitable agricultural businesses that do not have land as an asset but meet the requirements as stated on the bank sites.

In addition to financial challenges, The interviewee in Appendix A expressed the following;

- There is an increase in demand for transparency within the food supply chain by consumers. This has forced him to adopt safer methods for crop growth.
- The location where his crops are grown is embedded in a barcode which is stamped on the fruit box for consumers to inspect, thus allowing them to see where their produce comes from.
- He believes farmers would tokenize their crops and sell the profits received from future harvests for immediate capital to fund farming operations.

It is evident that crop farmers are tracking their produce through their supply chain and indirectly, the crops have been digitized. This has allowed farmers to gain access to other third party financial providers such as export companies as apposed to financial banks.

There is an increase in demand for transparency from consumers. This trend has forced farmers to share their crop growth methods with their consumers in order to maintain their market share. Farmers have become innovative in how data is shared throughout the supply chain and the idea of "sharing data" has become more common. Through the use of a barcode, other parties in the supply chain are able to track progress and follow the origins of the produce.

### 3.2.2 Third Party Agricultural Data

In order to register an asset, previous literature has shown that one needs to provide proof that the asset exists and provide a description of the asset. Apart from the information, the asset would need to be verified by a third party. Verification ensures that the asset exists and the owner is whom they say they are.

In order to satisfy the requirements needed to accept movable assets as collateral, the use of third-party agricultural data was explored. Macadamia Nut farmers operating in South Africa have adopted precision agriculture to help with productivity within the farm.

The precision agriculture company of choice for many farmers in South Africa is Aerobotics. Aerobotics assess the health of trees through the use of infrared images taken with drone technology. The images are analysed through an artificial intelligence algorithm that analyses the chlorophyll index of the tree. The chlorophyll of a plant indicates that photosynthesis is taking place within the plant, thus signifying health and "life".

Aerobotics provides farmers with four main functions;

1. Early warning detection of pests and diseases
2. Scouting functionality that tells the farmer which of his trees are problematic and should be attended to
3. Tree Monitoring
4. Management Zones for planning

Figure 3.4 below depicts Aerobotics offerings as shown on their website;

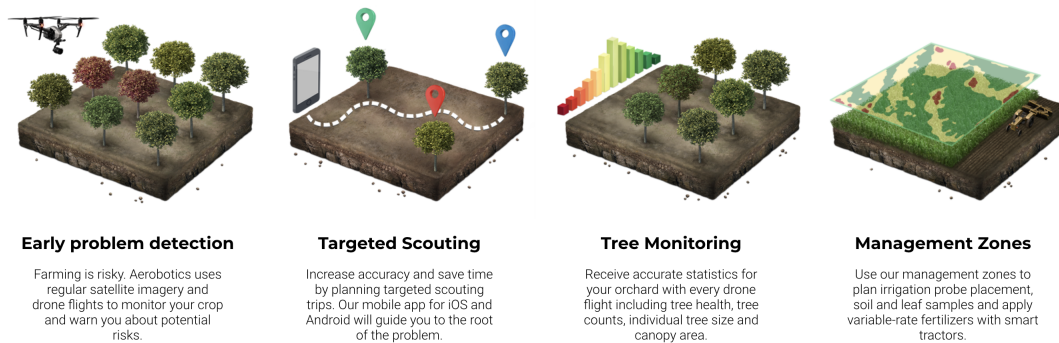


FIGURE 3.4: (*Aerobotics*) Product offerings 2018

These functions are provided through two applications;

### 1. Web Application

It is the main portal used by farmers to interact with Aerobotics and their data. They are provided with a dashboard which will allow them to see their best performing orchard, worst performing orchard, number of pests and diseases detected and overall interaction with the application.

The website application allows farmers to perform the following functions;

- Register their farm
- Request drone flights
- Receive farm data
- Create scout routes depending on problematic trees

### 2. Native Mobile Application

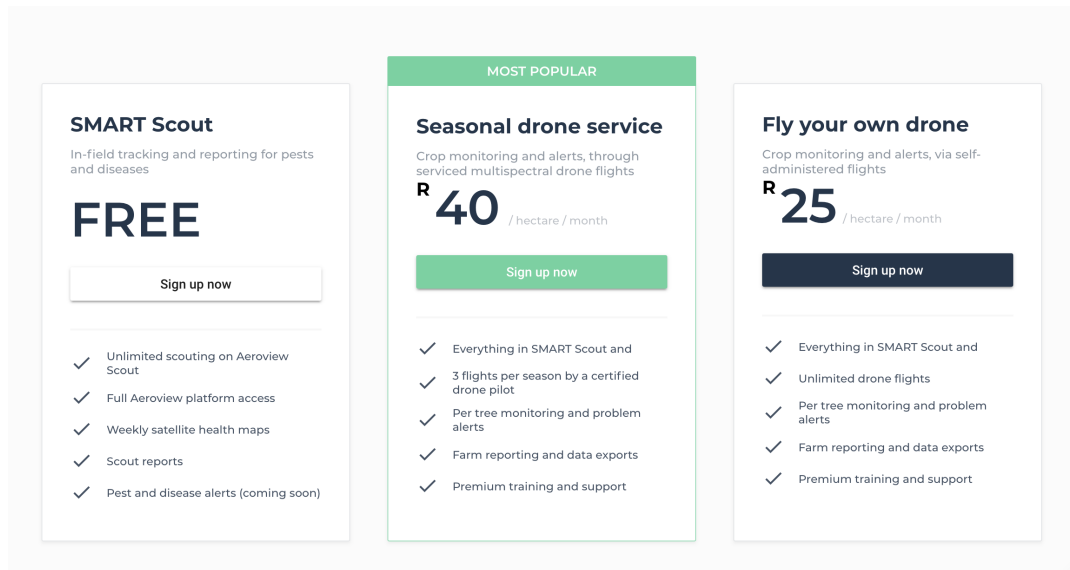
The mobile application serves as an on the ground tool which connects the scout workers to the farmer.

The mobile application can perform the following;

- Receive scouting route from web portal
- Take notes, voice notes, pictures of pests and diseases detected on the ground

### Pricing

Farmers gain access to this portal by paying a fee of R40 per hectare per month, see figure 3.5 below. One hectare is equivalent to a rugby field which can fit 312 trees. Farmers are given the option to fly their own drones with an added benefit of multiple flights per season at a lower price.

FIGURE 3.5: (*Aerobotics*) Product pricing for clients 2018

## Data

Aerobotics has the following data on farms;

Variable	Unit	Description
Tree Age	Years	How long the tree has been planted
Trees/Ha	Integer	Number of trees per hectare
Client ID	Integer	Unique client ID
Farm ID	Integer	Unique farm ID. Farmers can have multiple farms
Number of Logins	Integer	Number of times the user has logged into the web portal
Average Tree NDVI	Decimal [0-1]	NDVI* measures the health of the tree. The closer the value to 1, the healthier the orchard.
Variance Tree NDVI	Decimal	The variation of the tree NDVI within the orchard
Average Tree Area	Square Meters	The amount of land (in square meters) that the tree covers
Variance Tree Area	Decimals	The variation of the tree health
Percentage Canopy Cover	Decimal [0-1]	Percentage of the tree which covers ground area

TABLE 3.1: Aerobotics Data on Farmer

\*Tree NDVI stands for Normalized Difference Vegetation Index. It is a value between 0 and 1 which measures how healthy a crop is. It is the most important value in the database.

The data points are presented through the web portal using drone images that were captured during flights.

Figure 3.6 shows Aerobotics perspective of the farmer. On the left hand side, the farmer can toggle between Health, height and other tree data that was picked up by the drone.

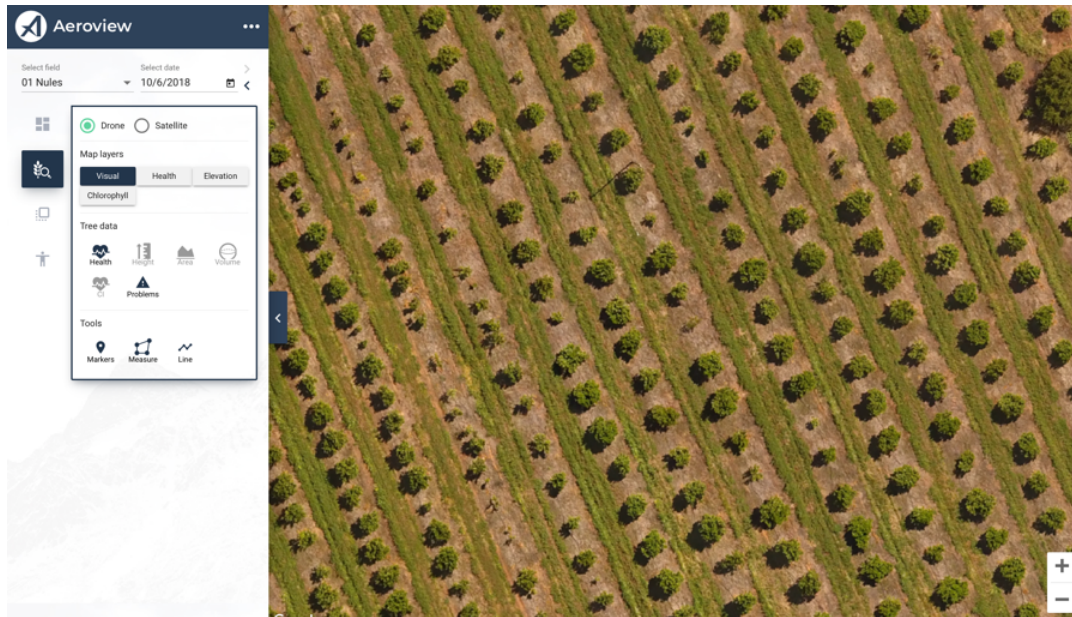


FIGURE 3.6: (*Aerobotics*) Web Portal from Farmer Perspective

Figure 3.7 shows individual tree data. The farmer is able to see how their trees measure individually and against the entire orchard. This will indicate whether additional resources are needed to improve the farm, and when action is taken, the farmer will be able to see if their orchard was improved.

