Enhance Transparency of Organic Food Supply Chain

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Declaration

I, M.A.S.S.P. Gunathilaka, 2014IS024 hereby certify that this dissertation entitled "Enhance Transparency of Organic Food Supply Chain" is entirely my own work and it has never been submitted nor is currently been submitted for any other degree.

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Abstract

Transparency in the food industry has become an essential feature all around the world. This research discovers a way to enhance transparency of the organic food supply chain using an information system by connecting all the stakeholders there. This research has consisted of three main stages namely, organic customer survey, organic industry stakeholders' case study and development of a PoC. Results of the customer survey show less trust in the genuineness of organic food and they expect more information regarding farming practices. Certification bodies expect real time tamper proof information to identify malpractices. To achieve all these requirements this suggests a blockchain solution in mobile and user friendly system even farmers can use. This research will enhance the transparency by having a proper flow of data while increasing the truthfulness of entered data. To increase the accuracy of data entering this suggest a heuristic rule by using progressive recording method while using IoT devices to monitor the soil condition which facilitates cross check with recordings. Further enhancements can be achieved in future researches in the IoT area to reduce the cost of IoT equipments and increase Return on Investment.

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Acronyms

CA - Certification Authority
EAN - European Article Number
HACCP - Hazard Analysis and Critical Control Points
IOS - International Standards Organization
IoT - Internet of Things
MSP - Membership Service Provider
NOCU - National Organic Controlling Unit
NOP - National Organic Program
PoC - Proof of Concept
PoW - Proof of Work
PBFT - Practical Byzantine Fault Tolerance
QR - Quick Response
RFID - Radio Frequency Identification
UCC - Uniform Code Council
UK - United Kingdom
USA - United States of America

Chapter 1

Introduction

1.1 Background of the Problem

Organic food production is the management of fields and farms to achieve sustainable agriculture, high-quality products and adhering to processes that do not harm human, animal or environment. In the current world context, so many people are suffering from noncommunicable diseases such as cancers and kidney diseases. Some experts in the medical sector believe conventional food which include synthetic chemicals could be a main reason behind that[1]. Therefore some consumers have moved from conventional food to organic food. Whether there are several motivations such as taste, natural, environment friendliness, animal welfare, no genetically modified ingredients, no synthetic chemicals and trend most of the organic consumers expect quality and healthiness as main motivational factors to buy organic food[2].

A product to be sold as organic it should have an organic certification. Even though these products have an organic certification, there are loopholes in this process. Consumer expectations are really high about the quality of food and therefore they request more information about the whole organic process for them to believe in organic food due to the lack of trust in organic certification bodies.

However, demand for the organic food industry is increasing. The USA and Europe are the largest markets for organic food. In the year 2016 USA organic market was growing at a rate of 8.8% and it was the fastest growing sector in the USA food industry [3]. The organic Market growth rate in Europe was at a level of 13% in 2015 [4].

There were a lot of researches conducted to understand consumer motives and behaviours behind organic food. But the results have been varied according to different cultural contexts in different countries. Consumers have problems about the transparency of organic certification processes and they tend to be information seekers regarding product quality, origins and processing, as well as ethical, social and environmental impacts of production [5].

1.1.1 Local Organic Food Industry

Sri Lanka is an ancient agricultural country. However, with the time farmers used to do farming with synthetic chemicals. But now a trend is creating more towards organic farming. Sri Lankan farming community's shift to organic farming is due to kidney diseases in conventional farming areas and a stable price of organic foods. Sri Lankan government also launch a programme called 'Vasa Visa Nathi Ratak' to help organic farming.[6] Under this, farmers are educated and provide subsidies for them to adapt to organic farming. Area of organic farming has been 19,191 hectares in 2008 and it has been increased to 96,318 hectares in 2015. Also, the yield has been 4,216 MT and 41,128 MT respectively in the year 2008 and year 2010. Within the same time period, the percentage of organic foods compared to conventional foods has been increased from 1.33% to 3.5%.[7] These stats have shown that Sri Lankan organic food industry is gradually increasing. However, there are no any researches conducted on the demand and motives of organic customers in Sri Lanka.

1.1.2 Export Market

Food categories	**Food Types**
Fruits	Pineapple, Papaya, Banana, Lime, Mango and Juices
Spices	Pepper, Cardamom, Cloves, Nutmeg, Cinnamon, Ginger, Vanilla and extracts
Wild Harvest	Kithul Treacle, Jaggery and Bee Products
Other	Tea, Coconut, Medicinal herbs, Essential oils, cashew and processed foods

Table 1.1 Exporting Food Categories

Above mentioned food products are exporting into a large number of countries. However major importing countries are USA, Germany, France, Japan, UK, Netherlands, Sweden, Switzerland, Australia, Canada, Belgium, Austria.[8]

Sri Lanka Export Development Board is working on to promote Sri Lankan organic food in foreign countries. The most important area they want to work on is the credibility of the process and increase transparency by providing more information to required parties to prove that products are genuine. This will help to enhance the brand name of Sri Lankan organic food products.

1.1.3 Organic Food Supply Chain

Product to be certified as an organic, all the members and processes through supply chain should be recognized as genuinely organic. Initial links of the supply chain are seeds and fertilizer providers. All the ingredients used for organic farming should be approved substances. However, there are practical issues such as when they buy natural fertilizers they may not provide any bills or paper work.

Farmers can be identified as the most important link in the supply chain. There can be either individual farmers or farmer groups. There are some farmers who are directly connected with retailers. But most of the farmers provide their products to a wholesaler. Usually, these wholesalers are

responsible for processing, packaging and delivery. There are several business modules. Sometimes farming, processing and packaging are done by one company. Also, there are instances these are handled by two or more companies. At the end of processing and packaging, those products should be delivered to either retailers or exporters.

Retailers will keep links with their closest supply chain member to inform about what products are required. Then that message will pass through to the farmer and that is how they balance demand and supply. In a case of export, products will be supplied to exporters and they will handle the process until it reached the retail shop of the foreign country. They have to satisfy all the requirements of the foreign country including the process of organic certification.

1.1.4 Standards and Certifications

Most of the countries have standards for their organic food industry. As an example, USA maintain their organic standards under the National Organic Program (NOP). This is passed as a USA Parliament act.[9] Not only countries, regional institutes such as European Union also have their own organic standards which have been passed through European parliament. These standards will describe what is the quality they expect from organic food. This will be applied to the processes from farm to folk. But Sri Lanka currently does not have any organic standards and it is in the process of developing. For now, a draft version of the standards has been published for the public comment.

The problem with these standards is they are vague and it can be interpreted either way. As an example, one of the clauses in EU organic standards is ‘organic plant production shall use tillage and cultivation practises that maintain or increase soil organic matter, enhance soil stability and soil biodiversity, and prevent soil compaction and soil erosion’. Therefore organic certification bodies are preparing a checklist for the inspection process which will cover the standards. Otherwise for inspection officers too will have a difficult time to decide whether the process is organic or not. This inspection checklist may differ from one certification body to another.

Every country will have an accreditation board. Sri Lanka Accreditation Board(SLAB) is one such example. They will give authority to certification bodies to issue organic certification within that country. These certification bodies are under the supervision of accreditation board and controlling authority(parliament) of both importing and exporting countries.

There are countries which accept products certified by some identified countries without inspecting their quality again. As an example, a certification which has been approved in the USA is valid for Canada. This faith comes because of transparent processes those countries adopted. When a country follows transparent processes, exporters of that country can easily access to foreign organic markets.

1.1.5 Issues in the Organic Food Industry

The biggest threat in the organic industry is products which are not genuine. One of the biggest frauds in the industry is to mix conventional products with organic products. These malpractices

will lead to reducing the trust of consumers. As an example, there are complaints about malpractices against Indian Organic food industry[10]. Also, such reports came from European countries like Italy too[11]. This has created a bad brand image about organic foods from those countries and therefore they have to create a method to prove their genuineness of the process.

Retailers and consumers in western countries expect more transparency about the process. Not only in the organic industry but also in the conventional food industry leading retailers such as Wal-Mart are tracking the traceability of the food products, especially to act in scenarios like food contamination[12]. In such a condition consumers expect more safety precautions from the organic industry. Therefore exporters to the western world have to work on methodologies to give more transparency to end consumers. At the moment there are no laws to reveal a lot of information. But it can be a law or a clause to mutual trade agreement in the future. As similar to this European Union has requested the geographic location of the place of fishing to grant the free trade agreement. As like that, transparency can be a critical factor for this industry too.

1.2 Motives

Transparency can be considered as a must have ingredient for every industry. Even though, having transparency every time and in every process might not be the most favourable thing in the business world. However, maintaining transparency could be really helpful in many ways. When considering about food industry, transparency plays a crucial role because consumers expect safety and quality of foods they consume and they want to ensure it.

Many studies show that organic food supply chains are becoming more and more complex due to many social and economic reasons like the growing popularity of organic foods, increasing export demand and etc. As a result of that, the chances of happening fraudulent activities such as using pesticides for organic farming and selling non-organic products as organic, are increasing[13]. Therefore it is obvious that transparency is becoming a much needed fact for the organic food supply chain. Other than the above mentioned factors following motives are expected to achieve through this research.

- **Provide information that consumers and other supply chain stakeholders demand**

Nowadays people more concern with the information about food that they consume which has made them more active information seekers. According to the 2016 Label Insight Food Revolution Study, it is obvious that the lack of product information creates distrust and confusion among consumers[14]. Furthermore, it emphasizes stated key findings.

- Consumers expect brands to provide complete and accurate product information
- Consumers are confused about the ingredients in the food products they purchase
- Consumers are open for using digital channels to find the information they need
- Consumers do not trust the way brands are currently providing product information

- Consumers want more product information in order to make informed purchase decisions

Here with increased transparency of the food supply chain, not only consumers but also every supply chain stakeholder get the chance to get all information regarding food from the state of the farm to the state of the fork.

- **Ensure genuineness of certification process and food production process**

The organic food supply chain is different from other conventional food supply chains. Basically, it can be considered as a system which is totally built on trust. For an instance, in the organic food industry, certification bodies keep trust in farmers' procedures like maintaining logs. On the other hand, accreditation bodies keep trust in certification bodies and standards organizations keep trust on both accreditation bodies and certification bodies. Therefore in organic food supply chain, the trust is a must fact.

Even though there are many regulation bodies, there is no assurance to ensure the genuineness and integrity of the organic food supply chain. There is a high possibility of happening fraudulent activities in food production processes and even in certification processes[15]. Growing high demand for organic foods and their premium price can be the main cause for this high possibility of happening frauds[16][17]. Basically, for now, the genuineness of the organic food industry depends heavily on people with integrity doing the right thing.

In addition to that lack of transparency could be a possible reason for this high possibility of fraudulent activities. It increases the chance for people to trick the organic food system. With much transparency in the organic food supply chain, farmers are forced to follow genuine procedures for farming and also certification bodies will be able to have correct information that they want for the certification process.

- **Assure food safety and quality and risk mitigation through traceability**

This point is not only specific for organic food industry but also for conventional food industries. Basically safety and quality are sensitive factors in food supply chains. Studies show that even consumers are increasingly concerned about the safety and quality of the food supply chain. Traceability plays a crucial role to assure food safety and quality. For an example, in United States, Niagara Bottling, a water bottling company, recently recalled its fourteen bottled water brands after finding out one of their water sources was contaminated by E-coli[18]. Here they had to recall all the items for the much more extra cost. If there was a transparent information flow, they would be able to trace to water bottles which had contaminated water recall only contaminated ones. On the other hand, in food poisoning situations in the consumers' end like 2008 milk powder scandal in China and 2008 peanut butter contamination in the USA, a much effort had to put to control the harmful situation[19][20]. In most of these situations, the industry and even related industries have to stop their ongoing processes until the origin of the problem found. For an example in the peanut butter contamination situation, it took almost four months to identify the origin of the problem. Therefore, it is important to find cause for such situations as soon as possible and having better traceability in the supply chain can stimulate this process.

- **Increase chances in the export market**

As mentioned above, there is a growing demand for organic foods especially in USA, Japan, and European countries. As a result of that, a good organic food export market has been established in those countries and many countries are trying to penetrate that market with their organic products[21]. When considering those markets, they are well regulated and monitored. Moreover, as mentioned their organic consumers are more active information seekers. If Sri Lanka wants to have a higher organic export market share, it also has to maintain a well regulated and monitored organic food supply chain. As an example the organic export market collapse in India can be used. India is one of the top ten organic food exporters in the world[22]. Even though, recently its market collapsed by some amount due to malpractices and frauds happened in their organic food supply chain[10]. Maintaining higher transparency in the food supply chain could be used to prevent such malpractices and enforce supply chain stakeholders to follow standardized procedures.

Furthermore, losing GSP+ of Sri Lanka for seafood export to Europe also can be considered as a potential alert for organic food exports of Sri Lanka. Sri Lanka lost GSP+ in 2015, since its illegal, unreported and unregulated fishing[23]. Basically, there was no transparency in the fishing supply chain. To regain GSP+, Sri Lanka had to re-engineer the whole fishing process. Even though this is not directly related to the organic food export market, there is a possibility for emerging such situation. Therefore, this emphasizes the need for a well regulated transparent organic food supply chain.

- **Attract new customers and retain existing customers of the Sri Lankan organic food market**

Sri Lanka is a country severely punished with kidney diseases and cancers. Pesticides use for farming accounted for a considerable percentage from it[24]. The use of these harmful pesticides can be controlled by putting more focus on organic farming. But organic production in Sri Lanka has a slow growth[25]. Mainly due to health concerns, the general public wants to move to organic food. But customers do not have much trust on genuineness of organic foods. Some studies show that providing sufficient information could have an impact on the buying decision of the customers and increasing consumer trust on products. [26]

1.3 Research Questions

The organic food industry is based on a well regulated and monitored structure. To ensure the genuineness and integrity of products, it is a must to have a proper information flow within the food supply chain. On the other hand, there is a higher probability of happening frauds and malpractices in every node of the supply chain. By increasing transparency of the supply chain, these issues can be addressed to some extent. In this research, one main research question based on organic food supply chain transparency and three sub-research questions following that main research question will be addressed. The identified research questions are stated below.

- **Main research question**

How to enhance the transparency of the organic food supply chain?

- **Sub research questions**
  - What information are customers looking for when they take the buying decision for organic foods?
  - How to improve organic food quality and safety using supply chain transparency?
  - What is the best information system infrastructure to enhance organic food supply chain transparency?

Under the first sub research question, customer perspective in the organic food industry will be addressed. Basically, required extra information and factors that affect their buying decisions in the industry will be identified. In the second sub research question, one of the major concern in the organic food industry, food safety and quality will be addressed. Here, it search for methods to tackle malpractises and inform those to relevant bodies such as certification bodies on time. Under the last sub research question, search for the best information system infrastructure to deliver the required transparency, quality and safety of organic foods.

1.4 Goals and Objectives

1.4.1 Goal

The main goal of the research is to develop an organic food supply chain traceability system which will enhance the supply chain transparency while increasing the quality and safety of organic food products.

1.4.2 Objectives

The objective of the current study is to provide a comprehensive review of the literature, organic industry practices and its problems in relation to thorough analysis and provide an effective system for organic food supply chain management.