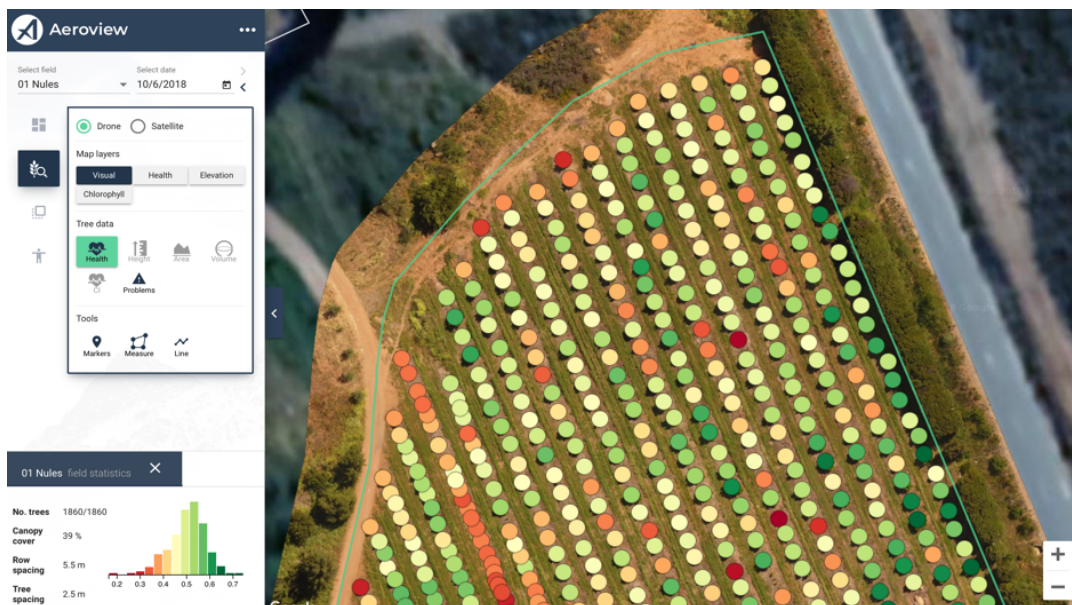


FIGURE 3.7: (*Aerobotics*) Aerobotics Web Portal showing health

We have explored the production cycle of the macadamia nut crop, the challenges faced by the farmers at each stage of the process as well as the Aerobotics platform

and its benefit to the farmer.

One of the limitations of introducing an agricultural asset registree is the quality of data. Reliable data is needed from the user which can be used in a legally binding contract. In order to facilitate the process proposed in this thesis, Aerobotics will be a crucial partner in the verification of the asset, thus acting as a third-party verifier.

## Chapter 4

# Proof of Concept

### 4.1 Introduction

The following chapter will focus on research objective 5 as detailed in 1.1.2 of the Introduction chapter. The section will demonstrate the development of an agricultural asset registry that uses blockchain technology. The registry aims to facilitate the use of agricultural assets as collateral for loan applications. The Macadamia Nut industry is an excellent example of an industry that is in need of financial interjection. Farmers own multiple crop trees which could be used collateral for a loan; the trees are investments which can provide positive profits for up to 40 years and, trees are much more stable when compared to a vehicle or cattle.

### 4.2 Design Iterations

#### 4.2.1 Design Iteration 1

The first iteration of the platform was designed to encompass the asset registry process as well as the investment process between farmers and granters. Farmers in this context are individuals who own macadamia nut trees and are in need of financial assistance. These farmers are unable to qualify for the traditional forms of finance due to the inability to provide sufficient collateral. This platform will allow farmers to apply for a loan using macadamia trees as collateral. The farmer will be able to perform the following functions;

- Register a farmer profile
- Choose the crop they would like to place as collateral
- Choose the desired loan amount

The following designs were created depict this journey. The designs were created from the perspective of the farmer.

To begin the farmer would be greeted by a landing page which details a short description of the process.

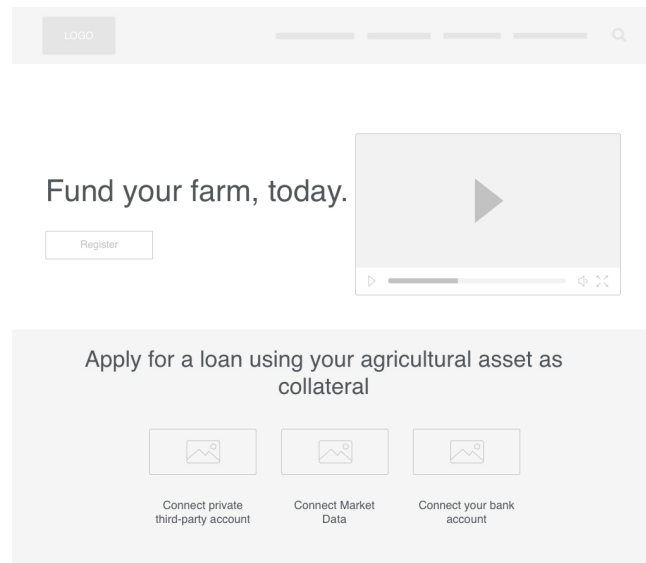


FIGURE 4.1: Design 1 Landing Page

The farmer would then be required to register a profile using their email address and a unique password. As mentioned above, there are a number of agricultural applications which farmers use to improve productivity. Using this third party data, farmers will be able to connect their existing accounts.

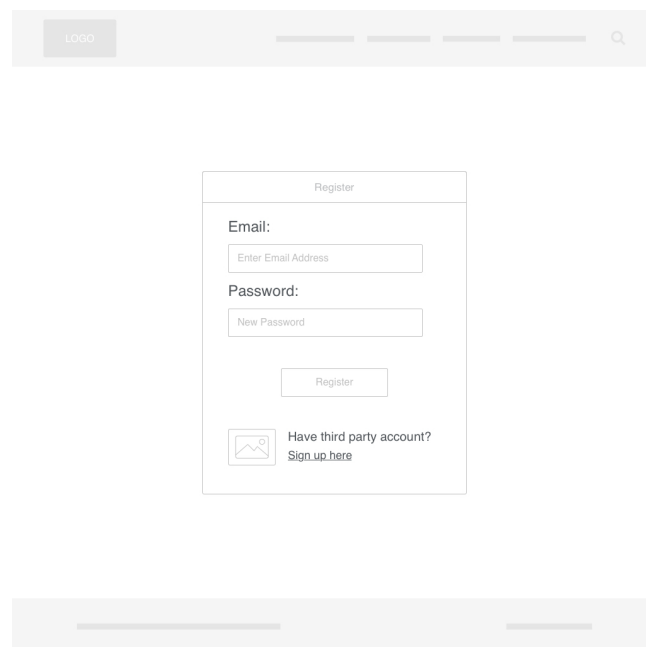


FIGURE 4.2: Design 1 Registration

Once registration is complete and third party integration is done, the farmer will be able to make a request.

The screenshot shows a web interface for a loan request. At the top, there is a header with a 'LOGO' button and a search icon. Below this is a 'Choose Crop' form. The form contains the following elements:
 

- Orchard:** A dropdown menu currently showing 'B'.
- Number of Crops:** A spinner control set to the value '10'.
- Amount available to borrow:** A text field displaying 'R 14 030'.
- Interest Rate:** A text field displaying '7.9%'.
- Request amount:** A slider control ranging from 'R 0' to 'R 14 030', with a marker currently positioned at 'R 7 030'.
- Borrow:** A button located at the bottom right of the form.

FIGURE 4.3: Design 1 Loan Request

Figure 3.4 above contains three sections that the farmer will have to navigate through;

#### Benefits of system

The platform allows farmers to connect multiple data sources in order to request finances.

- The process from registration to loan request can be done in a few steps.
- Figure 3.4 allows farmers to choose parameters of the loan easily in one view.
- The farmer is quoted immediately for the loan they require.
- The loan requirements are simplified to only the crops that the farmers own. This makes it easier for farmers to apply for loans.