Particularly, the study has following sub-objectives,

- To provide a comprehensive review of consumer perspective on organic foods and what are their future expectations on organic foods

A consumer survey on the organic food market is conducted to identify reasons for buying organic food products, extra information needs to know about organic foods and its production process. The motivation behind collecting this information is to build concrete requirement documentation for the final prototype.

- To provide a comprehensive review of the current organic food supply chain and its problems

As mentioned above thorough analysis has been conducted about the current context of organic food supply chain and its problems through a series of interviews with supply chain members to find better solutions to address those identified problems. At the same time, the information they want from other members in the supply chain and information they are ready to share with others also gathered.

- To provide a way to mitigate food fraud and enhance the quality of organic foods by strengthening safeguards related to food authenticity

It is important to provide an effective way to avoid substitution, tampering, misrepresentation of data flow across the organic food supply chain and reduces inaccuracies caused by traditional paper tracking and manual inspection processes. On the other hand, it will help consumers to see if the organic certificates of the company are real, and know the product is really organic.

- To develop a single platform for all users in organic food supply chain which establish traceability in organic food supply chain by tracking and storage of all product information at all stages of the supply chain

Finally, a common system for all organic food supply chain members is developed which enables tracking of all product information such as Farm origination data, processing data, and shipping data at all stages of the supply chain (farm to the fork) through transparency. This will lead to increases consumer confidence and trust towards the organic foods because producers and any related parties are held accountable for what they are doing.

1.5 Research Approach

At the first stage, the type of research that will be used in this study is qualitative research. The aim is to gather an in-depth understanding of consumer behaviour and the reasons that govern such behaviour to built the platform to provide the necessary information while increasing consumer trust towards organic foods. Therefore data has been collected from a vast number of sources from seeds suppliers as the starting node of the supply chain to the end customer as the finishing node of the supply chain.

- Survey on organic food consumers

This research is trying to increase the transparency of organic food supply chain. Any industry depends on its customers. Therefore it is important to know the reasons they are attracted to organic foods and problems they are currently facing in the industry. This customer survey is also focused to get to know information about the way customer keep their trust on organic food and what they expect to increase their trust. On the other hand, to check the financial feasibility of the project maximum extra amount customers ready to pay for their expected extra information is recorded.

- Analysing the current context throughout the supply chain

In this research, examined the current processes of all the supply chain members including seed providers, fertilizer providers, Farmers, government authorities, food processing entities, retailers and organic certification bodies. As organic food industry is not widely spread compared to conventional food industry it is hard to find the target population for the research study. Therefore snowball sampling technique which works like a chain referral has been used. Therefore initially selected a particular retailer and use snowball technique to identify and interview other members in the supply chain. This is the method used to collect the information across the supply chain.

- Develop and evaluate POC

Then all the factors find out above are considered and proposed a solution which increases the transparency in organic food supply chain by achieving customer expectations while it is feasible for all the supply chain members. After that, according to the proposed solution developed this as a POC and tested that POC using a selected farm and supply chain members relevant to that.

1.6 Delimitations

Few delimitations have been identified which does not cover under the scope of this research. They are as follows.

- Decision support system instead of decision making system

The flow of data has been optimized across the supply chain by developing supply chain traceability system and provided all the necessary information about a particular organic product at all stages of the supply chain to consumers and necessary party to decide whether the product is acceptable as organic or not. It will be difficult to decide exactly the product is organic or not. But it provides the necessary assistance for consumers and certification authorities by providing information to make their decision regarding that particular product or farmer. So consumers can buy that particular product at their own choice.

- Sustainability issues in a real implementation

During site visits, identified that some farms don't have sufficient facilities like electricity power to cater to a technological solution. In this study, any direct solutions to address these kinds of issues will not be provided. Therefore, POC is developed and tested in a selected farm with supply chain members relevant to that. This PoC system will not be implemented into a large number of farmers and supply chain members around the country.

- Training for supply chain members

Some farmers don't have much technical knowledge to understand the way of system works and use it in an accurate manner. So this study is limited to give a system which only caters comfort design with user-friendly interfaces for farmers and not to conduct any user training sessions and awareness programs for the long-term sustainability of the research.

- Financial feasibility of IoT Module

An IoT module is designed to increase the chances of detecting malpractices in the farm. While designing this it is considered only about the technical feasibility. Here, the aim is to show that there is a capability of using IoT to detect malpractices and to show a new path for further researches. In that case, does not consider applying it to real world conditions and financial cost.

1.7 Assumptions

Following are the assumptions made during the research.

- The supply chain members answered the interview questions in an honest way. They don't have any motive, to show a wrong picture to the society and get advantage from it.
- Participants in the consumer survey provided honest answers. The Customer survey was done during customers' purchasing behaviours and assumed they didn't take it as a burden for their purchasing.

1.8 Intended Contributions

The primary deliverable of this research will be an information system to increase transparency in organic food supply chain. In addition, we fill an existing knowledge gap by contributing the following,

- To the best of our knowledge, we are the first to analyze the Sri lankan organic food customer behaviour and their future expectations regarding the industry.
- To the best of our knowledge, we are the first to interview all the stakeholders in the Sri Lankan organic food industry including supply chain members such as seed suppliers, farmers, wholesalers, retailers, exporters and certification bodies to understand their problems and malpractises happening in the industry.

Chapter 2

Background

The Organic food industry is a developing industry. So, there are so many researches have been currently conducting throughout the world. Most of those researches try to enhance the organic market.The growth of the organic food industry mainly depends on 3 factors according to Michelsen et al.[27],

- The growing interest of customers
- Retailers, especially the multiples, which have had a key role in furthering growth, promoting products, increasing range and aiding farmers to convert
- Conversion support available to producers

Whether Michelsen et al[27], state only above factors, some other researchers add a few extra points to the above. Marques et al[28], state that not only retailers but also other supply chain members such as wholesalers and exporters support also important to the enhancement of the organic industry. The rationale behind that is since farmers and retailers are not connected directly all links in the supply chain in between that also important.

2.1 Stakeholders' View About Organic Food Industry

2.1.1 Organic Customers

Customers are the kings of any business. In the organic food industry also it has no difference. Therefore so many researchers have done researches focusing on different aspects of customers. Those researchers are mainly focused on the attitudes, behaviours, motives of organic customers, conventional food customers' reasons for rejecting organic and what do they expect to increase the purchase of organic food.

Motives to purchase organic foods

Motives of the customers to purchase organic foods were identified initially. Healthiness, taste, natural and environment-friendly factors are the most important motives behind organic customers

according to Marques et al. 2013 [24]. The fact that organic foods does not include genetically modified ingredients and synthetic chemicals also consider as motive to buy organic food[29]. There are specific instances people use organic food to increase the healthiness. Usually parents of babies and young children concerned about pure and natural food. Since they believe organic has those qualities, they buy those. Also, people who faced with serious illnesses use organic food expecting that it will speed up the recovery process. Animal welfare and trend are also identified as motivational factors to buy organic foods[2]. Overall researchers have identified healthiness, more taste, natural, environment friendliness, no genetically modified ingredients, no synthetic chemicals, animal welfare and trend as the full set of motivations for purchasing organic food. But healthiness, tasty and environmental friendliness are the biggest concerns accordingly[28],[2].

Barriers to turning into organic

Reasons behind conventional food customers not turning into organic food should be clearly identified. There are few researches focused on this. Price, quality, availability and distrust of organic certification are the facts which customers are kept away from organic foods[5]. Other than that visual product quality presentation and mistrust of supermarket chains have being identified as restraining factors for organics [29]. However, more than 70% of the customers would buy more organic products if they would cost less than they cost now. A bit less than 20% of customers did not consider price as a burdening factor for non-purchase of organic products and 10% were not sure whether they would purchase organic products with lower prices [30].

Other than the price, distrust of organic certification also identified as a barrier to organic purchases. According to the current context, this is not one of the biggest barriers. But this is emerging as a threat to the organic food industry in recent years [4]. In the year 2010, 71% of customers just want 'organic' word printed in the package and only 27% checked the organic certification. But in 2014 just 63% of customers satisfied with the 'organic' word and 30% of customers looking for organic certification information. There are different stats which shows 40% of people always checked organic certification, 27% sometimes check while 30% never check organic certification [29]. Distrust in organic certification has now being spread out from Italy to few retail chains in the UK too [5]. Both buyers and non-buyers would like to be better informed and would appreciate more supplementary information about the organic certification process when they make a purchase[31]. These stats show that there is a growing concern about the credibility of organic certificates and there is a requirement to address that in the near future.

Demographics of organic consumers

It is important to identify the customer base to understand the required transparency information for them. There are two main types of customers have identified as regular and occasional customers. Regular customers consider the potential benefits of organic foods rather than on price premiums. But they want more availability of organic foods and information about the products [29]. Regular customer tempted to think more about the society and environment[32]. They did tend to be information seekers, however, particularly regarding product quality, origins and processing, as

well as ethical, social and environmental impacts of production [5]. Occasional customers have few problems with organic foods such as high price, less belief about organic food benefits and not easily accessible in shops they visit [29]. Occasional customers are usually expecting pleasant appearance presentation of foods and taste. They usually show less care about environmental facts [32].

2.1.2 Retailers and Wholesalers

Retailers and other supply chain members also have to do a great amount of work to develop the organic food industry. At least three parties will be involved in the food supply chain before it comes to the hands of customers mainly farmer, wholesaler and retailer. Wholesalers are monitoring the process, use of contracts with premium price established and transport and distribution of the product to the shops. Most technical and marketing information coming from wholesalers. Retailers want to build a direct relationship with farmers to give customers the experience they expect as soon as possible. They are trying to conduct workshops on behalf of farmers and they want to share information they have with farmers and vice versa. But due to geographical barriers, it is a bit difficult task. Wholesalers also oppose that because they believe a direct relationship between retailers and farmers will eradicate the requirement of wholesalers [28].

Organic food supply chain is usually dominated by supermarket chains. In the UK 80% of market share is controlled by four supermarkets while in Australia the same proportion is controlled by two supermarket chains. They are providing a wide product portfolio of organic foods. Their biggest factor for their success is they are addressing the price problem via targeting a large number of customers at a low-profit-margin [2]. But some of the consumers have put more faith in specialized organic retail shops rather than supermarket chains [29]. Other retail shops can be in form of organizations that use cooperative business structures, independent outlets, farm shops, farmers, markets, community-supported agriculture schemes and productive gardens. Also, there is a processed organic food market such as restaurant, pubs and institutions including schools, hospitals and government organization [2].

2.1.3 Farmers

Farmers are one of the initial and most important links of the value chain. The biggest problem farmers are facing in the organic industry is the low yield through the conversion period [27]. Now, most of the governments are taking actions to support farmers in the conversion period. Especially, UK government is providing huge subsidies to farmers during the conversion period to attract farmers [33]. But that's not the only problem they have. They want proper education about the organic farming and timely information such as price, demand and weather predictions to increase their efficiency of work. Researchers have found that by integrating government bodies to provide accurate long-term climate forecasts will help farmers to grow vegetables and fruits which suits those climates[34]. Price is an important factor for a farmer to take the selling decision. Therefore it is important to have prices of foods in a publicly available place. This will reduce the undue power

of the wholesalers [35]. As like this, an integrated information flow will solve most of the farmers problems.

As like this all of the parties involved with organic food are expecting more and more information. This will lead the organic food industry to a more transparent industry. As described above, consumers prefer organic industry expecting quality products. They are expecting to take more informed decisions. Supply chain members such as retailers, wholesalers and farmers also expecting more timely and accurate information to make their decision. The government also want real-time information about what is happening in the organic food industry rather than reports a few months later when an incident happened.

To achieve the above specified objectives, so many researches have been conducted under the topic "Food supply chain transparency". Most of the researchers proposed food traceability systems with RFID technology to trace the product and get the information of the product at all stages of the supply chain and several other researchers proposed collaborative platforms to integrate with supply chains to share the information effectively and efficiently across the supply chain while achieving transparency. Moreover, some researchers provide the determinants as well as best practices to achieve transparency in supply chains.

2.2 Existing Systems to Improve Transparency

2.2.1 Food Traceability Systems with RFID

One of the major problems in the agricultural industry is the information gap exists in the agri-food supply chains. That problem can be happened due to two reasons. First one is an unwillingness to share information between supply chain members and another one is lack of sufficient technologies to make transparent information flow in supply chains. H. Hong at el.[36] have suggested a framework for promoting a food traceability system for a store supply chain of manufacturers, Distribution centres, and retailers. In this research, they conducted a case study of RFID implementation in the chain of convenience stores in Taiwan and proposed traceability system which provides food distribution information to all supply chain members by storing relevant information in RFID tags, therefore, it provides supply chain transparency. But in this research, they have only considered the information in distribution link and also not considered about food consumer's perspective like what are their expectations and information they need to know about food products.

Thomas and Katerina [37] proposed an information infrastructure for RFID enabled traceability in a supply chain and it provides verifiable traceability across the supply chain in an efficient and effective manner. According to the proposed system company requires only the installation of the RFID reader devices and a personal computer, through which all information is sent to and received from the central information system. And also members in the supply chain can integrate their own system with this proposed system so that production information of the product is provided automatically to the traceability system. Rather than giving the information about distribution link like early mentioned research this gives more focus on food safety across all the supply chain links by capturing product information at all stages of the supply chain therefore it enhance transparency

across the supply chain and give significant benefits such as companies can act proactively may save themselves from potential problems like food contaminations, proposed system can reduce product recall costs, once a food deficiency happens and advertised traceability can raise customer's confidence and loyalty, acting as a competitive advantage mainly for retailers, but also for producers. But the weakness of this study is they have not tested the proposed system effectiveness and efficiency through practical implementation.

D. Folinas et al.[38] have proposed a traceability data management conceptual framework for food supply chains. In this paper, the proposed framework for the management of traceability data is introduced for fresh, non-processed food products supply chains. The main objective of this framework is the establishment of an environment that will support information flow transparency and efficient decision making in the examined supply chains. The proposed system can be used to find and communicate information regarding product quality, origin, and consumer safety while achieving supply chain transparency like above-mentioned researches. Other than the previously described research findings this proposed system ensure entering information comply with HACCP and ISO standards, while RFID is based on EAN -UCC standards. therefore it maintains the quality of the information which shared across the supply chain and it gives more transparency for users. The main limitation of this research is they have not proposed a solution to avoid unnecessary tampering of the data.

2.2.2 Collaborative Platforms to Achieve Supply Chain Transparency

The transparency allows companies to reposition themselves in the production chain and dynamically collaborate with other companies for the purpose of optimizing their business. Claudia et al.[39] have proposed a theoretical framework to analyze the route of the use of collaborative platforms to integrate supply chains. This study investigates the aspects of using collaborative platforms for the integration of supply chains, a qualitative research approach was adopted and developed through two case studies in companies from the manufacturing sector and the results show that firms can share information effectively and collaborate with partners to support supply chain activities by achieving transparency through such platform. But this research analyzed only one party of the supply chain (manufactures), but it is very important to conduct an overall study by engaging all supply chain members that are using this platform.