#### Limitations of this design

The following limitations exists with this design;

- The process relies on farmers being able to navigate through the loan request steps themselves.
- Figure 3.4 is complicated for an individual who does not have sufficient financial literacy and technology literacy.
- When choosing which orchards to use as collateral, no assessment is made of the asset prior to using it as collateral for the loan.
- The simplicity of the process decreases the ability to mitigate the risk associated with providing financial products.

- Farmers are unable to view data after the loan has been requested and granted. This creates a disconnect between the user and the financial product.

### 4.2.2 Design Iteration 2

The second iteration of the platform focuses on the financial life cycle of the farmer and the grantor. The first design failed to address what would take place once the loan was granted. For iteration 2, a marketplace/dashboard was added for the farmer and the grantor to view information regarding the loan request and the asset.

Upon registering a profile, choosing which crop to place as collateral and choosing the loan amount, the farmer will now be able to track the asset and the loan product throughout the loan period.

Previously the designs have been exploring the platform from the perspective of the farmer. One of the objectives of the study is to introduce multiple parties in order to facilitate the process of providing capital for the farmer. The next step involved designing the steps that the grantor would take to facilitate the loan. It is important to note that the grantor sees this as an investment product. Banks and financial services offer banking solutions in return for profits. Design iteration 3 takes this into account.

Design iteration two will allow grantors to perform the following functions;

- Register a grantor profile
- View all the loan requests which include information provided by the farmer
- Invest in an agricultural asset (from a farmer's perspective, this would be receiving a loan)
- View insights into the asset and financial gains throughout the investment life cycle

To begin, the farmer will access the platform through an investor landing page that is different from the farmers;

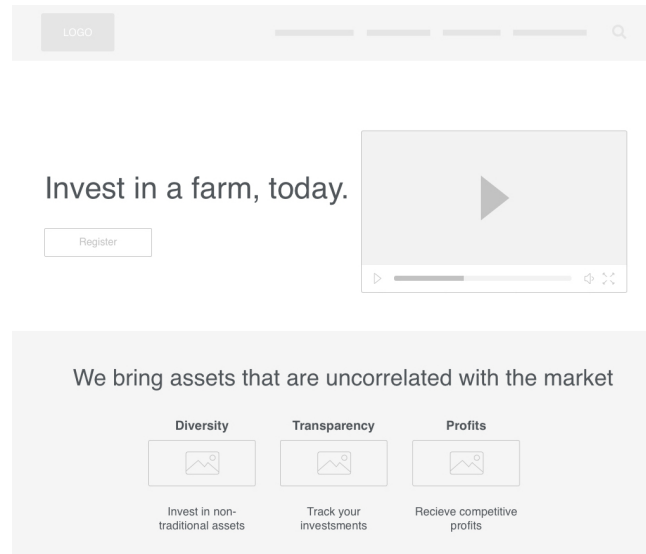


FIGURE 4.4: Design 2 Landing Page

The loan grantor would then be required to register a profile using an email and a password for their account.

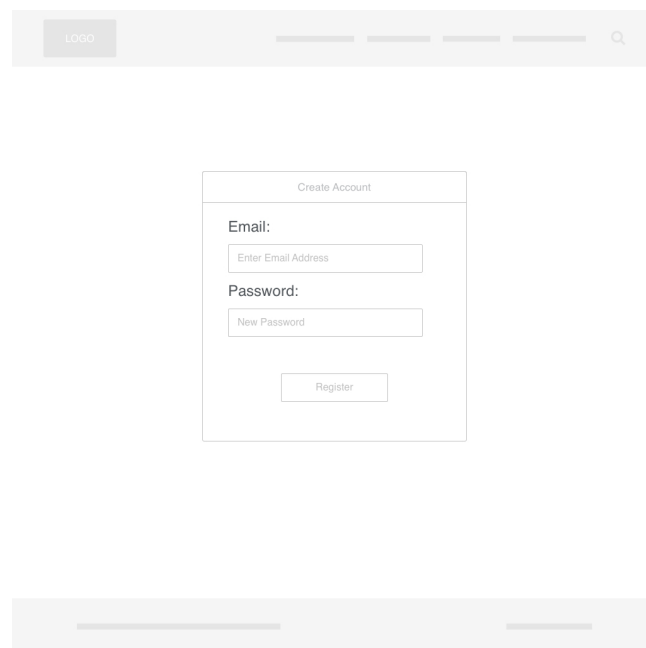


FIGURE 4.5: Design 2 Registration

Once registration is completed, the grantor will have access to a marketplace. The marketplace is a page that displays all the loan request made by the farmers. The grantors will be able to view the type of asset that is being placed as collateral and be presented with the option to choose the product.

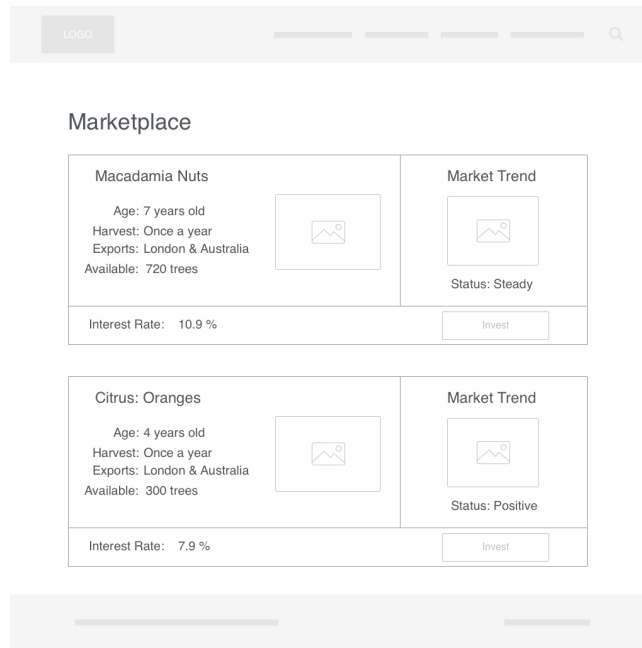


FIGURE 4.6: Design 2 Marketplace

Once an investor has chosen the product, and the farmer has received the funds requested. Both parties will be able to view insights into the investment. The dashboard aims to provide transparency between the farmer and the finance grantor.

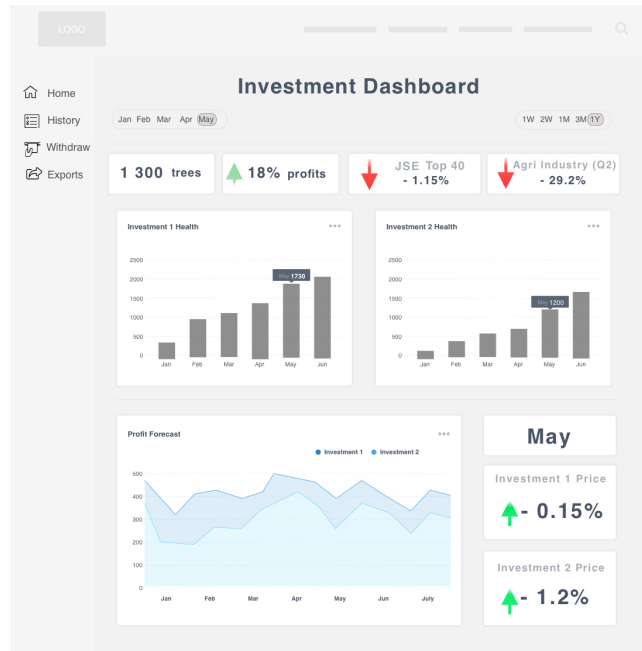


FIGURE 4.7: Design 2 Dashboard

### **Benefits of system**

- The process from registration to the investment can be done in a few steps.
- The marketplace allows financiers to view all the investment products that exist in the platform and they can view the market trend as well.
- The dashboard creates a transparent relationship between the farmer and the investor

### **Limitations of this design**

Design iteration 2 expanded on the first iteration by adding investor (grantor) functionality. Many of the limitations from Design 2 still exists.

### 4.2.3 Design Iteration 3 - Final Design

Design iteration 1 and 2 presented a few challenges. Both designs presented a simple solution to alleviate access to financial products. Although the designs appear to be consistent with solving the financial problem, the solution is still unable to address the concerns surrounding asset registration and the validity of ownership. This resulted in the researcher decreasing the scope to only asset registration.

In design iteration 1 and 2 provided an overview of how both parties could interact but deemed to be too complicated for farmers, and the simplicity of the system presented some risks. These risks included the inability to protect the financier against fraud, and the system was unable to adhere to laws surrounding financial lending.

To simplify the process, the creation of an asset registry was concluded as the most beneficial solution to the problems presented by literature. Several authors discussed in the literature that businesses in emerging markets were excluded from the financial landscape due to the inability to meet loan requirements. Ownership of land was the most common reason for individuals to be rejected from acquiring credit facilities. Many governments in Kenya, Uganda, and Zimbabwe introduced laws which allow financial services to accept immovable assets as collateral. This came in the form of a bill and the introduction of an asset registration platform that is open to all parties.