Lorena et al.[40] have proposed a system which provides a collaborative framework which involves all the supply chain members in a food supply chain. This system integrates with other systems in production plants, warehouses, and stores and it enables receiving and sending information on real time through mobile devices. So every supply chain member can monitor supply chain activities in real time because it will enhance the supply transparency. Moreover, this system includes services like collaborative supply planning, collaborative demand forecasting, global inventory visibility and collaborative order promising. The proposed system is tested based on a fish supply chain composed of a fish provider, distribution company, and consumer goods retailer. The results of the pilot test show that benefits like collaborative purchasing, traceability, transportation management, collaborative supply, marketing, resources planning and quality control

can be achieved through transparency. But in this study, they have not mentioned the accuracy of information, flow across the supply chain and how the information credibility can be achieved when using such a system.

2.2.3 Determinants and Best Practices to Achieve Supply Chain Transparency

Zhang et al.[41] have investigated the best practices regarding food supply chain transparency. They conducted inductive research to investigate the underlying patterns and derived hypotheses to develop a theoretical framework regarding best practices. Finally, they compare their findings with the literature and as a result validate the proposed theoretical framework. This study identified four transparency domains (food safety, quality, origin, and sustainability) which represent a hierarchy of transparency domains and also it shows that information sharing is the key element for increasing transparency. For that Information, quality is a much needed requirement of food chain transparency and information quality mostly includes aspects of accuracy, relevance, timeliness, reliability, completeness, usefulness, credibility, trustworthiness and being up-to-date. Furthermore it identified that performance indicators like avoidance of abuse (“avoid falsifying information and prevent the cheating of consumers”), the increase of market share (“contribute to higher market shares”, “assures market access and recognition”), the possibility to act quickly in crisis situations (“be able to act quickly in case of an epidemic or crisis” “quick access to data”) and the improvement of competitiveness (“develop competitive strategies”, improved competitiveness of producers”) can directly or indirectly evaluate the success of a transparency practice.one of the limitation of this research is countries and sectors involved in the study was limited due to time and budgetary constraints.

M. Deimel et al.[42] proposed a measurement model that integrates various perspectives on transparency and, moreover, considers various measurement concepts. In other words, the main objective of this paper is to identify the determinants of transparency in supply chain and integrate them into a measurement model to measure the correlation between determinants and transparency in German pig and dairy production. In other words, it shows that what determinants have more impact to supply chain transparency. So this proposed model enables business management to identify strengths and weaknesses of specific chains and identify strategies and actions necessary for improving transparency in food supply chain.

2.2.4 Achieve Food Supply Chain Transparency Through Food Safety Standards

Many public and private standards on food safety and quality have been developed as a result of food quality and safety incidents happened around the world. But there are some problems in developing countries and emerging economies when complying with these standards. Trienekens and Zuurbier [43] stated that government departments which relate to the food industry should ensure the food quality and safety of agri-food products by setting legislation and regulations. In this research, they provide a comprehensive review of all existing food safety standards around the

world and they proposed future outlooks for quality assurance in the food industry to guarantee the quality and safety control through the transparency of the agri-food supply chain management.

2.3 Blockchain

As emphasised above, many studies have been conducted and many solutions have been implemented covering the areas of the food safety and quality, fraud prevention, trust within food supply chain, traceability and balancing demand and supply. Ultimately, the expected end result is to increase the transparency of the food supply chain. In addition to the above mentioned proposed solutions, in some studies, a concept called "Blockchain" has been suggested to use to implement solutions for optimizing the food supply chain.

When considering Blockchain, the concept was originated with cryptocurrencies and it was the base technology for Bitcoin: a peer-to-peer electronic cash system [44]. Simply, Blockchain is a chain of blocks which is replicated across a distributed peer-to-peer network. It can be considered as a distributed ledger which holds immutable data in chronological order. To insert data or information into the blockchain, a consensus algorithm is used and as the principle evolves, many other blockchain platforms have been implemented with different consensus algorithms and it gradually evolved as a technique which has much broader applications than just acting as the backbone of Bitcoin. According to Marco Conoscenti et al. [45], Blockchain has use cases in data storage management, trade of goods and data, identity management, rating systems and many other various areas. Here, food supply chain in trade of goods and data is a widely addressed use case of Blockchain technology.

In studies on food supply chain based on Blockchain, the researchers have tried to achieve different goals such as security, traceability, trust, efficiency and fraud prevention through transparency. Moreover, these relevant studies have been conducted in different contexts like Indian, Chinese, Australian and European [46][47][48][49]. In these studies, some are focussed on whole food supply chain and some are focused on a certain part of food supply chain and infrastructure wise, these studies can be categorized based on their focuses on information flow, payment flow or both.

2.3.1 Conceptual Models of Blockchain Implementations in Supply Chains

In their study Daniel Tse et al.[50] have shown how blockchain technology can be used to ensure information security in food supply chain through increased traceability, transparency and immutability of data. The study has been conducted based on two main hypothesis; blockchain ensures the traceability and reliability of each transaction in the food supply chain and blockchain can fulfil the demand of governments, enterprises and consumers, aiming national conditions of China. To identify potential problems which should be addressed in the study, they have conducted a PEST analysis and proposed a conceptual model to optimize the food supply chain. But since the study was about a conceptual model, they have not addressed the implementation difficulties and challenges while using blockchain technologies in the model. On the other hand, Feng Tian et al.

have suggested a similar model based on HACCP which is a risk management model invented by NASA and Internet of Things for Chinese context [48]. Their proposed solution is supposed to work as a decentralized information system which aims to cover openness, transparency, neutrality, reliability and security in food supply chain. Moreover, in this study, in addition, to using Blockchain directly, they have discussed the limitations of typical bitcoin blockchain such as low throughput, low capacity and high latency and especially about the scalability issues of Blockchain. In the study, they have elaborated the model using a hypothetical scenario and also they have emphasised that even with a decentralized architecture, there is a chance for happening frauds and misbehaviours in the food supply chain if there is an overpowered monopolistic agency in the system. But in their study, they have not considered about required advanced IT infrastructure for implementation and delivering real business benefits for supply chain stakeholders. Furthermore, in an extension of this study, they have suggested a model which uses RFID for insert and update information stored in the blockchain which has the ability to handle genuineness of feeding data to the system [46].

In this context Lan Ge et al. have tried to figure out the relevance and implications Blockchain technology in the agri-food supply chain using a proof of concept in an application based on a use case concerning table grapes from South Africa [47]. In the study, they have emphasized the increasing demand in society for greater information about food which reflects the need for more transparency and trust in food supply chain and potential risks in food safety, food quality and sustainability. Through their study, they have identified some problems in the current situation such as high cost and inefficient paper based processes, fraud and corruption in both manual and IT based systems, the integrity of digital records and double spent of certificates. Moreover, they have discussed opportunities, challenges and learning objectives for different stakeholders including food producers, certification bodies, government agencies, retailers and etc. in grapes supply chain in South Africa.

2.3.2 Blockchain for Complex Supply Chains

Even though there are some studies have been conducted on the transparency of food supply chain based on Blockchain technology, there are no studies specifically targeting organic food supply chain. As elaborated, since the organic food supply chain has a complex structure, unlike typical food supply chain, it may not be fair to use those results from studies on typical food supply chain for organic food supply chain, but those studies might be helpful to have some insights on organic food supply chain. When considering the complexity of supply chain, in the study conducted by Kristoffer Just [51], a conceptual blockchain design for the case partner COOP Trading was proposed for Extra Virgin Olive Oil (EVOO) supply chain which is considered as a relatively complex supply chain. In this study, the researcher was trying to figure out the influence of Blockchain in the role of inter-organizational trust in fragmented supply chains. Based on suppliers' insights on the supply chain of EVOO through interviews, questionnaires, workshop, field study and documents, he has examined three aspects that can be achieved through Blockchain based solution; Contractual trust in between two parties, Predictability of supply chain stakeholder behaviours and Dependability which refers refers to expectations that the partner will act in the

alliance's best interest. Ultimately this study has proposed a blockchain based conceptual model to ensure the trust in the supply chain to minimize identified frauds in the system. But since it's a conceptual model, the sustainability of the proposed model was not addressed.

In this manner, André Jeppsson and Oskar Olsson [52] have tried to address traceability issues from the perspective of a fourth party logistics firm and to increase the transparency of the food supply chain. Here, they have argued that one way of solving traceability issues, and at the same time achieve transparency, could be to use the blockchain technology. In this study, in addition for suggesting a blockchain based model, they have identified few key challenges in using blockchain for addressing such problem like the immature and complex technology behind blockchain and conversion of present collaboration processes into blockchain suited ones and also they have discussed the heavy time consuming mining process in tradition blockchain approaches and have suggested using Hyperledger Fabric blockchain framework in which is not required any mining process at all.

Based on other related studies, M. Caro et al. [53] have suggested a blockchain based food supply chain management system covering all the stakeholders of the food supply chain. In the suggested model, the data feeding to the system happens through IoT devices which means the data feeding is automated and it has increased the integrity of the process. In their study, they have concerned the occurring of issues in a manual data feeding process and have addressed those issues using automation. Moreover, they have controlled this automation process using smart contracts which is a key feature of blockchain technology that allows run predefined logic in Blockchain and also the same mechanism, IoT and smart contracts, have been used to maintain the process within the supply chain at every node. The pushed information from one end can be delivered to consumers through a smart tag. The speciality of this study is that for evaluation purposes, they have implemented two separate models using two blockchain frameworks; Hyperledger Sawtooth and Ethereum and have compared the performance of these two models. Ultimately they have concluded that Hyperledger framework is more efficient than Ethereum framework.

2.3.3 Use Cases of Blockchain Implementations in Different Supply Chains

In addition to the above discussed studies, there are many other Blockchain based traceability systems implemented for food supply chain for different use cases such as wine supply chains, rice supply chains and tuna supply chains. In their study, K. Biswas et al.[54] has discussed a traceability system for wine supply chain based on Blockchain focussing on preventing possible counterfeits of stored information as required and he has focused on three key aspects where blockchain can achieve a significant breakthrough: extended visibility, dynamic optimization, and open forecasting. Moreover, in this study, the researcher has shown how a mining process which is a block validation methodology in Blockchain [54] can be used in this kind of blockchain implementation. Same as wine supply chain, C. Visser and Q. Haniche [55] have identified the possibilities of happening fraudulent activities in the Tuna supply chain have suggested a blockchain based system to address those issues. In their approach, they have suggested using RFIDs which is a common method in this kind of systems to acquire data in to the system, but the speciality of this study is that they

have addressed the infeasibility of using only relatively high cost RFIDs for whole supply chain process and have proposed a low cost RFID and QR mixed approach. Moreover, V. Kumar and N. Iyengar [56] have suggested a similar blockchain based traceability system targeting rice supply chains from an Indian perspective. They have discussed, how Blockchain technology can be used to avoid a single point of breakdowns in a traditional information system and they have emphasised the possibility of using smart contracts for validating data transactions in the proposed system.

As mentioned above, the blockchain technology has been used not only for optimizing whole food supply chain but also for optimizing a specific part of the food supply chain. For an instance, Yu-Pin Lin et al. [57] have discussed using blockchain technology to create a decentralized farmer groups region wise targeting to increase farmers' access to agriculture information, high quality data, improved traceability and higher compliance with international standards. The proposed model is more likely a local government service. Here, they have listed improved trust and information intensive farming as the proponents of the study and they have emphasized that blockchain technology can be used to improve trust and integrity in the system by eliminating centralized administration bodies and preventing data distortion by ensuring the immutability of stored data. Moreover, they have identified the scalability issue of typical bitcoin blockchain as a limitation of their proposed model.

2.3.4 Commecial Blockchain Implementations

As the concept evolves, in addition to these conceptual or proof of concept (PoC) models, commercial blockchain implementations on food supply chain also can be identified. An Australian based company called Beef Ledger has suggested and implemented a blockchain based provenance and payment platform for the beef supply chain.[58] According to their white paper, there is a growing demand for food security from their potential importers, China and other Asian countries and also they have identified provenance, authenticity, exacting ethical standards and concerns for safety are amongst key drivers of consumers' interest in Australian food products. Furthermore, in addition to consumers' interests they have addressed 3 dimensions of possible risks in the beef supply chain; product substitution, origin misrepresentation and cut substitution. Here, they have shown, by having traceability of provenance, all supply chain stakeholders including consumers, producers, processors and regulators can have win outcomes. Even though there are many conceptual models, PoC models and even commercial products based on Blockchain targeting food supply chain, in most of the cases, those proposed solutions only ensure the integrity and genuineness of data within the systems, but not the genuineness of initial feeding data. Furthermore, they do not discuss the motives of food supply chain stakeholders to adapt to the new systems.

Chapter 3

Methodology and Design

The primary focus of this study is to propose a traceability system in order to increase the transparency of the organic food supply chain. But the problem here is, to give a technical solution it needs a lot of information about the context. However, no proper researches have been conducted in Sri Lankan organic food industry to gather information. In this case, to establish solid requirements and proper understanding of the environment, the approach consists of three main parts;

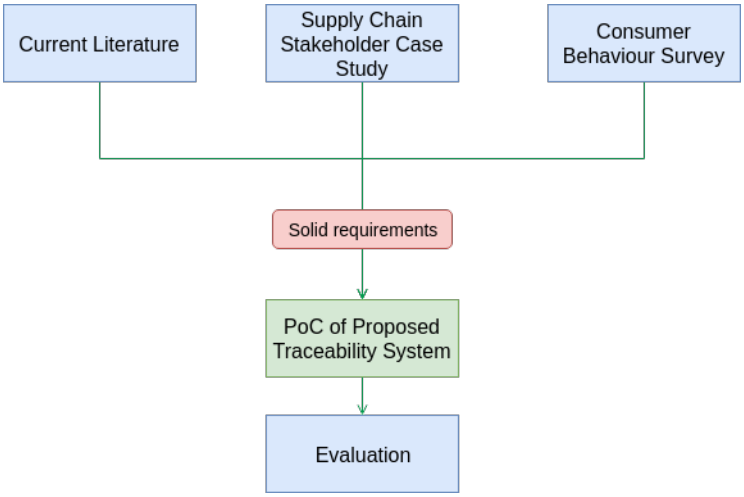

Fig. 3.1 Research Methodology

Related literature of previously conducted studies, mostly in foreign countries were studied initially. Then supply chain stakeholder case study to understand the process from each type of supply chain member perspective and organic consumer behaviour survey to generate patterns and behaviours of organic food consumers conducted to get the insights. Based on those information PoC for a traceability system to increase transparency in the organic food supply chain is proposed.

3.1 Supply Chain Stakeholder Case Study

3.1.1 Case Study Design

The main idea of conducting a stakeholder case study is to gain a thorough understanding of the organic food supply chain processes and its participants. Here to conduct the case study, snowball

method was used to find the target population for the research study. Initially, few well known retailers were selected from specialized organic retailers, supermarket chains and processed food retailers. Using these retailers as the base of the case study, other members in the supply chain were selected using snowball technique. Data collection was made through a series of interviews which had helped to gather all the information relevant to the organic supply chain while increasing the validity of the results. In this comprehensive case study, it describes behaviours of each supply chain member and their role while elaborating on their problems, objectives and business model.