There were many limitations with the laws and the platforms which made it hard for finance providers to engage in the new system. The laws require multiple parties to determine and verify the ownership of the assets. Parties include cattle owners, tribal elders and finance providers thus making the entire process lengthy and costly. In order for such a system to work seamlessly, the literature shows that specialised services are needed to facilitate the registration and the overall process up until the loan is repaid. High levels of trust between all parties is needed. This is a significant limitation for emerging markets as corruption, and lack of trust in state services are high as opposed to developed nations.

Due to multiple limitations, design iteration 3 focused on asset registrations. The objectives on the platform included;

- To allow farmers to register movable assets such as cattle and crops
- To facilitate the verification of ownership by a trusted third party such a community agent
- To allow financial services to view assets that have been registered and verified
- To allow financial services to label an asset as "used" if the farmer has placed the asset as collateral for a loan

- To allow all parties to view all assets and transactions that take place which involve the asset

## Technology Stack

To achieve the above mentioned objectives, the following system was built.

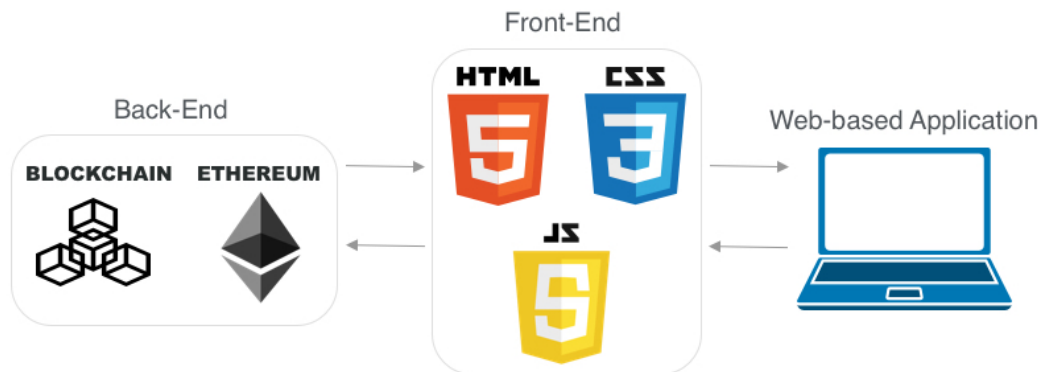


FIGURE 4.8: Technology Stack

### Back-End Functionality;

- Blockchain technology was used as a decentralised database to house the transactional data.
- Smart Contracts were used to facilitate the transactions through the Ethereum network.

### Frontend Functionality;

- HTML, CSS were used to build the front-end application using the Bootstrap 4 development network.
- Javascript (JS) was used to provide functionality onto the platform.
- Web3.js library was used to connect the smart contracts to the front-end

### Web-based Application;

- Access to the platform was provided through an online portal (design included below).

## Blockchain Technology

### Why Ethereum?

The Ethereum network allows for the execution of smart contracts. (Bogner, Chanson, and Meeuw, 2016, p. 177) defines smart contracts as "cryptographic box which stores information, processes inputs, writes outputs and is only accessible to the outside if certain predefined conditions are met". In this case study, smart contracts can be used to store information regarding the asset that will be used as collateral. Smart

contracts will allow for the registration and collateralisation process of the asset to be written in code and for specific functions to be completed only if certain conditions are met.

Ethereum offers an entirely programmable blockchain that is run on a decentralised server. Once programmed, there is no "downtime, censorship, fraud or third-party interference" (*Ethereum Project*, p. 1). Ethereum allows anyone to create decentralised applications called "Dapps". Dapps make use of smart contracts and are run on the "Ethereum Virtual Machine"(EVM) platform. As of December 2018, there have been 2 432 Dapps launched on the Ethereum network using EVM (*State of Dapps*). Smart contracts are stored in a binary format that is only accessible from the Ethereum network. A high-level programming language is used to write the contracts. Ethereum is "Turing complete", meaning it can run programs which have been written using any language. Developers can use Solidity (similar to Javascript), Serpent (similar to Python) and LL (similar to Assembly) to write smart contracts and they all will compile successfully. Once contracts have been written and compiled, the contracts transformed into byte code through the EVM compiler. The byte code is then uploaded onto the blockchain using the Ethereum network (*Ethereum Documentation*).

Ethereum holds two types of accounts; (1) Externally owned accounts - These accounts are controlled outside of the Ethereum network. They have an Ether balance, can send Ether transactions, and they do not have any code associated with the account. (2) Contract accounts - These accounts have code associated with them. To execute the functions in the code, transactions and messages are sent by other contracts. These contracts can send message calls to other contracts.

In order to execute a smart contract, Ether is needed. Ether is the native currency for Ethereum. To store information and run a transaction, Ether is the payment method of choice. Ethereum charges the user for each computational step taken, and this charge is called gas. The price of gas is determined by the miners in the community and in order for your transaction to be accepted and mined onto the next block, a reasonable price needs to be paid. Similar to any brick and mortar store, customers need to pay for services. If the price is too low, miners can refuse your transaction.

Users are charged for the gas they use which is similar to a pay-as-you-go model. Any gas that is not used during the process is refunded back to the user. Users can set gas limits which specify the maximum amount of gas that a user is willing to pay for a transaction. This helps eliminate overspending because there are pre-conditions, users are always aware of what they are paying for, and they can rely on the safety net of the code.

The following equation determines the price of a transaction;

$$price_{transaction} = (computations \times price_{gas}) + price_{start}$$

## Transactions

Transactions are packets of data that are sent from one externally owned account to a contract account (*Ethereum Documentation*). They contain the following information;

- the transaction recipient - the smart contract user
- the signature of the sender
- value field - the amount of wei being transferred
- start gas value field - maximum number of computational steps the transaction execution is allowed to take
- gas price value field - the price the sender is willing to pay for gas

## Message

Messages are similar to transactions, but they are sent from one contract to the next. For example, through a decentralized application, a user can call a function stipulated in the smart contract in order to return specific information. This will be returned in the form of a message. Messages contain the following information;

- the transaction recipient - the smart contract user
- the signature of the sender
- value field - the amount of wei being transferred
- start gas value field - maximum number of computational steps the transaction execution is allowed to take

## Blocktime

Block time is the amount of time taken by the network to process pending transactions. At the time of writing this thesis, the block time was recorded on (*Ethereum Average Blocktime Chart*) to be 15.3 seconds, which is much longer than the 12 seconds specified on the Ethereum Yellow Paper (Wood, 2014). Bitcoin, on the other hand, takes an average of 10 minutes to mine a block (*Blockchain Average Blocktime Chart*). Ethereum is considered one of the fastest blockchains which have made it attractive for developers looking to build responsive applications.

To facilitate the objectives of the platform, one smart contract was designed.

AssetRegistry.sol

The contract is available to all parties namely; farmers, financial providers and third-parties. The contract contains the following main functions;

Table 4.1 shows the main functions which the platform uses to fulfill the objectives stated in the beginning of this chapter. See B for the full contract.

Function Name	Description
registerAsset()	This function allows any party to register an asset. In order to fulfill the objective, the function needs to be supplied with (1) the public address of the asset owner, (2) the name of the asset (3) a short description of the asset and, (4) the current date. Once the asset has been created, an event is emitted.
verifyAsset()	This function allows third parties to verify the ownership of the asset. The unique identification of the asset is needed in order to initiate the function. Once it is verified, an event is emitted.
createCollateral()	This function is only available to finance providers. Once an asset has been registered and verified, it may be used as collateral for a loan. In order to mark an asset as collateral, the function needs to be provided with (1) the unique identification number of the asset, (2) the public address of the asset owner, (3) the public address of the finance provider and, (4) the public address of the third party who verified the ownership of the asset. Once the asset has been used as collateral, an event will be emitted.
removeCollateral()	At the end of the loan period, the collateral will be removed. The unique identification of the asset is needed in order to initiate the function. Once it is verified, an event is emitted.

TABLE 4.1: Smart Contract Functions

The contract was developed using Solidity which is similar to the Javascript programming language. In order to compile and test that the contract does function indeed, Remix was used. Remix is an online smart contracts compiler that allows for easy editing and testing of contracts (*Remix Ethereum*).

Once the contracts were completed, the Ethereum Javascript API called web3.js was used. Web3.js is a library that holds various predetermined functions which are used to interact with smart contracts and the ethereum environment. Using javascript as a language, developers can connect the smart contract back end with the HTML front end of the application. When implemented, Web3.js creates a connection with a web3 provider which connects to a private address and allows for ether to be exchanged between an account and the decentralised application.