3.1.2 Participants

For this case study, all types of members in the organic supply chain including farmers, wholesalers, raw food retailers, processed food retailers, exporters and local foreign organic certification bodies are interviewed to gather information from their perspectives.

3.1.3 Time

The case study was done throughout a four months period of time. This time has taken to prepare structured interview questions, find a particular retailer and then find other supply chain members through that retailer, interview them, analyze and document the interview findings.

3.1.4 Interview Questions

Separate structured interview questionnaires were created for each type of participant in the organic food supply chain by covering all the aspects they have involved in. As an example, in the farmers' questionnaire, their problems, day to day activities (reporting, land management and etc.) and inspection processes were included. Information was collected across the supply chain using these types of questions targeting to identify stakeholders' motives, expectations and facts which cause for inefficiencies that work as a fact to reduce the transparency of organic food supply chain are identified.

3.2 Consumer Behaviour Survey

3.2.1 Survey Design

This is the first ever survey conducted in Sri Lanka to analyze the organic food consumers' behaviour. Hence, deriving information for the design from previously conducted local studies was not possible. But since there are some foreign studies on this area, it was possible to have some insights to some extent. Therefore initial survey questionnaire was designed using the insights from researches in foreign countries and problems identified during the initial case study survey. Other than the organic customers, conventional food customers also interviewed to identify reasons for not to buy organic foods. It was designed to conduct as face to face interviews and prepared to achieve following objectives;

- To identify organic food consumers' motives to consume organic food
- To identify on what organic customers currently putting their trust
- To identify organic food consumers' information needs
- To identify organic food consumers readiness to adapt to the new system
- To identify reasons for conventional food customers not turning into organic food

Sample

The target population of this research is Sri Lankan organic and conventional food customers. As the sample of the study, customers from Colombo, Kandy and Gampaha districts were selected. In those districts, customers from 3 supermarket chains, a specialised organic food retailer and a processed organic food retailer have been selected to acquire ideas from different parts of the society. Also, the survey was conducted in both weekdays and weekends to capture both working and non-working communities.

Time

The customer survey was conducted in the months of June and July. Due to the high number of location and the same research team is visiting all the places eight days were used to conduct the consumer survey.

Questions

The questionnaire was designed with a clear and specific question structure in which one question depicts a single area and questionnaire can be answered within a maximum of five minutes. Furthermore, the questions were designed in a way that participants can answer without revealing their exact personal information. For example, instead of asking a participant's specific salary, it was asked as salary ranges. Questionnaire is attached into Appendix A.

3.2.2 Data Gathering

In the survey, only the customers who were eligible to take the buying decision of the family have been interviewed using supermarkets, processed food retailers and specialized organic retail shops. In specialized organic food retail shops and processed food retail shops, customers have been interviewed after the payment process was completed. But in the supermarkets, customers were interviewed during their purchasing behaviour.

3.2.3 Data Analysis

The gathered data have been analysed using SPSS tool. This tool helped to analyze all the required information and figure out hidden correlations and significance among different variables.

3.3 Traceability System

As the final stage of the study before evaluation, an organic food traceability system is implemented as a proof of concept according to the findings derived from supply chain stakeholder case study and consumer behaviour survey. After a thorough analysis of the current literature, as elaborated in chapter 2, from many possible solution architectures, a blockchain based solution architecture has chosen for the proposed traceability system. To justify this selection below facts can be emphasised.

- Stakeholders need a tamper-proof information flow in the supply chain. Tamper-proof data is a key feature of the blockchain.
- The organic food industry is a sensitive area which has a higher probability of happening fraudulent activities. If there is a centralized overpowered authority in the system, these chances are increased. Therefore, the need is for a decentralized architecture which can be achieved through blockchain.
- Ability to tracking the provenance of a product is critical and needed so that it enables take actions immediately in case of happening fraudulent or disastrous situations.
- The solution should be sustainable while at the same time being efficient.

3.3.1 Selecting the Blockchain Framework

In blockchain, there are different implementations such as Bitcoin, Ethereum, Hyperledger Fabric, Hyperledger Sawtooth and etc. These platforms have different characteristics in areas like consensus, transaction model, identity management and etc. Therefore, to implement a traceability system for organic food supply chain, the most suitable blockchain platform should be chosen and also match physical characteristics of organic food supply chain with characteristics of the blockchain platform is important. For this study, Hyperledger Fabric has chosen to implement the PoC of the traceability system and below status, facts can be considered as the motives to do such selection.

- In organic supply chains, it is important to protect sensitive data for complying with data protection laws or regulations therefore information privacy and confidentiality is a key requirement in the organic supply chain because the stakeholders in a Business-to-Business (B2B) network want to share their information in a secure manner with their supply chain members except for other supply chains and their members. As mentioned in the Hyperledger introduction, it offers the feature called “Channels” for this important requirement. Basically, each these channel have their own private ledger in the blockchain network.

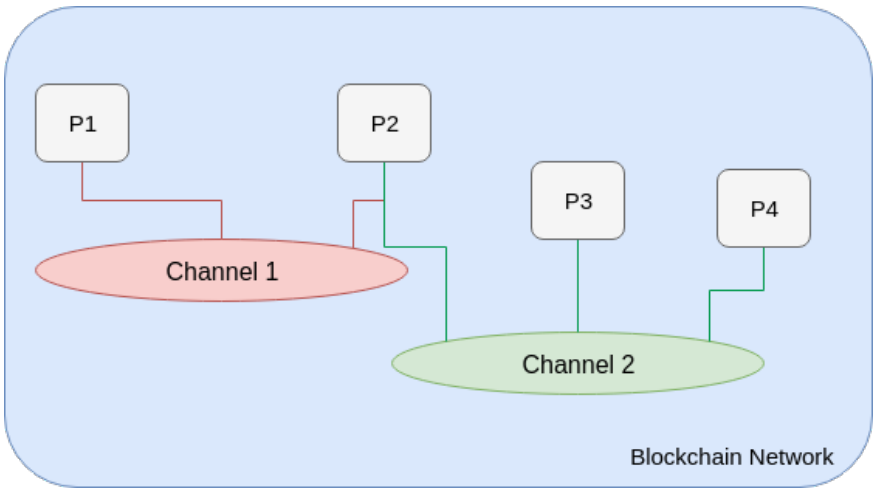

Fig. 3.2 A Hypothetical Blockchain Network with Channels

This blockchain network consists of two channels where P1 peer resides in Channel 1, P3 and P4 peers reside in Channel 2 and the P2 peer is relevant to both channels. Here, P1 can only access data transfer in Channel 1, P3, P4 can only access data in Channel 2 and P2 can access data in both channels since it is connected to both channels. [59]

- Hyperledger Fabric provides a modularity architecture which can be customized and it allows organizations to adopt suitable encryption, consensus protocols and other components based on the domain specific business requirements and relationships existing between network participants [60]. Depending on the practicalities in the organic supply chain it has the freedom to adopt a suitable consensus protocol rather than using a standard protocol like PoW which has low performance figures according to Table 3.1.

Property	**Permissioned consensus (Kafka , PBFT)**	**PoW**
Speed	Good	Poor
Scalability	Moderate	Good
Finality	Good	Poor

Table 3.1 Comparison Between Permissioned Consensus and Standard PoW

[61]

- The organic food industry is a sensitive area. It is important to ensure the integrity and accuracy of data in it. Moreover, the tracking identities of participants in the industry are crucial (Only permissioned participants can access the system). Hence, in this scenario, Hyperledger Fabric is the optimal solution, since it is private and only allow permissioned participants to interact with the system. In Hyperledger Fabric, there is a separate model to manage the identities of the participant which is called as Membership Service Provider (MSP). Basically, MSP is responsible for issuing identities to a participant through a model called Certification Authorities (CA), revoke memberships and tracking information about issued identities.

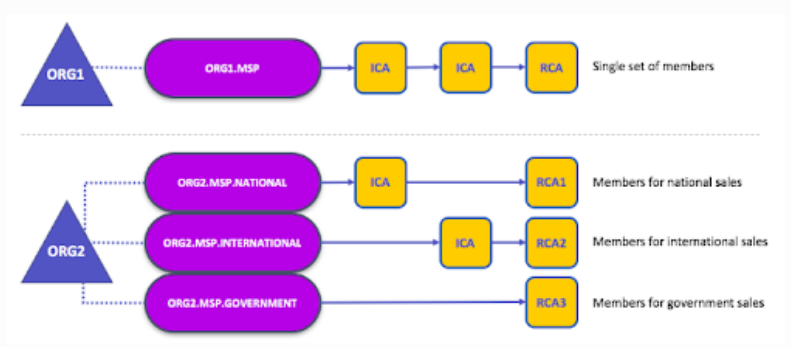

Fig. 3.3 MSPs and CAs

An organization can have either single MSP or multiple MSPs according to their needs. Different MSPs can be used to maintain groups of members. Each MSP can consist of one or more certification authorities[62].

- In Hyperledger, as mentioned in Table 4, there is no mining process. Therefore it does not consume a lot of time to validate a transaction and add it to the blockchain when compared with a framework like Bitcoin which uses mining process and this will help to increase transaction process speed and scalability as well. Hyperledger can perform 100,000 transactions per second in the standard production environment [63]. Since an industry like organic food industry thousands of transactions happens in a day, it is better to choose a platform that has better performance which does not depend on mining in the consensus process.

3.3.2 System Design

In this study scope, a PoC is developed for a single channel in which all stakeholders belong to a single supply chain path. When considering from an abstract level, each stakeholder/node such as farmer, retailer or distribution is considered as a single participant of the system without considering their organization. For an example, in a hypothetical scenario all farmer, packaging and distribution nodes could belong to the same company, but in the proposed system each these node are considered as separate participants.

Data Flow

As shown in Figure 3.4, the data flow of the system starts with fertilizer and seed providers. They provide seeds and fertilizer assets to the farmer. Farmer initializes his/her process by creating plot asset which represents the actual plot in the farm. All farming details such as watering, manuring are recorded with respect to the plot. The product asset is generated referring respective plot at the harvesting stage. This product asset is transferred through the supply chain and also updates to the products such as dividing products in the warehouse for distribution, merging two product assets in the warehouse and update sensor readings, is happened while these transfers. Here the certification body and accreditation body have the ability to audit these relevant product transfers,

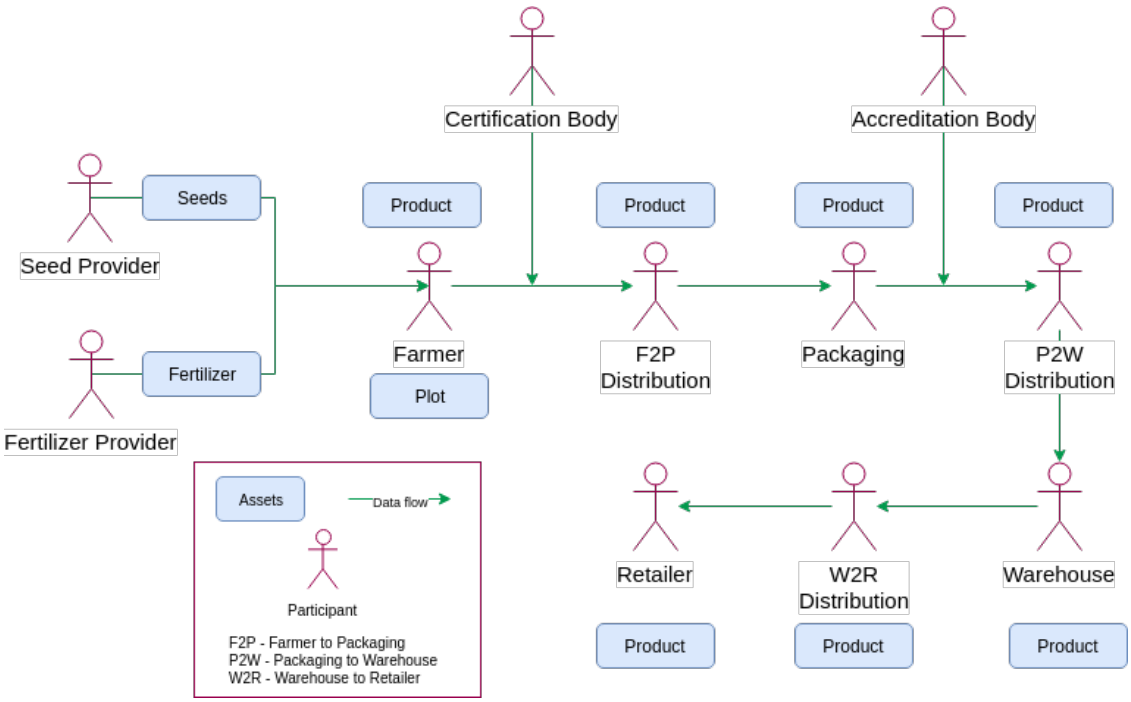

Fig. 3.4 Data Flow

products, plots and comment on these transfers, products or plots accordingly. But they don't have any superpower to control these transactions.

Participants and assets

When considering participants, in this PoC, seed provider, fertilizer provider, farmer, distribution, packaging, warehouse, retailer, certification bodies and accreditation bodies can be identified as main participants. On the other hand, Farms, seeds, fertilizers, natural pesticides, plot and product can be considered as assets.

Access control

Since a single channel is considered in this study, inter-channel access control constraints are not considered. But there can be few organizations in a channel. Hence, it is planned to use MSPs for each organization to manage their own participants. Then only permissioned members through these MSPs are able to access the system. Moreover, an asset can be accessed only by its current owner. These access control rules define the interaction between asset, participant and transaction and it restricts which participants are allowed to create, read, update or delete resources in the business network. There are two main types of access control rules in Hyperledger framework: business access control rules and network access control rules.

As shown in the figure 3.5, system namespace is used to define both participant and resource fields. Participant field indicates the person who submits or access the blockchain. In here it is Network Admin. Operation field indicates the actions which are allowed to participants. In this case Network Admin can do all operations. Action filed uses 'allow' or 'deny' values to grant above operations.

```
rule NetworkAdminSystem {
    description: "Grant business network administrators full access to system resources"
    participant: "org.hyperledger.composer.system.NetworkAdmin"
    operation: ALL
    resource: "org.hyperledger.composer.system.**"
    action: ALLOW
}
```

Fig. 3.5 Network Access Control Rule

Following code snippet shows business access control rule which grants all participants to read access to all resources in the business network.

```
rule StakeholderCanView{
    description: "Allow all participants read access to all resources"
    participant: "org.ucsc.agriblockchain.Stakeholder"
    operation: READ
    resource: "org.ucsc.agriblockchain.Stakeholder"
    action: ALLOW
}
```

Fig. 3.6 Business Access Control Rule

Transactions and Consensus

In Hyperledger Fabric, the consensus process is happened according to a new three phase approach which is called as endorsement-order-validate; (1) execute a transaction and check its correctness, thereby endorsing it, (2) order transactions via a (pluggable) consensus protocol and (3) validate transactions against an application-specific endorsement policy before committing them to the ledger [64]. Moreover, to assess endorsement, in the system, each peer contributing to the transaction are considered as endorsement nodes who are responsible for endorsing the transaction.

In the proposed model, the transaction is always invoked by the receiver of the transferred asset. When a node invokes a transaction it is added to the blockchain through following steps.

- Node invokes the transaction and submits transaction proposal
- Endorsing peers verify the signature and execute the transaction
- Proposal responses are inspected and endorsements are assembled into a transaction. (ordering)
- The transaction is validated and committed into the ledger

Client Application

To interact with the backend blockchain runtime in the client side, in this study, Hyperledger Composer which is a programming model containing a modeling language, and a set of APIs to quickly define and deploy business networks and applications in to a blockchain runtime [65], is used and a REST API is used in each node as a bridge in between composer and client application. For the client application, an Angular application and an Android application are to be implemented.

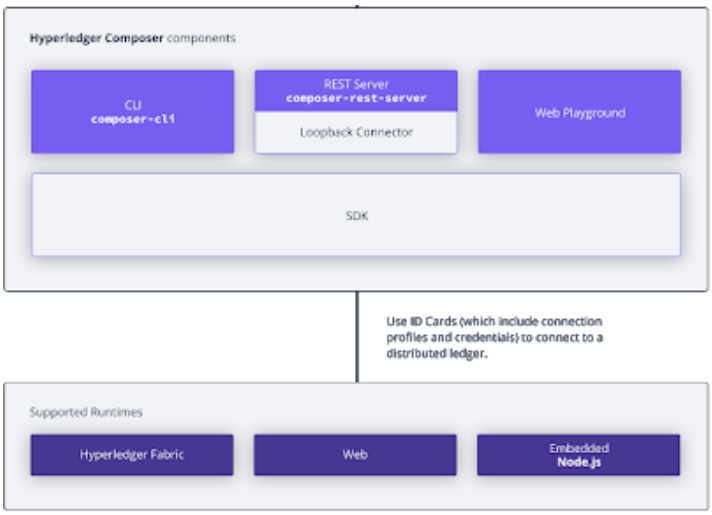

Fig. 3.7 Solution Architecture

Client applications are connected to Hyperledger Composer through a REST API and Composer is the intermediate node in between client application and Fabric runtime. [66]

According to the Figure 3.8 Hyperledger composer mainly composed of Command Line Interface (CLI), REST server, composer playground and JavaScript SDK. Composer CLI tool helps developers and administrators to deploy and managed business network definitions. REST API does the communication between the application layer and Hyperledger composer (Developer Tools) and on the other hand, connection profiles enable the composer to connect with Blockchain Runtime (Hyperledger Fabric). Hyperledger composer playground can be used to define and test business network quickly and SDK is set of Node.js APIs to perform CRUD operations of resource in blockchain distributed ledger [21]. Hyperledger Fabric is running distributed ledger and composer is designed to support web and embedded runtime implementations as well.

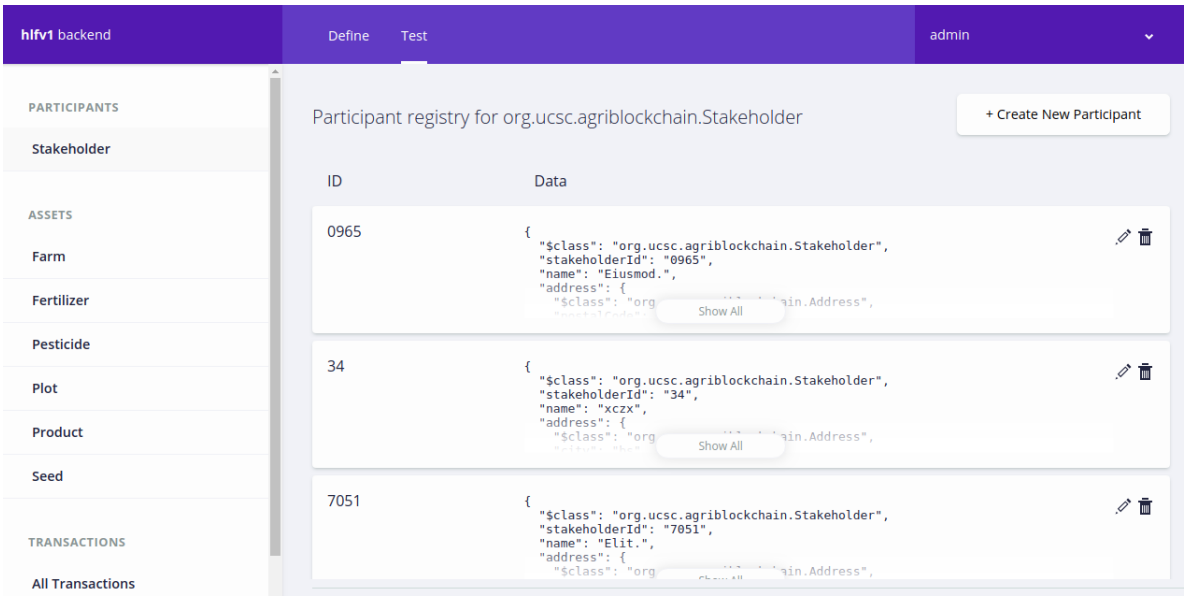

Fig. 3.8 Hyperledger Composer Playground

Registries

Hyperledger composer mainly has three types of data registries: Participant, Asset, and Transactions.

- Participant Registry

All the above mentioned stakeholders (Farmers, Retailers, Certification bodies, Distributors, packaging and warehouse people) are included in the Participant registry. Figure 3.9 shows an example of creating a stakeholder of Participant registry by inputting all the necessary information.

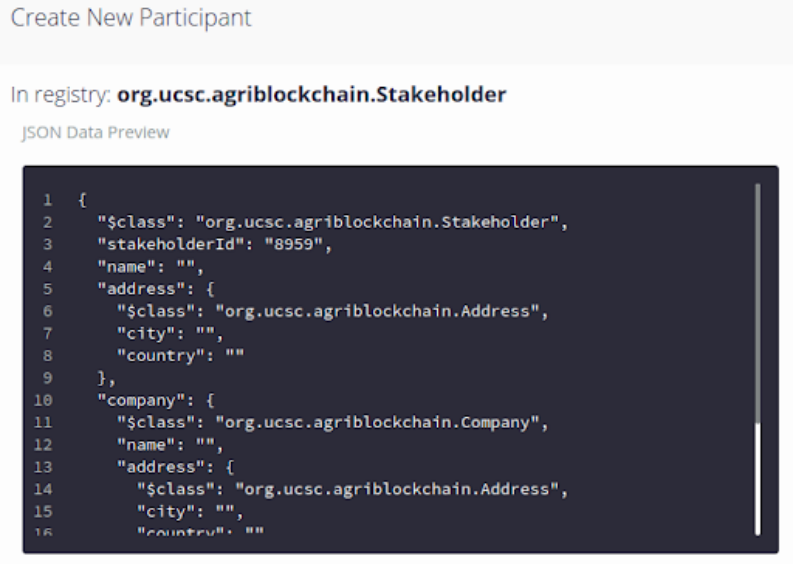

Fig. 3.9 Create Stakeholder

- Asset Registry

According to our use case Farms, Plots, products, Seeds, Fertilizers and Natural pesticides are taken as assets in the asset registry. Figure 3.10 shows an example of creating a product as an asset.

Fig. 3.10 Create a Product

- Transaction Registry

Supply chain stakeholders can use transactions to interact with assets. After creating assets and participants as mentioned in the above sections, it is possible to execute a transaction to fulfil the real activities like in the organic food supply chain. In our use case, there are five transactions types: transferring the ownership of products(transfer package), activities (watering, manuring), divide assets, merge asset and Ph readings. Figure 3.11 shows an example of a transfer package transaction. Finally, all these activities (create participants, create assets, transactions) are recorded in the blockchain historian which acts as an activity log as shown in figure 3.12.

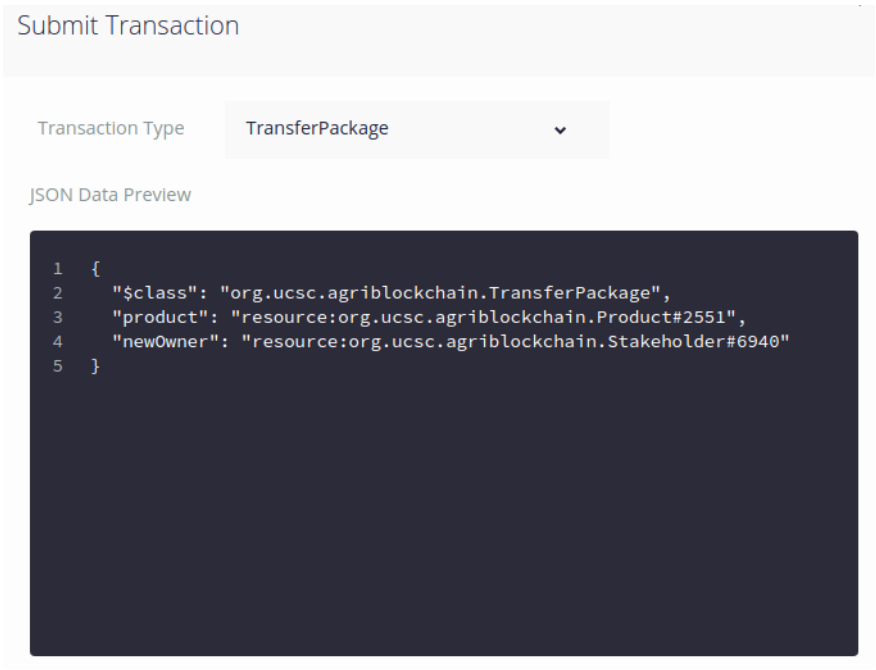

Fig. 3.11 Transfer Package Transaction

Date, Time	Entry Type	Participant
2018-09-20, 12:52:24	AddAsset	8559 (Stakeholder)
2018-09-20, 12:51:13	AddParticipant	admin (NetworkAdmin)
2018-09-20, 12:29:15	IssueIdentity	admin (NetworkAdmin)
2018-09-20, 12:29:12	AddParticipant	admin (NetworkAdmin)
2018-09-20, 12:14:17	UpdateAsset	admin (NetworkAdmin)

Fig. 3.12 Blockchain Historian

Data Feeding

In this study scope, data feeding to the system is mostly done in manual ways. But it has been designed to cater automatic data feeding through IoT sensors as well. However, financial optimization of automated data feeding can be considered as a future potential of this study.

Chapter 4

Results

It is important to understand different means that researchers have followed to understand Organic food industry. Dynamics of Organic food industry is there due to the large number of stakeholders in the industry. As a result of that research is conducted under three main parts as mentioned in the methodology chapter. Those are Supply chain stakeholder case study, consumer survey and proof of concept to increase transparency in the organic food supply chain. Therefore results chapter is described under those three main topics.

4.1 Supply Chain Stakeholder Case Study

This case study has been mainly focussed on organic vegetable, fruit and spices industry in Sri Lanka. Five farmers were interviewed from different parts of the country. From those, two farms were visited and the other three were contacted through telephone calls. Other than the farmers two wholesalers, two specialized organic retailers, a processed food retailer, leading supermarket chain in the organic food industry and organic food exporter have been interviewed. Other than these supply chain members, two local organic certification bodies and a foreign certification body were interviewed.

4.1.1 Farmers

Ingredients

Organic farmers are using natural fertilizers, pesticides and seeds without any synthetic chemical ingredients. Therefore their processes are different from conventional farmers. Basic ingredients required for a farm are seeds, fertilizer and pesticides. According to organic farmers Nitrogen, Phosphorus and Potassium would not be enough for proper growth of a plant and they have to provide fifteen chemical elements to achieve that. But to provide those chemical elements they use natural ingredients as the sources.

There are two main methods of fulfilling these needs. Those are by

- Buying from external sources
- Prepare on their own within the farm

When farmers initialize a farm they have to buy seeds from organic seed sellers. Also, they are using 'Eppawala Rock Phosphate', hen waste and seafood as fertilizers. Other than that they buy fungicides and pesticides from external sellers which they can't produce within the farm. However, they produce so many ingredients required for organic farming on their own. They get seeds/plants from the existing plants to cultivate fields in the next season. In that case, they do not need to buy seeds from external sellers. All the organic farmers usually prepare compost within their farm. Kohomba liquid is one of the pest control mechanism produced by themselves.

Recordings

Every organic product should be certified by an accredited organic certifier. Certification bodies use the record log book of organic farmers as the main source of inspection. Some certification bodies will give very brief and abstract information about the format of the record book while others provide the record book by themselves with a pre-fixed format. There is no universal format for the record book. But all formats usually include following important steps of cultivation;

- Landscaping
- Purchasing of seeds, fertilizer and pesticides
- Production of seeds, fertilizer and pesticides
- Applying of seeds, fertilizer, pesticides and water
- Growth of plants
- Harvested date and amount
- Storage methods within the farm
- Identified diseases in plantation
- Payment to workers
- Details about sales of harvested products

All of the recordings should be done with a proof. As an example when farmers buy seeds from an organically certified supplier invoice should be taken and then paste it into the record book with the record. But there are situations with no evidence such as buying hen waste. Those selling places won't issue any invoices. On the other hand, if the farmer produces seeds by himself then farmer should provide methods, use for seed production. As similar to that own prepared fertilizers and pesticides should support with facts.

All of the records should be done on daily basis. But practically it isn't happening. They accumulate it to weeks and therefore some records are not exactly correct since they can't remember the exact figures at the time of recording. According to the certification bodies, the record book should be provided to them at any short notice or when they have an uninformed visit. But all of the farmers usually do not keep record books on the farm and they keep it in their home. According to them the reason behind that is if they bring it to the farm, chances of misplacing can be high. If it misplaced and they can't provide the record book to certification bodies their certification will be revoked. Certification bodies also accept the farmer's point.

Plot

These organic farming lands are usually large scale lands. Biggest among them was a twenty five acre land. But the whole land is not covered with plantation and there are bare land areas. Production of compost and other fertilizers are done in this sort of bare land areas. Usually, they grow a large number of fruits, vegetables and spices on one farm. They are doing this to spread the risk of market fluctuations among several vegetables, fruits and spices. But fluctuation of prices are far less compared to the conventional food market. Some of these farmers cultivate lands currently use for other varieties of plantations such as coconut, to grow vegetable, fruits and spices. But the important point is all of those plantations are organic.

Mostly they use twenty feet * twenty feet land for a plot. But it can differ according to the requirement of the plantation type. These plots are usually created by filling soil and fertilizers and in a way, that the height of the plot is higher compared to the normal land. Each of the closer plots may have a different type of crops. But it won't have any effect on one another since plots are separated clearly in a way fertilizers and pesticides added to one plot will not go to the nearby plot due to rain.

Planning of Crop Types

Planning of crop types is done year ahead by the farmers. But the amount from each crop type is decided by farmers according to the advice from retailers directly or from wholesalers. They may not tell the exact amount of yield they want. But will give a rough estimation of the yearly requirement. Based on those requirements they will plan crop types and expected production from each. Then farmers will divide the land for each crop type according to the expected yield. Organic certification is issued a year ahead and farmers have to provide their yearly plan to organic certifiers before the start of the plantation. This plan should consist of crop types and expected area of land for each type of crop. According to this plan, certification bodies will issue a certificate with the maximum amount of yield for each crop type. If there are any mismatches identified about the maximum expected yield between farmers and certification bodies then farmers can change the way area has been divided among the crop types at that time. After the certification issued it won't be allowed to change the maximum amount of expected yield or area of the plantation for each product type.