In order to interact with the decentralised application, users will need to install Metamask. This will allow users to use Ether stored in their wallets to pay for the transactions within the decentralised application. For this thesis, MetaMask was used as a web provider of choice. *MetaMask* has the following functionality;

- provides a connection to the distributed web
- allows for dapps to be run through a browser
- has an identity vault that houses private addresses
- can be installed on Chrome, Firefox, Opera and Brave Browser

### Platform Design

The platform will facilitate the following process;

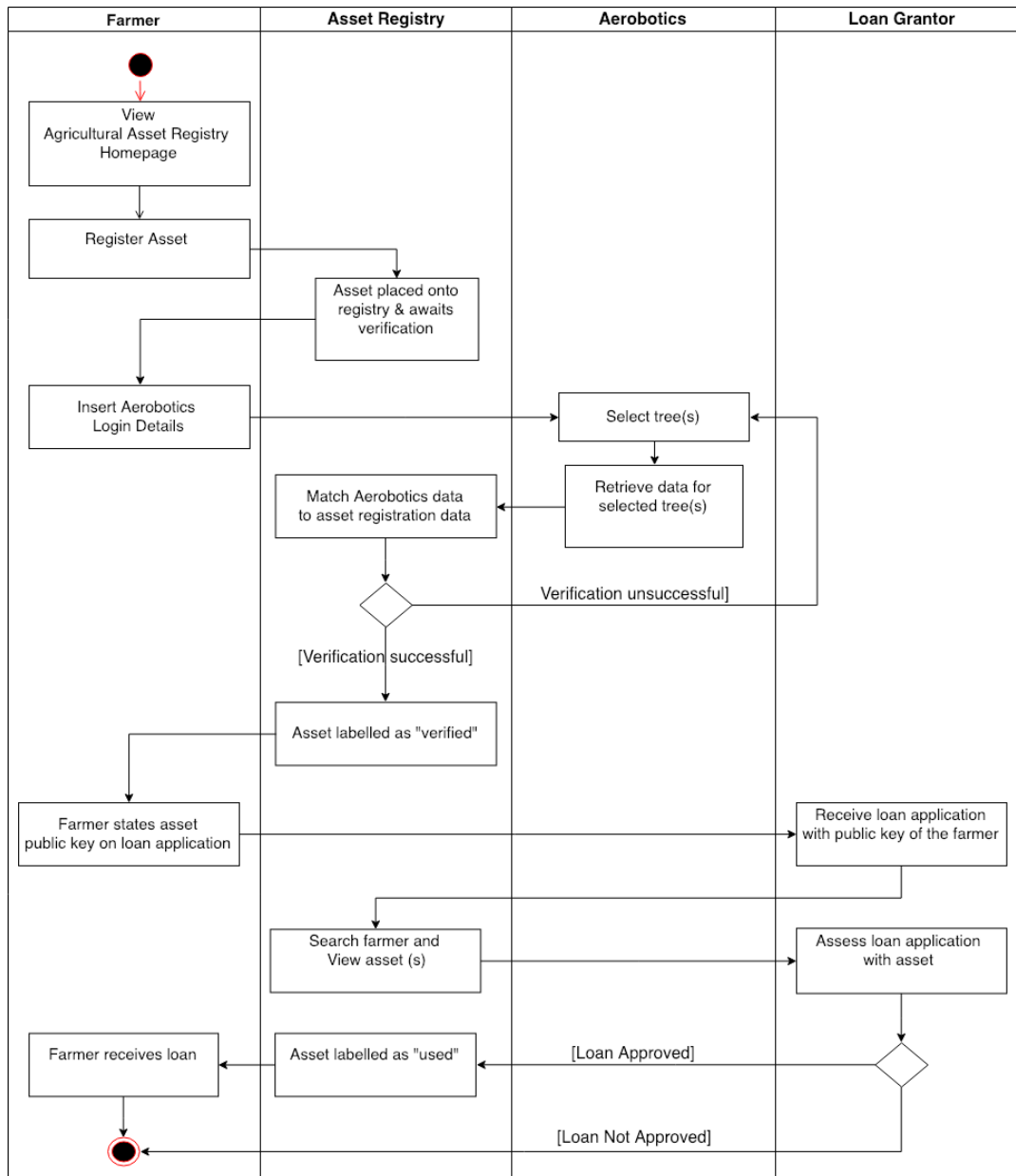


FIGURE 4.9: AgriRegistry Process

Farmers will be able to add their asset of choice to the asset registry platform. Once added, the farmer will use their Aerobotics Login Details to verify that indeed the asset exists. Once verified, the farmer can share their public key with a financial institution when applying for a bank loan. Their public key can be used to search the database and view assets that are owned by that owner. The loan grantor will have the opportunity to view whether or not the asset was verified by a trusted third party, in this case, Aerobotics. Using the data provided about the asset, the

loan grantor can assess the loan application and if granted, change the state of the asset to "used".

A front-end was created used HTML, CSS and bootstrap 4 as a framework. All users are presented with the same information upon entering the platform and any user (farmer, government or private institution) can register an asset. In this scenario, only farmers with an Aerobotics account will have the ability to verify an asset.

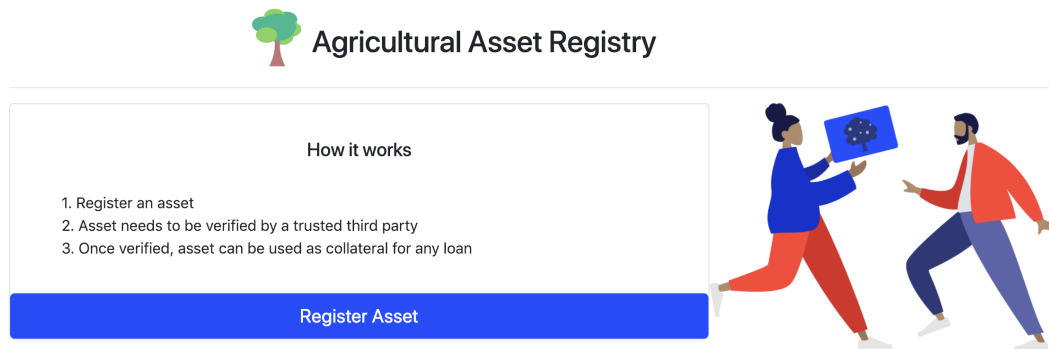


FIGURE 4.10: Platform Instructions

To register, the user will have to provide information regarding the asset. This includes the public address of the owner, the name of the asset and a short description of the asset.

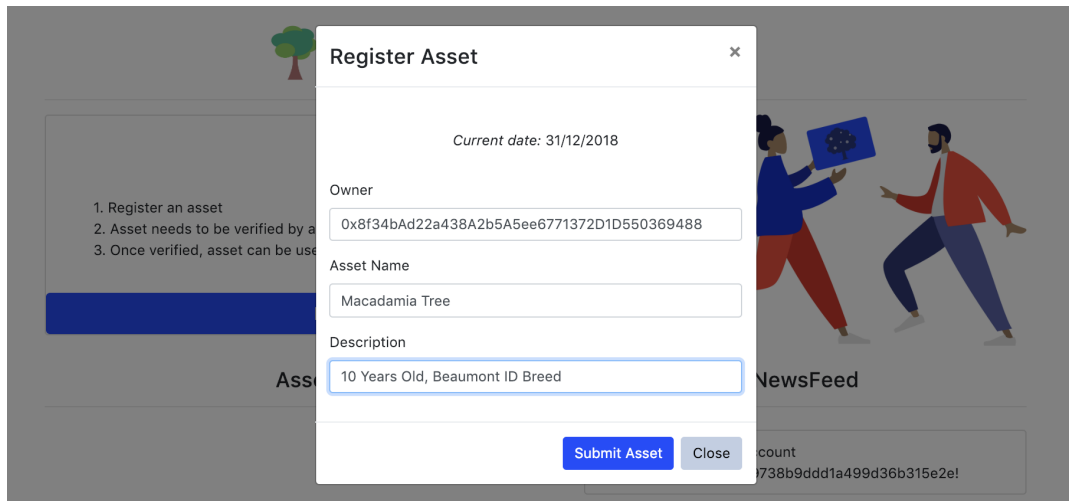


FIGURE 4.11: Register Asset

Once the asset has been registered successfully, it will be added onto the registry. Assets that have just been registered will need to be verified by a third party who is not the owner of the asset. Third parties can be a government agent, a community leader or a private company. In this thesis, the verifier is Aerobotics. All assets that are not verified will contain a button, giving users the option to verify. On the right hand side of 4.12, a news feed is populated with notifications after each transactions on the blockchain.