Technical Capability

Both farms that conducted on-field interviews have a good mobile signal coverage. Therefore most of them can connect to the internet through mobile. Within a farm, there can be three to twenty workers who work under a lead farmer. From here on, literacy of farmers means literacy of the lead farmer since he is the one who is doing all recordings. All five lead farmers have the ability to read and write Sinhala. Four out of five lead farmers participated in interviews, had a smartphone. Three out of four farmers who own smartphone has downloaded apps related to farming. Some of them have taken the help of their children to download those apps.

But one big challenge some of the farms facing is they do not have electricity within the farm. This has been seen mainly in large farms. There also electricity is reached to the entrance of the farm, but not into the farm. One of the farmers has stated that when they take electricity to large farms, the other end of the farm may have a very low voltage of current. To solve this issue they have to use transformers in the middle of the farm and it may cost a large amount of money, which is not feasible.

Farmers' Problems

The main problem of organic farmers compared to the conventional farmers is lack of yield within the first few years. But with the time yield will increase gradually and usually it stops at a level less than the conventional food product yield. This has created economic instability for farmers within the initial years in the organic food industry. It will usually come to a point closer to conventional yield after three years of cultivation.

The recording process is one of the never ending headaches in the organic industry for farmers. The best practice is to record all the actions then and there. But farmers are not bringing in their record books into farms due to the fear of misplacement. Because book misplacement will lead to revoking of certification. Since they are accumulating and recording, figures are not exactly correct. However, they are expecting a solution to this problem along with an easy way of entering information for record purposes.

Also, there was a farmer who takes the help of his children to maintain his record books to have a more clear book with clear handwriting. This farmer also has the ability to read and write Sinhala. But he has a perspective that when they maintain a clear record book there is a high chance that certification authorities will accept it. When asked about this from certification bodies they reject that claim. However, they accept that the handwriting of some farmers are very difficult to understand and they have faced complications in such scenarios.

According to large-scale farm owners, some of their best farmers have lost the organic certification not due to any malpractices but because of inefficiencies in the recording. As per them, It's unfortunate to loose efficient and enthusiastic farmers just because of inefficiencies in recording and this can badly affect the growth of the organic industry of a country which is in its primary stages of building an organic cultivation culture.

Business Model

There are two main types of farm ownership in this industry. First one is one person own two or more farms around the country. In this case mostly he works as a businessman rather than a typical farmer. Usually, those owners have packaging centres for them and do the wholesaler's role too.

The other type is small-scale farm owners who just own one land. They usually do the farmers role rather than a businessman role. These people usually don't have their own packaging centres and they have to sell it to a wholesaler or directly sell it to a specialized organic retail store.

Other than these, there are mixtures of the above two methods. One such common method is to form farmer groups by several small-scale farmers. Then they can sell their products with more bargaining power and help each other in most cases like the certification inspection process.

Usually, farmers sell all of their products to one wholesaler. The reason behind that is when they built a strong bond with one wholesaler he will buy their total yield. But there can be exceptional cases where one farmer does business with more than one wholesalers.

4.1.2 Wholesalers

Wholesalers can be considered as an integral part of the organic food supply chain and they will have few main duties. However, according to the requirements of the retailer, it can differ. Following are all the main duties which are supposed to be done by wholesalers.

- Buy products from farmers by visiting the farm
- Package products which have the required quality level with the required information on it
- Deliver to retail stores or centralize distribution centre of the retailer

Here it will use two transportation vehicles to bring products from farmer to packaging centre and then packaging centre to a retail shop or a centralized distribution centre.

When wholesalers sell their products to any of the main supermarket chains in Sri Lanka they have to follow all the above steps because they sell organic products as packaged products only. But if they are selling to specialized organic retail stores some of them might directly accept unpacked fresh products. Therefore they can miss the second step of packaging and deliver it to retailers.

Business Model

Wholesalers are buying products from more than one farmer. If himself own number of farms which can fulfil the demand he received from retail stores he will only buy products from their own farms. If the demand is more or wholesaler himself doesn't own any farms then he will buy from independent farmers or from farmer groups. Usually, if they build a good relationship with a farmer and the farmer follows the instruction of the wholesaler about crop selection, they will buy all of their yields.

These wholesalers are not usually dealing with one retailer. They may sell to all supermarket chains. But they kept one retail chain as their main buyer. They pass the instruction to farmers

mainly focussing on the requirements of their main buyer. Then if there is any surplus after providing it to the main buyer request from other retailers will be accepted and provided those to them. One of the important points that observed is the involvement of wholesalers are less when it comes to specialized organic retailers. In here farmers are directly linked with the retailers.

Technical Capability

As mentioned above there are three main activities in the wholesalers' process. They are delivery from farmer to the packaging centre, processing, packaging and delivery from packaging centre to a retailer. As per the two wholesalers have been interviewed, at least one person in each place will have a smartphone. Also, they are capable of working with mobile applications. Head of a packaging centre is fluent in English while some of the workers in delivery vehicles are not fluent in English.

Wholesalers' Problems

Wholesalers' biggest problem is to find farmers who can fulfil the demand of organic retailers. This problem has increased due to the certification revokes of farmers during the last few years. When they are unable to fulfil the demand from retailers they will distribute their quota for that food product among other wholesalers because retailers don't want to lose their customers due to lack of availability.

The other biggest problem wholesalers and farmers face together is some misconceptions of consumers. Most of the consumers judge the quality of the food product using the appearance of the product such as size and colour. But according to wholesalers, there are instances where they get yield as huge size food products without using any synthetic chemicals. When the size is big retailers reluctant to buy those because most of the consumers won't buy those and it will be a waste. Wholesalers and farmers expect better and reliable way for them to decide a product is organic or not, then consumers will drop those misconceptions.

4.1.3 Retailers

Retailers are the ones who kept direct contact with the customers and the best stakeholder to understand exact customer requirement. Organic food retailers can be mainly divided into three categories. Those are specialized organic retailers, supermarket chains and processed food retailers.

- **Specialised Organic Retailers**

Specialized organic retail shops only sell organic food and we have interviewed three such retail shops. One of them is a government-owned one. Prices of the specialised organic retail shops are high compared to the conventional retail chains. In these places, consumers can buy vegetables and fruits which are not packaged. They also sell cereal, grains, spices and honey relevant products.

Business Model

Specialised organic retailers keep bonds with farmers or farmer groups directly rather than using an intermediary. They are keeping bonds with a large number of certified farmers. They always try to provide fresh food by mostly buying vegetables and fruits on daily basis. Their business model is to buy a small amount of food products from a large number of farmers. So they can buy fresh products daily from different farmers in a rotation policy. They stated that the products farmers brought on the morning will finish at the end of the day mostly.

- **Supermarket Retail Chains**

A leading supermarket chain who has the largest organic food market share in Sri Lanka has been interviewed. They mostly sell organic products as packaged food products. The reason behind this is the inability to differentiate among organic and conventional food when both are available in the same store. Cashiers can take details such as price and weight by scanning the barcode on the package.

Business Model

They are using a limited number of suppliers. All of them are wholesalers and they are not in frequent contact with the farmers. They are distributing their expected demand among the suppliers and asked them to redistribute it among their farmers as they like. Usually, they keep only three or four wholesalers for one food product. As an example, they buy bitter gourd from only three wholesalers. Their rationale behind this decision is they believe when they give the responsibility to few of the wholesalers they have a better bond with the retailer. On the other hand, this will give the ability to give quality products. Since they have only a few suppliers they can inspect them at any time very easily. Once a year they do a surprise visit and take samples from retailers and send them to Netherland to test whether those are really organic or not.

Distribution Channel

They have a central distribution centre in Peliyagoda. All of the wholesalers delivered there packaged products into Peliyagoda distribution centre. Through this distribution centre, they distribute to retail shops all around the country. But there is another newly established distribution centre in Jaffna. All wholesalers around that area will deliver the products to Jaffna distribution centre and it will distribute to retail shops around that area.

Problems

Supermarket retail chains buy the total yield of their farmers within the limits they have given, irrespective of consumer demand. Due to some miscommunications, there are times where farmers' yield is more than the expected demand given by retailers. At those times also usually retailers buy most of it to protect farmers since they have a greater bond. Therefore retailers have to bear the total waste of the products.

According to this supermarket, some of their consumers ask for more information about the products such as manufacture date and location of the farm. But they don't have that information and does not have the ability to satisfy the customer requirements.

Another problem they face is there are instances where batches are getting mixed. In such instances, new products get mixed with old products. Then again they can't regroup those since it does not have indications such as manufactured date or batch number. Therefore it can lead to spoiling the vegetables and fruits which increase the waste percentage.

- **Processed Food Retailer**

Another method of selling organic food is as processed food. In foreign countries, there are many processed organic food retailers. But there are not much-processed food retail shops in Sri Lanka. An organic lunch packet retailer has been interviewed. This is a government-approved retail shop. They are purchasing all the vegetables from organic retailers. But they do not have a way to prove the raw materials they are using is organic.

Problems

Their biggest problem is they don't have any certification for the processed food and therefore consumers buy products totally depend on the trust. They expect a system which can prove the raw materials they use are really organic. Because it can add more value to their product rather than just sell on trust.

4.1.4 Exporters

One food exporter has been interviewed. Their main concern is the quality of the product. Farmers have to take certifications from relevant certification bodies to qualify to export into each country. Their business model is much similar to the specialized organic products retailers and as like them they also buy products directly from farmers. The reason behind this is they want to keep direct contacts with farmers to assure the quality.

One of their suggestions was to implement a system to cross-check the area of the farm with the amount of harvest. According to their perspective, most of the malpractices do not happen within the farm when foreign certification bodies involved in the inspection process. But they can mix conventional food with organic food after taking the yield. This can be reduced by cross-checking the total yield with the farm area.

Problems

According to them, traceability is a regulatory requirement for countries such as USA. Most of the foreign countries are adapting to this system currently. Therefore these exporters want to expose the exact farmer who has been produced this food. Currently, they are producing this as a paper document. But the importers from foreign countries use information systems to manage their details and force our local exporters too to do so.

4.1.5 Certification Bodies

There are several organic certification bodies accredited to operate within Sri Lanka. But there are three main certification bodies. From the three certification bodies, two of them are local certification bodies and the other is an international certification body whose certification is accepted by countries like US, Canada, Japan and European Union countries.

Award of Certification

When a farmer request a certification from a certification body, their representatives will come to the farm and instruct them on how to prepare the farm in a way which is suitable for organic farming. Meanwhile, they will take a soil sample to check whether the soil quality is in line with the required limits for organic farming. Price of this test is really expensive and farmers have to bear it. Other than this a farm to start as an organic farm it should at least have a conversion period of one year(local certification) or two to three years(foreign certification) without using any synthetic chemicals. This period can differ according to the certification body.

Inspection Process

Representatives from certification bodies will have one or two informed visits per year and if they have any concerns then will plan an uninformed visit. When they visit a farm they mainly check record books as the primary source. However there they can only check whether they have filled the books in the proper manner or not. But inspectors have noted that there are chances for farmers to manipulate the books before they show it to the inspectors. It's because farmers usually keep the record book at home and they take some time to return it if it's an uninformed visit.

Inspectors have a checklist to check the field activities. But they are not disclosing a checklist to the public. If two certification bodies give certificates for the same country still their checklists can be different. There are two main reasons for not disclosing the checklist. One is because that checklist is one of their intellectual assets and the other is if it reveals, farmers will try to show they have completed the checklist rather than following correct procedures.

In the process of inspection, they are mainly checking about changes to the natural conditions in the farm environment. They will check whether the height of the grass closer to the plot is different from other places. Also, they will look at the colour of grass, mushroom distribution around the plot. Whether these are not totally scientifically proven methods, they are used to get some indications via this. According to these inspections, they will plan further actions.If they caught any suspect actions in the above inspections then they will use more scientific methods such as tissue test. But for those test facilities in Sri Lanka are very less. Therefore they have to send those tissue samples to countries like Netherland to check it. However, this is a very costly operation.

However, the certification and inspection process does not only include the farmers. It will cover all the supply chain member starting from seed/fertilizer providers to retailers. They have to check all the processes and transaction among each supply chain member too. They will only check the transfer documents among companies and not within companies. If two supply

chain members belong to the same company they won't check their transfer documents. The certificate is renewed from year to year. Therefore before renewal of the certification farmers should inform the certification body about the number of hectares they are planning to grow each type of vegetable/fruits. According to that certificate will state the maximum amount of organic yield they can have.

Foreign Organic Certification and Accreditation Bodies

There are superior controlling bodies on top of the certification bodies. One such place is the European Union parliament. When export to any of the European countries they have the power to check supply chain processes as well as certification body activities. They can review the process of certification bodies and remove their accreditation. Similar to these foreign certifications Sri Lankan certification bodies are accredited by Sri Lanka Accreditation Board and they also have the same power.

Problems

All 3 certification bodies have accepted the fact that they can't tackle all the malfunctions and there can be malpractices regardless of the effort they have put.

When they want to check the total amount of yield they have to contact each and every retailer and get the amount they have received from each farmer. This is a really difficult task. Whether they do that, still farmers have the chance to sell it to a different organic retailer who is not in contact with that certification body. Mixing of inorganic food with organic food can happen and therefore chances of malpractices are there.

Another area of concern is since they don't have any real time information they can't plan a visit to farms in a proper manner. If they have real-time data they can visit places when they see any anomalies in data and do a more efficient inspection process.

4.2 Consumer Survey

This is the first ever consumer survey on organic food in the history of Sri Lanka. However, under this survey 70 organic customers and 50 conventional food customers were interviewed.

4.2.1 Organic Food Customers

Demographic details of the customers are described below. According to the analyzed results shown in Table 4.1, more than 80% of the customers' monthly household income is higher than Rs.100,000. However, there are 10 people whose monthly household income is less than 100,000 and still buy organic. 8 out of 10 of those people have babies who are less than 5 years old.

Income	<50,000	50,000-100,000	100,000-150,000	150,000-200,000	Above 200,000
Freequency	4	6	22	18	20
Percentage	5.7%	14.3%	31.4%	25.7%	28.6%

Table 4.1 Monthly Household Income Distribution of Organic Customers

In the acquired sample age is highly distributed. There are customers from age 18 to 56 and above. Age 18-25 and 45-56 age groups have less population in the sample and other groups have an almost similar population as shown in Table 4.2.

Age Range	18-25	26-35	36-45	46-55	Above 55
Freequency	9	19	14	11	17
Percentage	12.9%	27.1%	20%	15.7%	24.3%

Table 4.2 Age Distribution of Organic Customers

As shown in Table 4.3, more than 75% of the organic customers at least follow/followed a degree programme or a professional qualification.

Educational Level	O/L	A/L	Under graduate	Graduate	Masters	PhD	Professional Qualification
Freequency	1	16	4	23	7	5	14
Percentage	1.4%	22.9%	5.7%	32.9%	10%	7.1%	20%

Table 4.3 Education Level Distribution of Organic Customers

From the taken sample, 36(51.4%) were male and 34(48.6%) were female. Also, 56(80%) of them were married and 14(20%) of them were single. 23(32.9%) of them were having children under 5 years of old.

Food Types	vegetable	Fruit	Spices	Grains	Honey
Freequency	58	44	16	34	11
Percentage	82.9%	62.9%	22.9%	48.6%	15.7%

Table 4.4 Types of Organic Food Customers Purchase

There are so many types of organic food in the market. But customers are not equally interested in all of those product categories. Table 4.4 shows the number of purchases for each type of organic food according to the survey. According to Table 4 vegetables, fruits and grains are the popular types of organic food while less number of people buy honey and spices as organic.

The frequency of organic food purchasing is also an important factor to know customer loyalty to organic food. Table 4.5 shows the results of the survey regarding the purchasing frequency of Sri Lankan organic customers.

Purchasing Frequency	Once a week	Several Times a week	Once a month	Several times a month	Few times a year
Freequency	27	5	17	18	3
Percentage	38.6%	7.1%	24.3%	25.7%	4.3%

Table 4.5 Purchasing Frequency

According to the above-analyzed results, 45.7% of customers buy organic food at least once a week and 95.7% of customers buy organic food at least once a month from our selected population.

The awareness of the customers about organic food is important to decide on the areas that customer should get educated. Therefore a question in the survey was targeted to find out awareness of customers about the word 'organic food' and the following meanings have been selected by respondents.

Meaning	Natural	No synthetic chemicals	Traditional food	No hormones	Not genetically modified	Herbal
Freequency	32	67	1	32	29	4
Percentage	45.7%	95.7%	1.4%	45.7%	41.4%	5.7%

Table 4.6 Awareness about the Word 'Organic'

95.7% of customers have a general awareness that organic food doesn't use synthetic chemicals. Only closer to 50% of customers accept the fact that the word 'organic' has meanings such as not using genetically modified organisms or added hormones. However, they refused the definitions such as traditional food and herbal food.

It is important to know the customers' motives to understand their expectations from the organic food and customer responses regarding that are shown in Table 4.7.

Motivation	Healthy	Environmental Friendly	Prefer taste	Quality
Strongly disagree	0%	12.9%	14.3%	1.4%
Disagree	0%	22.9%	12.9%	4.3%
Neutral	5.7%	17.1%	25.7%	30%
Agree	24.3%	30%	35.7%	50%
Strongly agree	70%	17.1%	11.4%	14.3%
Mean	4.64	3.16	3.17	3.71
Std. deviation	0.591	1.315	1.227	0.819

Table 4.7 Motivation to Purchase Organic Food

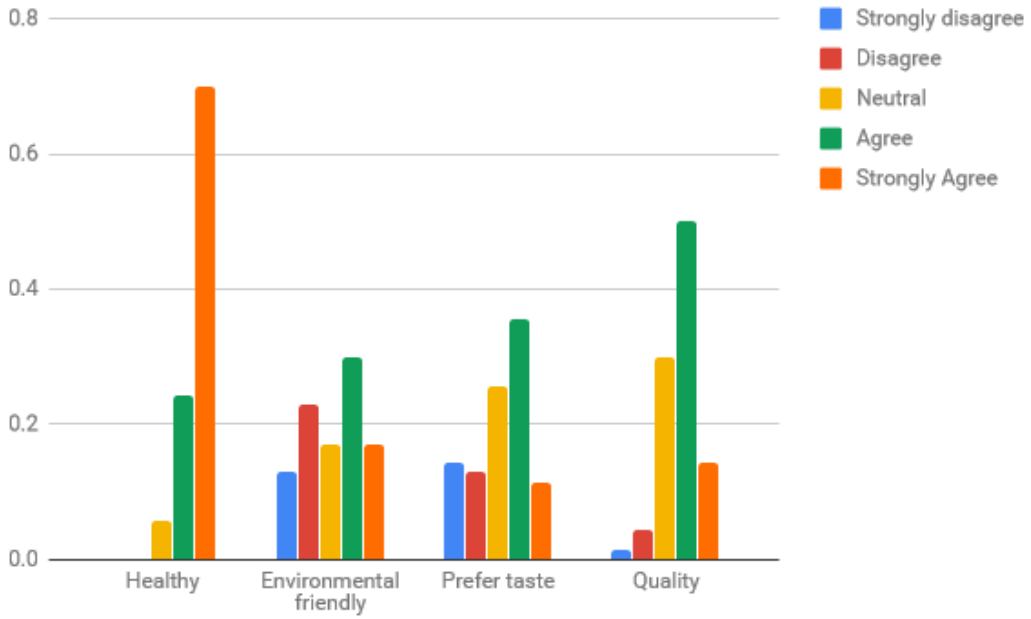

Fig. 4.1 Motivations to Purchase Organic Food

Most common motivation behind buying organic food is healthiness as none of them disagrees with that. Environment friendliness and tasty also shown as a positive motivator to buy organic, but with comparatively lesser means in the 5 points Likert scale as 3.16 and 3.17 respectively. However, there is a standard deviation of 1.315 and 1.227 respectively. There are correlations between age and environment friendliness with a Pearson correlation of -0.669 and age prefer the taste with a Pearson correlation of 0.542.

Organic certification issued by an accredited certifier is the only legal way to verify a product as organic. But the problem is 'does every customer know about organic certification?'. According to the results of the survey, only 53% of the customers heard about the organic certification. 47% of customers who buys organic never heard about organic certification.

The customers who heard about organic certification were questioned about their level of belief in organic food certification. This shows that only 23.7% of customers who know about the organic certification is satisfied with the organic food. Following are the results received from the customers.

Trust on certification	**Strongly dissatisfied**	**Dissatisfied**	**Neutral**	**Satisfied**	**Strongly satisfied**
Freequency	2	15	12	8	1
Percentage	5.3%	39.5%	31.6%	21.1%	2.6%

Table 4.8 Level of Trust on Certification

Next important thing to find out in the research is on what, customers currently putting their trust to verify a product as organic or not. Respondents to the survey are using Product brand, retailer brand and appearance of the food as factors to verify whether the product is organic or not. Table 4.9 has summarized the responses for each of the factors.

Verification method	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
Product brand	5.7%	40%	28.6%	22.9%	2.9%
Retail brand	4.3%	10%	30%	38.6%	17.1%
Appearance	8.6%	25.7%	31.4%	20%	14.3%

Table 4.9 Verification Methods

Retail brand is an influential factor for most of the customers. But product brand and appearance may not have the same effect on organic food buyers mind. But a set of organic buyers strongly believe appearance as the main factor to verify whether a product is organic or not. However, there is a great percentage of customers who are not believing in either certification or above-mentioned methods.

Most of the customers put their belief on unscientific methods to verify the genuineness of the organic food due to lack of information and they are expecting more information about various stages of the organic food supply chain to increase their trust. Following are the information customers are looking for;

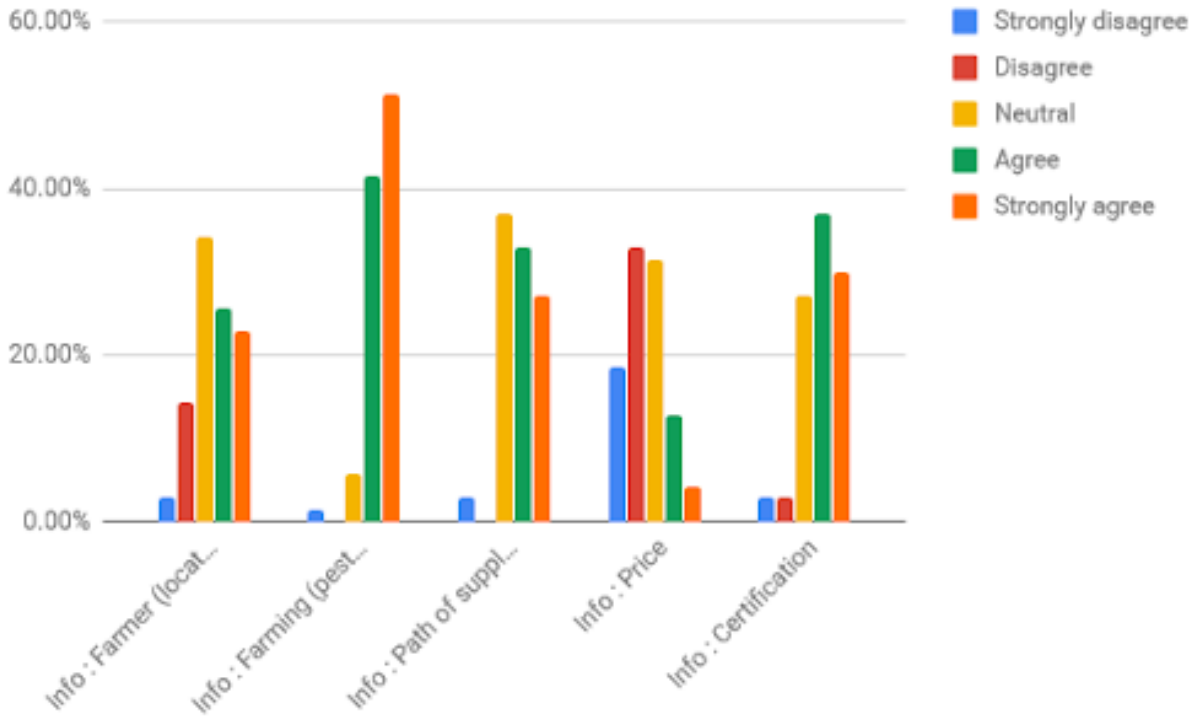

Fig. 4.2 Extra Information

Extra information	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
Farmer (location, employees)	2.9%	14.3%	34.3%	25.7%	22.9%
Farming (seeds, Pesticides)	1.4%	0%	5.7%	41.4%	51.4%
Path of supply chain	2.9%	0%	37.1%	32.9%	27.1%
Payments for supply chain members	18.6%	32.9%	31.4%	12.9%	4.3%
Inspection process	2.9%	2.9%	27.1%	37.1%	30%

Table 4.10 Extra Information

Farming information which includes applying of pesticides, fertilizers and seeds was the most important information. However, customers didn't give much value to the price pay for each supply chain member.

But to provide all these information each party should put some extra effort to enter information. Therefore the organic customers' readiness to pay an extra price for the above-mentioned information has been checked. The extra payment that customers ready to pay for information on top of what they are currently paying is displayed in the following table.

Extra payment	0%	0% - 10%	10% - 20%	20% - 30%	30% - 50%
Percentage	8.6%	21.4%	35.7%	27.1%	7.1%

Table 4.11 Extra Payment

4.2.2 Conventional Food Customers

During the customer survey 50 conventional food customers were interviewed. Table 4.12 shows the reasons for conventional food customers to not turning into organic food.

	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
High price	6%	16%	20%	36%	22%
Lack of trust about genuineness of organic foods	8%	18%	16%	44%	14%
Lack of awareness about benefits	12%	18%	42%	22%	6%
Lack of availability	24%	32%	14%	22%	8%

Table 4.12 Reasons for not to buy Organic Food

4.3 Proof of Concept

According to the study design, as the third stage of the study, a proof of concept of a traceability system was developed. As underlying technologies, Hyperledger Fabric, Hyperledger Composer, Hyperledger Caliper, Angular and NodeJs were used as elaborated in the Methodology chapter. In this section, the proof of concept design considerations and the derived design which is used to validate and justify the results of the case study and consumer behaviour survey, are stated. Throughout this section, to elaborate the system design relevant user interfaces will be used.

4.3.1 Stakeholders

In the developed system, each stakeholder of the organic food supply chain has a unique identity and also a unique stakeholder type. All the interactions and access controls of the system are controlled according to this user identity and stakeholder type. As elaborated in the methodology chapter, Farmer, Seed Provider, Fertilizer Provider, Certification body, Distribution, Packaging and Retailer stakeholder types can be identified in the system. At the beginning, all the users of these types are redirected to the system login screen (Fig. 4.3). In here users have to enter their credentials to log in to the system. Then according to their stakeholder types, users are redirected into their corresponding dashboards to carry out supply chain related work.

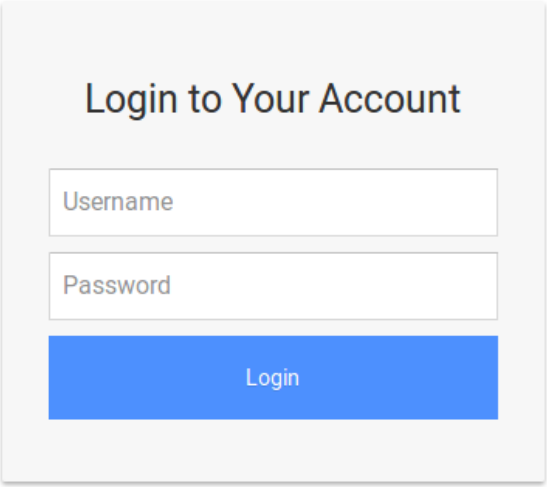

Fig. 4.3 Login

Following will be explained according to different stakeholder aspects. In general terms, in developing all these aspects, user experience and user interface design of the system were considered in a higher priority.

Administrator

After logging in to the system, he can directly access his system dashboard and do tasks using its features. Admin dashboard mainly consists of two sections called Resources and Stakeholders.

Resources section consists with manage farms section and manages plot section. In here, admin can create, view, update and view all the farms and plots. All the tiles in each section are ordered in a specific order according to their use relevance.

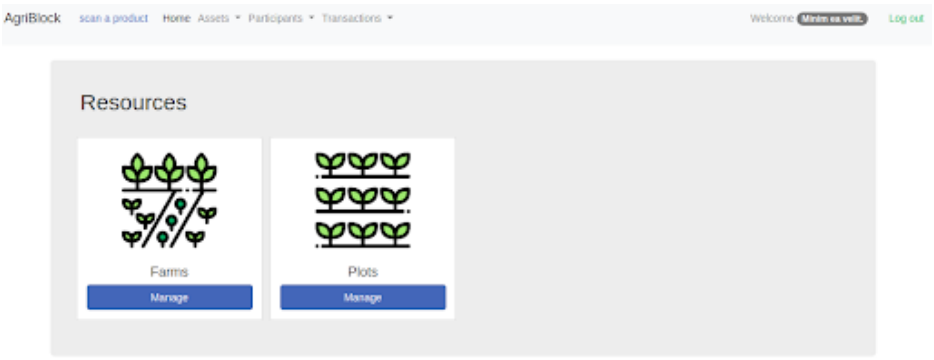

Fig. 4.4 Resources section in Admin Dashboard

When admin going inside to manage farms section or manages plot section he allows to create a new farm or plot by filling all necessary information. The following figure shows the initial interface of admin when he goes inside the manage farm section.