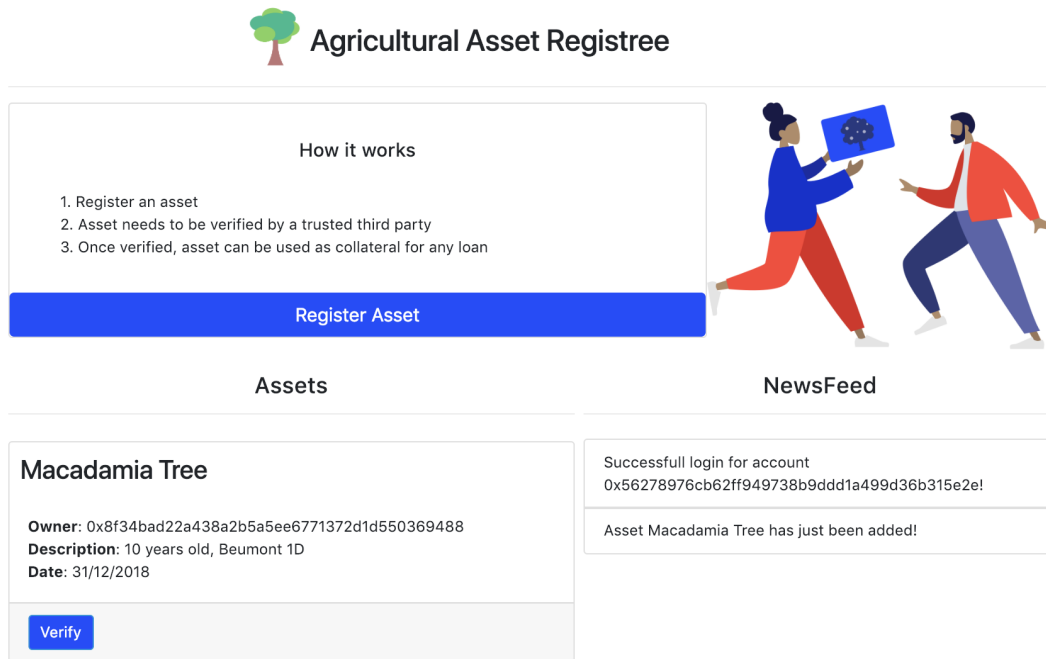


FIGURE 4.12: Asset registered successfully

Once the ownership of the asset has been verified by a third party, the "verify" button will be removed and the "use as collateral" button is added. This will allow a financial institution to use the asset as collateral.

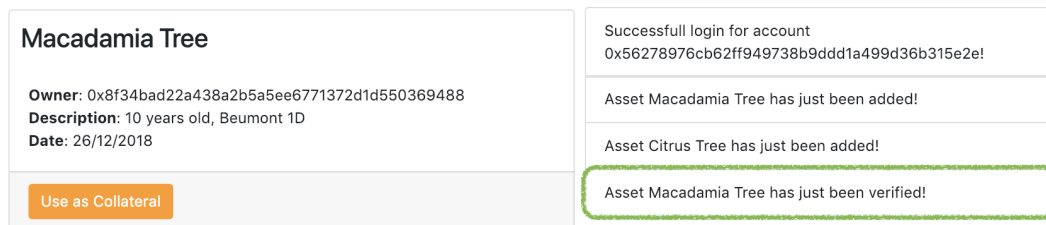


FIGURE 4.13: Asset Available as Collateral

When an asset is being used as collateral, users will be able to see the asset on the registry although interaction will be restricted. 4.14 below depicts an asset that has been used.

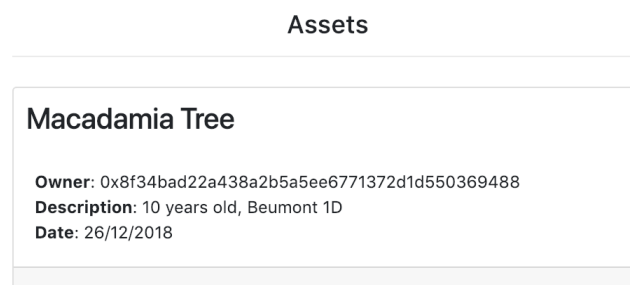


FIGURE 4.14: Asset Not Available

## Chapter 5

# Proof of Concept Evaluation

### 5.1 Introduction

The following chapter will focus on research objective 6 as detailed in 1.1.2 of the Introduction chapter. The section will discuss the limitations presented by a decentralised agricultural asset registry. The registry aims to facilitate the use of agricultural assets as collateral for loan applications.

### 5.2 Evaluation of Proof of Concept

Chapter 4 of this paper demonstrated an agricultural-asset registry that uses blockchain to connect multiple parties in order to use an asset as collateral.

The following **benefits** were realised;

- Asset owners can make use of their public keys to register an asset.
- Using the Asset owners public key, third parties (Aerobotics) can verify an asset and financial providers can use the asset as collateral.
- There are four steps to follow in order to use a agricultural asset as collateral. Stating the steps up front allows for all users to view the instructions each time they register an asset.
- The asset registry and asset registration process is completed on the same page. In previous design iterations, the process steps were in different web pages. This made the process more complicated and hard to understand.
- Once an asset has been used as collateral, no user can interact with the asset until the collateral period has ended.

The following **limitations** are presented by an asset registry platform powered by blockchain technology;

- Verification of the asset information is heavily reliant on one party, the 3.6 platform. This introduced a single point of failure.
- The platform may be difficult for farmers to navigate. In South Africa, majority of farmers speak Afrikaans, Xhosa and Zulu. Only a small number of farmers understand English as it's not their native tongue. This can cause confusion particularly on a platform that is only online.
- Blockchain technology is an emerging technology and most of its benefits are soon to be realised. Farmers are risk averse and introducing a technology that is new and unproven may be hard to adopt, especially when finances are involved.
- There is a time lag between when the asset collateralisation is completed on the platform, versus when the blockchain registers the asset.
- The South African regulatory landscape has not adopted a movable assets bill unlike many of its African neighbours such as Zimbabwe, Uganda and Kenya. This makes it hard to hold either parties accountable should there be a dispute. At the date of completing this paper, it is unlikely that the government will introduce such a law anytime soon.

## Chapter 6

# Conclusion

### 6.1 Conclusion

It is concluded that blockchain technology can assist in expanding access to finance for agricultural businesses in South Africa by providing the following benefits;

- Blockchain allows for multiple parties to interact in a trustless environment. Thus farmers can create digital representations of their biological assets and share this information with finance providers and other interested parties. The ability for blockchain to create trust means that entities can "trust" the data provided and a the registry can be used to settle disputes that arise during the loan process.
- Farmers will be able to use their biological assets as collateral for loans, thus helping them meet loan and banking requirements even if the farmer does not own land.
- By using the asset registry as a tool, farmers can create a financial history which can be used to gain access to other financial products.
- Precision agriculture is increasingly being adopted as technology becomes cheaper and more accessible. This data can be harnessed by financiers in order to price loans and get access to data that was previously unattainable. In this paper, Aerobotics was used a supplier of agricultural data and it was shown that such a platform is integral in the execution of a decentralised agricultural registry.

The research was conducted as a call for the expansion of access to finance for South African farmers. A decentralised agricultural registry was designed and developed in order to meet the financial needs of the macadamia nut farmers, majority of whom were previously unable to get access to finance. It is hoped that this research paper will be used as the foundation for a nation wide asset registry platform by government or any institute willing. Blockchain technology has many benefits that are soon to be realised, this paper details one of many solutions that blockchain can create for the African countries particularly within Agriculture.

Github Repository can be found here: <https://github.com/KMzuku/AgriRegistry>

## Appendix A

# Interview 1

Date: 30 August 2018

Interviewee: Hein (hein.gerber@1stfruits.co.za) from 1st Fruit. Hein is consultant by profession, FirstFruit decided to venture into farming for a period of five years. Their model was to lease old orchard plots and flip them. The 5-year period has ended, and they are closing their farming project to focus on their main business, consulting.

\*Interview Starts\*

Kungela: We want to build a platform where farmers can get loans, and as collateral they can use agricultural assets. As a fruit farmer you can put up a tree crop as collateral. All the fruits that are harvested from the crop in future, is what you will be paying back as interest. For cows it would be every time the cow has a calf, the farmer can sell the calf, and all the profits from the calf will be paid back to pay for the initial capital received in the beginning. What I want to find out is, is this something people would opt to use and also is there a need for it?

Hein: Yes, I think so, you know there's different ways to do it and that is actually how we started our farming, because obviously we didn't have capital to, i mean it was five years ago, we took a loan from an export company. That came to look at that orchard, it was in a very poor state then. So you could see they were thinking, are we going to help them or not help them. And we basically had to guarantee that crop as a way to pay off the loan, so how that one worked was that because they're an export company, they make their commission from selling your fruit. Basically being a broker for the fruit. So we had to sign a contract saying, if they will help us with this loan for a certain period, then we have to guarantee that we will supply or fruit through them, for that same period. And then that is their guarantee that they will make back that money. So that is basically how we started. And we wouldn't have been able to do it, uhm, any other way.

Kungela: Is that a common practice?

Hein: Uhm it is with some companies. There's quite a lot of., uhm.. if I think about one of our neighbours as well, he basically went into a deal, a 25-year deal, with an

export company. Where they pay half of his establishment costs, of his trees, but then he has to export through that company for a period of time.

Kungela: Is he a big farmer?

Hein: Yes, he's a large commercial farmer, that's how he started out.

Kungela: Is it mostly for emerging farmers or for people who want to go into commercial farming?

Hein: So that's one model that I've come across where the whole business remains yours, but you just getting a loan. The other one is where they actually partner with you and supply the money, but then it's a joint venture. You're doing it together. And then in some instances, you're bringing the land and they're bringing the funds and then the profits are shared.

Kungela: And for a farm this size (see images), do you think they still have finance needs?

Hein: Yes, definitely because this is, especially if you're talking emerging farmers, but for us, we fall more in the category of emerging farmer. So it's difficult to, if you talk about economies of scale, and you've sort of have a general mix of citrus on your farm. Then economies of scale is a unit of about 50 to 100 hectares. These days, there are cultivars that are a lot higher value that you can farm a small area and be profitable, but it's quite difficult to start with a small production unit, buy all of the equipment that you need, because even if it's small, for 5 hectares, and 20 hectares, you need the same about of equipment, tractors, spraying machines and so on. So no definitely, I mean we have a client here, he gets funding, like there's a type of funding that you can apply for from the municipality and also from HortGro. It's a BEE initiative, but then he can apply for that as an emerging farmer and get funds for buying a tractor, buying a spray cart, having production costs. So this guy is also a client of ours and it has definitely helped him to take the next step. He's actually planted new trees now. And he is renting new land from this year. And i don't think he would be able to do it without the funding. Funding is very important. Very crucial, I mean you're talking big numbers for establishment costs and if you're talking citrus, I don't know how it works for cattle. But for citrus, i mean you start normally year 5 to 7. That's where you start breaking even.

Kungela: So the contracts are quiet long?

Hein: Yes, that's why for fruit crops, it's normally long. Especially for citrus. Citrus is a slow crop. And then obviously for annuals, and maybe cattle and sheep it's a different type of model you're looking at.

Kungela: What is your definition of emerging farmers?

Hein: For me, I would say it's anyone that has maybe not been in the commercial scene, not been a commercial full-scale farmer that's basically now starting up. And

that maybe you've got access to land now, or like for us, it was these sites that basically approached to people, it wasn't farmed and then we can start on that. Wayne the guy I just spoke about, he saw what we were doing and then he also approached someone that had an outdated orchard, and started that way, and sort of advised him on that for a while. But then obviously it can also be someone that's got land, but they've been using it for something else, or not using it optimally or whatever. Taking it from a self-sustaining unit, to something that will start exporting or selling, or whatever. That's what I see as emerging farmer. Kungela: Is there more of a need for financing capital or is it access to markets. I mean the reason why some people would go for the export company is because it gives you access. So which one is more of a need?

Hein: It is both, on fruit, it's not so hard to get access to market. There is however a few, on the administrative side it can be heavy. There's audits, there's GlobalGap, there's SIZA, so there's a few compliance audits and systems that you need to get in place in your farm. Which is also difficult for smaller farmers. But in some cases there are bigger organisations that help. Like I know people from the Eastern Cape that farm in the Sunday Sugar Valley, they're a big co-op. Like it might be worth to speak to them as well, so they assist emerging farmers, by doing a blanket type of audit, to include everyone in that.

Aerobatics employee: SRCC?

Hein: Yes, so the compliance is a tricky one because you have to have all of the compliance in place to be able to export. And it can get quite complex even for us, we're a small unit. We get help in. we get a company that basically helps, assists us with our compliance and all the steps in place. They come and do 2 or 3 audits on our farm to see that everything is fine. So then markets, if you've got your compliance in place, market access is quite easy.

Kungela: In terms of amount for the loans, what are the figures that people need?

Hein: I can only talk about citrus, is that okay?

Kungela: Yes, that's fine.

Hein: So if you want to establish an orchard, you're probably looking at R150 000 to R170 000 a hectare to establish.

Kungela: A hectare is how big?

Hein: A hectare is a size of a rugby field, more or less. 100 by 100 meters. So you need some capital to be able to pay your production costs until year 3, which is the first year you start setting a crop sometimes only in year 4. And then dependent on the value of your crop, that's going to determine how quickly you get a return and i've got those figures, i can give you figures for year 1, year 2, year 3... ( if we can email a bit.. )

And then if you now farming, let's say this orchard (see images), you're looking at a production cost of about R80 000 a year. This is to do all the actions that need to take place in this orchard.

Kungela: Do people usually have that money up front?

Hein: No, a lot of the established farmers that have been farming for years, they often have quite a big facility at the bank. Like some guys do their full production out of their banking facility and then get an income and pay it all back. And do the same again. But for us, we weren't able to get that type of facility, even though our business is quite profitable, we still aren't able to get such a large facility to cover us for the year. So for us, in about year 3, we were able to become self-sufficient, we were able to fund our own, on that orchard where we were this morning (see images). But we've still got blocks, we've got an 11 hectare orchard, where for this year the export company still gave us a loan of R100 000 to farm it.

Kungela: Why is that you weren't able to get a facility with the bank? Was it requirements?

Hein: Yes it was requirements. Because it's not our own land, we don't actually have something that we can give up as surety. We don't have buildings or a lot of equipment or machinery or a farm. I think those farmers give their farms as surety for the amount of money, which we can't do.

Kungela: Do you think this is something one of the farmers would actually do? Place maybe three tree crops or a row of crops in their orchard for immediate income and then paying it off over the crops lifespan?

Hein: Yes definitely people would consider that. I think for you, just important, you're still going to need, maybe some sort of insurance, something can go wrong.

Kungela: How often do things go wrong?

Hein: Around here, not often. It depends on the area. If you're up in Nelspruit, things go wrong regularly (laughs). There most of the time, if the guys want to get a loan with the bank, they probably have to get , stuff like that. So there are somethings you will need to get insured about. It also depends on the technical ability of your producer.

Kungela: How do you ensure that your crops are growing as predicted or expected. Because you're not the one doing the farming? (Hein is a consultant not a farmer)

Hein: I can tell you how we work. Okay so every Monday we have a meeting with everyone from the farm. It's with the farm manager. Then we have a meeting and we discuss everything that's going on and the planning for the next week, two weeks and we talk planning and we get feedback on what's going on. And then we normally go out to the sites. One of the girls from our consulting business goes with the scout. A scout from Zimbabwe, so his role is to check on a weekly basis. All

the traps for insects, anything else funny that he sees. So basically the most crucial part is irrigation. So Johannes, he's the main guy with irrigation but he's also got guys who are under him. He is the site supervisor for this site and he's got two guys working with him and everyone's got their section. So Johannes, if he's walking around and sees a problem here, he will know that this is Denzil's section and he can talk to Denzil about it. So the water is 80

Kungela: So all farmers have that agent?

Hein: No (laughs), most big commercial farmers will do that but you'll find farms where there's no scout. And then you say "but how do you take care off..??" maybe I have to say that, there's two approaches. Integrated Pest Management, which is more of working with nature where you try and protect the beneficial organisms in your orchard so that they help you protect your crop. And on the other hand you have a set program where you use harsh chemicals and you just spray. So often, some of the farmers who don't have a scout, they don't often see a need for it because they stick to a harsh program and they just kill everything. But as an industry we're moving away from that and we have to move away from that because supermarkets are expecting it and there's a lot more awareness about farming with nature and food safety.

Kungela: How do you guys ensure that you meet that demand? Do you give the supermarket information to say this is how we're growing crops in our farm?

Hein: So basically there's two audits, Global Gap and SIZA (as mentioned above). So SIZA is an ethical audit and Global Gap is more like a "are you following good agricultural practice?", "are you being responsible", it's a risk assessment of your farm. What are the things that could go wrong, what are the spillages, are there injuries that could happen. What are you going to do if you spray the wrong chemical and now there's a dangerous residue on the fruit. And then there's drills, you have to make a plan and produce evidence of that plan. We send fruit to the pack house and they test. And if it doesn't meet the specification, how do we discard that fruit in a safe way.

Kungela: Where is the pack house? Is it on this farm?

Hein: Not here, it's in Willington.

Kungela: Is it your business? Or do you pack it and give it to someone else?

Hein: We transport it to the pack house and then it's not our responsibility anymore. We pay the pack house for the packing and the exporter handles everything from there. The specifications for the packing, the market where it's going, the transport to the port, the shipping and logistics, they do all of that.

Kungela: Is there a stamp on the fruit that says it's from this specific farm?

Hein: Yes, from a specific orchard even.

Kungela: Really?

Hein: Yes

Kungela: Is there some form of QR code or use of scanners?

Hein: Yes, each box, it's normally in a box of 15 kgs, sometimes in local supermarkets, I've got to Harmanes and then I pick up a box of clementines, I can see which client and orchard and everything. And I'll be like "oh I know this orchard". It's quite nice if it happens that someone on the other side can get full transparency. And each box has a code.

Kungela: What kind of code is it? It is used together with a website or?

Hein: I'm not so sure, I think it's like a barcode. I can send you that as well, I've got photos. It's just a label and I normally just check for the block number. It's like a label with destinations, where it's from and that year.

Kungela: Are there any farmer groups or community groups around the area?

Hein: Not so much here, we've tried. There are in some other areas in South Africa. There are organised groups. Here, apparently there are three groups in the area, we've had our name added to the contact list but there's nothing happening. We've spoken to some of the farmers around us, maybe do something once a month, like eat together and discuss what is happening at the moment. We've been speaking about it. We've contacted the regulatory body of the citrus industry and they've told us about the groups and added our names but nothing has happened. I don't think they're meeting often. Maybe they just exist on paper.

Kungela: So the groups depend on where you are?

Hein: Yes, some of the areas have really well organised groups, they meet together weekly, monthly or bi-weekly and they discuss whatever is happening at the moment.

Kungela: What are your future investment plans or plans to expand?

Hein: For us not, Our five year period of farming has just ended. But we still farming this farm for one year. All I can say is farming is hard work. It's really satisfying to do this, especially the types of orchard we take and turn around. I mean if I showed the orchard we went to this morning, you wouldn't believe it's the same place. It was left for dead. It was just dry branches, it looked dead. So it's very rewarding to do this. Our plans, we need to focus on our main trade.

(interrupted)

Speaking about a company he used to work for Farm Secure (no longer exists)

\*Interview Ends\*

## Appendix B

# Asset Registry Contract

```

pragma solidity >=0.4.22 <0.6.0;

contract AssetRegistry {

    // Owner of the asset
    address owner;
    // Person who has the ability to verify an asset
    address verifier;
    // A list of verifiers
    address[] public verifiers;
    // A financial provider
    address grantor;
    // A list of financial providers
    address[] public grantors;

    // A struct containing information–
    // about the asset which will be used as collateral
    struct Asset {
        // The Owner of the asset
        address asset_owner;
        // A unique identifier of the asset
        uint assetID;
        // The name which will be displayed on the
        // asset registry platform
        string name;
        // The description of the asset
        // The description needs to describe in–
        // detail what the asset looks like and its current–
        // condition.
        string description;
        // when the asset was bought or –

```

```
// when the individual became the owner of the asset
string date_of_acquisition;
}

// Array of assets
Asset[] public assets;
// Array of assets that have been verified –
// by a trusted party
Asset[] public verifiedAssets;
// Array of assets which have NOT been verified
Asset[] public unverifiedAssets;

// Assign owner to asset
mapping(address => Asset) public ownerAddressToAsset;
// Assign assetCounter to owner
mapping (uint => address) public idToOwnerAddress;
// To check if asset exists for a specific owner
mapping (address => bool) public assetCheck;
// AssetID to Asset
mapping(uint => Asset) public idToAsset;
// To check if the asset has been verified or not
mapping (uint => bool) public assetVerifiedCheck;
// To map each asset to a verifier
mapping (address => Asset) public verifierToAsset;

// Assign contract to the owner of the asset
constructor() public {
    //creator of the asset
    owner = msg.sender;
}

// Permissions
modifier onlyOwner() {
    require(msg.sender == owner,
        "Only the owner of the asset can perform this function");
    _;
}

//track the number of assets
uint public assetCounter = 0;

//register Asset event
```

```
event AssetRegistered(address indexed _asset_owner ,
                      address _registerar ,
                      string _name,
                      string _date_of_acquisition);

// Register an asset
function registerAsset(
    address _asset_owner ,
    string memory _name,
    string memory _description ,
    string memory _date_of_acquisition) public {
    // check whether the sender of the transaction
    // is the creator of the contract
    require(
        msg.sender == owner,
        "This address is not authorized."
    );
    // Increment assetCounter
    assetCounter++;

    //fill asset with information
    Asset memory thisAsset = Asset(
        _asset_owner ,
        assetCounter ,
        _name,
        _description ,
        _date_of_acquisition);

    // Checks if the asset already exists
    require(
        thisAsset.assetCounter != assets[thisAsset],
        "Asset already exists."
    );
    // Push asset to all assets
    assets.push(thisAsset);
    // Push asset to unverified list
    unverifiedAssets.push(thisAsset);
    // Map the assetID to the owner
    idToOwnerAddress[assetCounter] = _asset_owner;
    // Map owner address to asset
    ownerAddressToAsset[_asset_owner] = thisAsset;
    // specific address owns an asset
```

```
    assetCheck[_asset_owner] = true;
    // specifies that the asset is not verified yet
    assetVerifiedCheck[assetCounter] = false;
    //ID to asset
    idToAsset[assetCounter] = thisAsset;
    //omit and show asset has been registered
    emit AssetRegistered(_asset_owner, msg.sender,
        _name, _date_of_acquisition);
}

// Get number of assets registered in the whole platform
function getAssetsRegistered() external view returns(uint) {
    //require there to be assets
    require(assets.length > 0, "no assets registered");
    //create a counter
    uint counter = 0;
    // for each asset in the asset array
    for (uint i = 0; i < assets.length; i++){
        //increment the counter
        counter++;
    }
    //return the total count
    return counter;
}

//get number of assets registered in the whole platform
function getUnverifiedAssets() external view returns(uint) {
    //require there to be unverified assets
    require(unverifiedAssets.length > 0, "no assets unverified");
    //create a counter
    uint counter = 0;
    // for each asset in the asset array
    for (uint i = 0; i < unverifiedAssets.length; i++){
        //increment the counter
        counter++;
    }
    //return the total count
    return counter;
}

//event to verify asset
```

```
event AssetVerified(uint indexed _assetID , address _owner);

// Verify Asset by Third Party
function verifyAsset(uint _assetID) public {
    require(ownerAddressToAsset[msg.sender].asset_owner != msg.sender ,
        "Owner cannot verify asset");
    // store the address of the verifier
    verifiers.push(msg.sender);
    // return the specific asset
    verifiedAssets.push(unverifiedAssets[_assetID]);
    // uint index = unverifiedAssets[_assetID];
    if (unverifiedAssets.length > 1) {
        unverifiedAssets[_assetID] =
            unverifiedAssets[unverifiedAssets.length - 1];
    }
    // Implicitly recovers gas from last element storage
    unverifiedAssets.length--;
    // specifies that the asset is verified
    assetVerifiedCheck[assetCounter] = true;
    // notifies user of verification
    emit AssetVerified(_assetID , msg.sender);
}

//get number of assets registered in the whole platform
function getVerifiedAssets() external view returns(uint) {
    //require there to be verified assets
    require(verifiedAssets.length > 0, "no assets verified");
    //create a counter
    uint counter = 0;
    // for each asset in the asset array
    for (uint i = 0; i < verifiedAssets.length; i++){
        //increment the counter
        counter++;
    }
    //return the total count
    return counter;
}

// Get all assets
function getAllAssets() public view returns (uint[]) {
    // prepare output array
    uint[] memory assetIds = new uint[](assetCounter);
```

```
uint numberOfAssets = 0;
// iterate over articles
for(uint i = 1; i <= assetCounter; i++) {
    assetIds[numberOfAssets] = idToAsset[i].assetID;
    numberOfAssets++;
}
//return all asset IDs
return assetIds;
}

// Struct to store details about collateral
struct Collateral
{
    // A unique identifier of the collateral
    uint collateralID;
    // the asset ID created in the
    // asset registration
    uint assetID;
    // the owner of the asset
    address asset_owner;
    // the financial provider who has
    // agreed to accept the asset
    // as collateral
    address grantor;
    // the trusted party who has verified
    // the asset
    address verifier;
}
// CollateralCounter
uint public collateralCounter = 0;
// an array of collateral
Collateral[] public collaterals;
// Map each collateral to address
mapping (uint => address) public collateralIDTOwnerAddress;
// Map ID to collateral
mapping(uint => Collateral) public idToCollateral;

// Event to verify asset
event collateralCreated(address indexed _asset_owner,
    address indexed _grantor);

// Use asset as collateral
```

```
function createCollateral(
    uint _assetID ,
    address _asset_owner ,
    address _grantor ,
    address _verifier) public {
    require(msg.sender == _grantor ,
        "Only the fund provider can create collateral");
    //increase counter
    collateralCounter++;
    //store the new data into the struct collateral
    Collateral memory thisCollateral = Collateral(
        collateralCounter ,
        _assetID ,
        _asset_owner ,
        _grantor ,
        _verifier );
    // Checks if the asset already exists
    require(
        thisCollateral.collateralCounter != collaterals[thisCollateral],
        "Collateral already exists!"
    );
    //push new collateral into array
    collaterals.push(thisCollateral);
    //map the collateral id to the owner address
    collateralIDToOwnerAddress[collateralCounter] = _asset_owner;
    //map id to collateral
    idToCollateral[collateralCounter] = thisCollateral;
    //emit event that the asset has been created
    emit collateralCreated(_asset_owner, _grantor);
}

// Event to show the collateral has been removed
event collateralRemoved(uint indexed collateralID_ ,
    address indexed _grantor);
// Remove collateral
function removeCollateral(uint _collateralID) public{
    require(idToCollateral[_collateralID].grantor == msg.sender ,
        "only the grantor can remove collateral" );
    //remove the collateral from the collaterals list
    delete collaterals[idToCollateral[_collateralID].collateralID];
    //emit event that the asset has been created
    emit collateralRemoved(_collateralID , msg.sender);
}
```

```
    }  
}
```

\* End of Contract \*

The following github project was created as part of the MPhil FinTech Minor Dissertation.

Link: <https://github.com/KMzuku/AgriRegistry>

Follow these steps to run the project

1. It is recommended you use Google Chrome or Mozilla Firefox
2. Ensure that MetaMask is downloaded onto your browser of choice
3. Download the project by cloning or by downloading the zip folder
4. Ensure that Ganache is operating in the background
5. Remove the build folder
6. Open terminal
7. Enter "Truffle Migrate"
8. Enter "Truffle Compile"
9. Enter "npm run dev"

The project should be open on your browser.

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