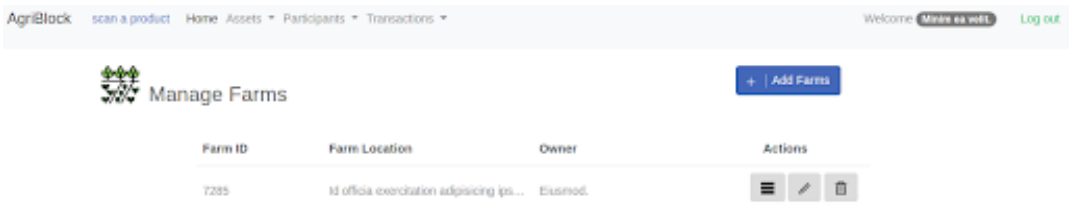

Fig. 4.5 Manage Farms

If the admin wants to create a new farm he can click ‘Add Farm’ button and then following ’Stepwise wizard’(Fig. 4.6) will facilitate the process of creating a new farm.

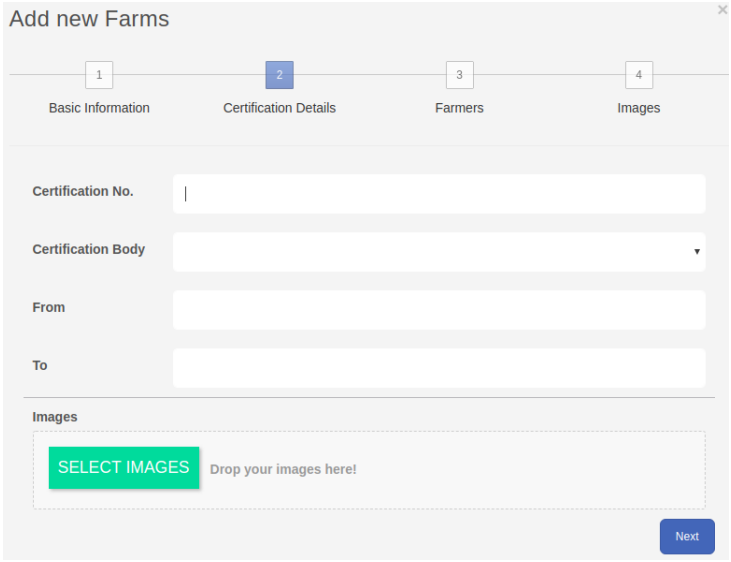

Fig. 4.6 Add New Farm

Manage Assets section allows the user to manage assets of the system such as products, seeds, fertilizers and pesticides.

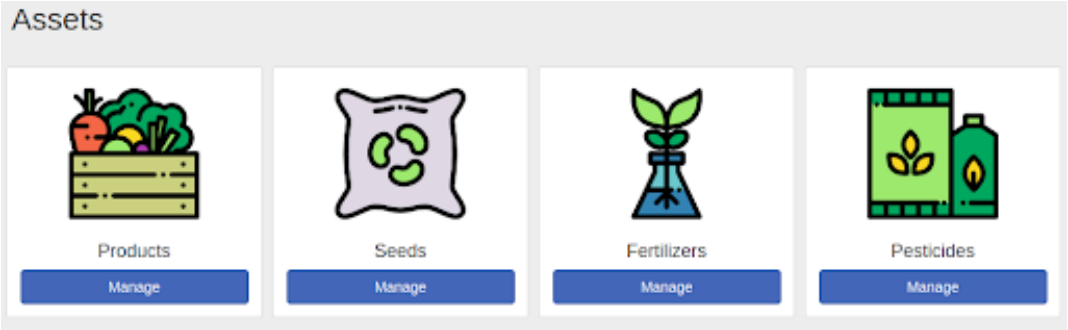

Fig. 4.7 Assets Section in Admin Dashboard

The following figure (Fig. 4.8) shows the initial interface of admin when he goes inside the manage products section.

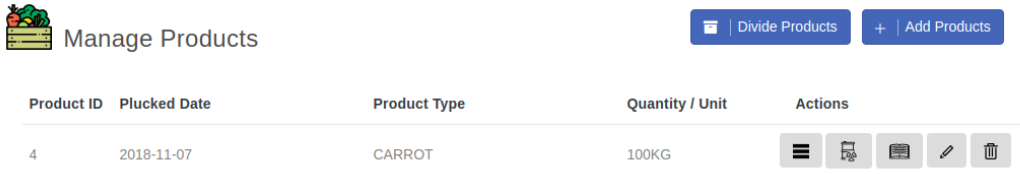

Fig. 4.8 Manage Products

As an example, If the user wants to create a new product as an asset in the system he can click the 'Add Product' button in the top right corner after that following stepwise wizard will display to create a new product.

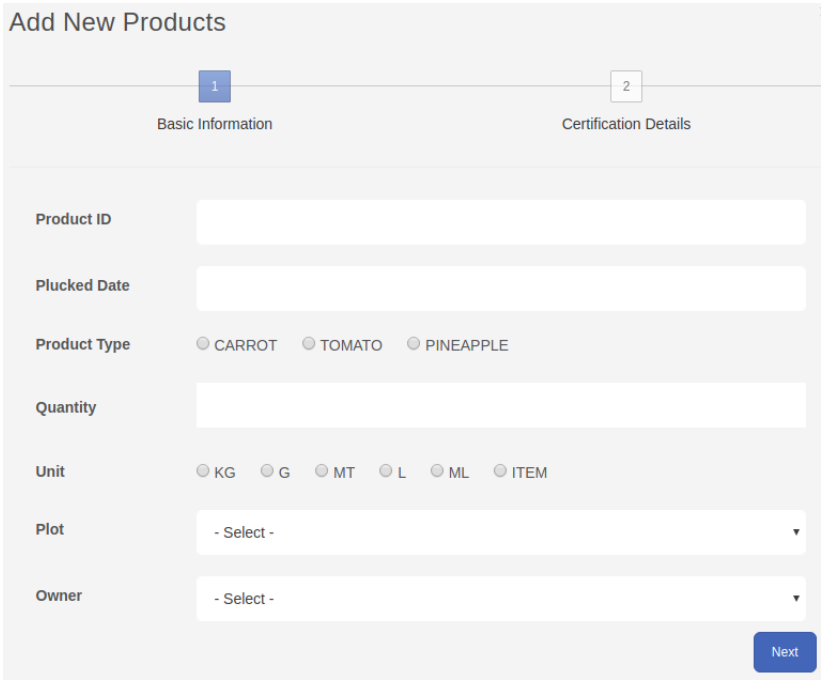

Fig. 4.9 Create New Product

As shown in the Fig. 4.10, Stakeholder section in admin dashboard includes all the stakeholders in the supply chain and admin has all privileges to create, update, delete and view stakeholders and their details.

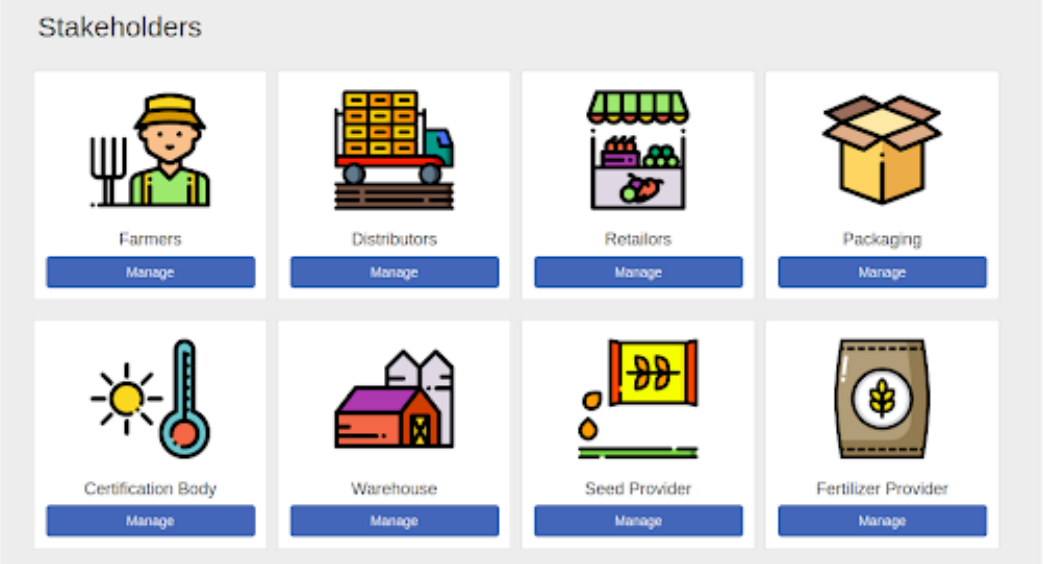

Fig. 4.10 Stakeholder Section in Admin Dashboard

As shown in the Fig. 4.11, when admin select one of the stakeholder categories he allows to create a new member under that category and if that category already has members he can insert, update, delete and view their details. The following figure shows the initial interface of the admin when he goes inside the farmer section.

Fig. 4.11 Manage Farmer

If an admin wants to create a new farmer he can click the ‘create participant’ button in the top right corner after that following stepwise wizard will display to create a new farmer as a stakeholder.

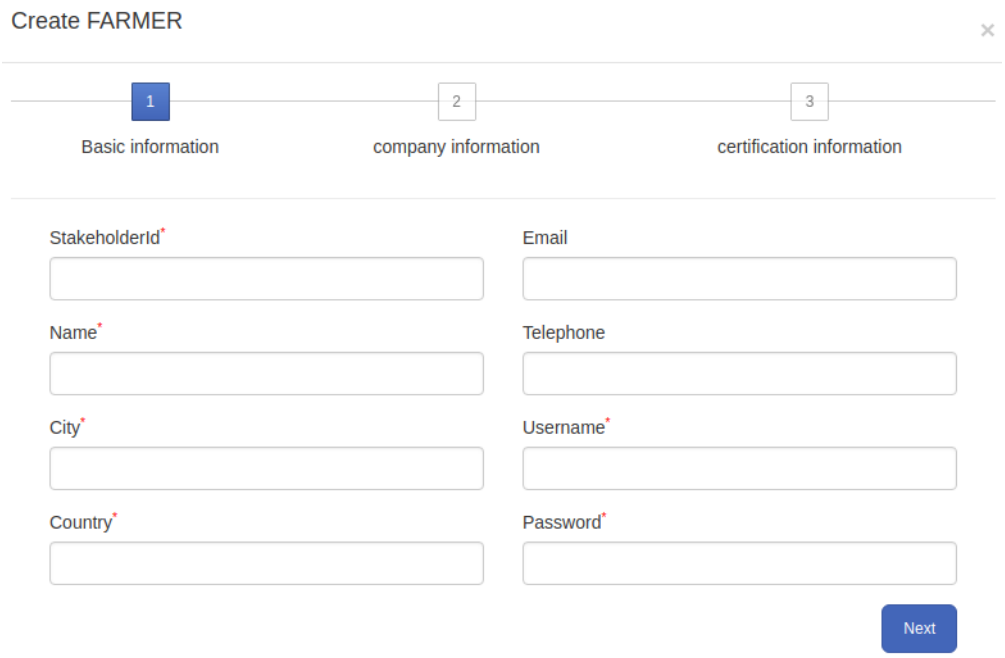

Fig. 4.12 Add New Farmer

Manage Activities section consists of Seeding, Watering, Manuring, Growth Progress Recording, Harvesting and Diary Keeping.

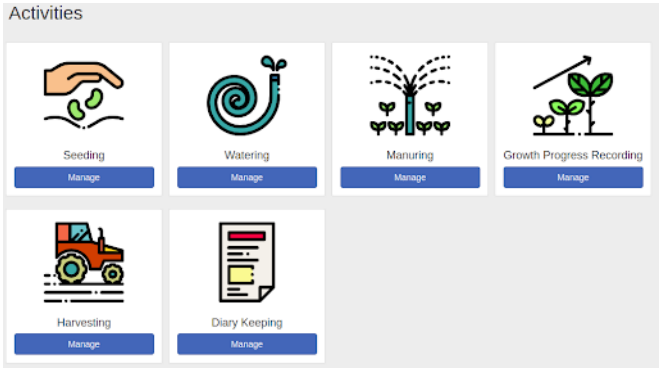

Fig. 4.13 Activities Section

Certification Body

Certification bodies only have view and comment privileges for resources (Farms, plots) and stakeholders. In here they can only view, comment and get information about their registered stakeholders and they cannot view, comment and get the information about stakeholders who got registered under another certification body. If there is any malpractice occur, certification body can comment on that particular farm or plot or participant.

The following figure shows the initial dashboard of the certification bodies when they logged in to the system and it includes all the above mentioned sections such as resources, stakeholders, assets and activities. As mentioned earlier certification body can comment on resources like farms, plots and stakeholders using the following interface. In here, certification body can enter inspection date, inspection time and necessary comments regarding farms, plots and stakeholders.

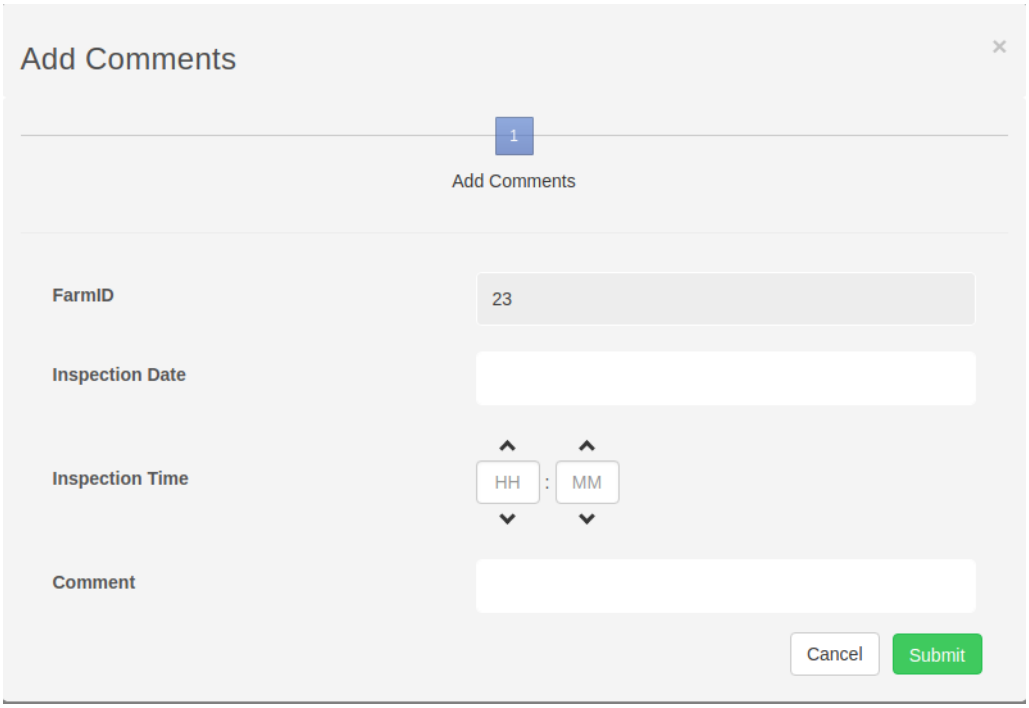

Fig. 4.14 Add Comment for Farm

Farmer

Whenever a farmer logs in to the system, he or she will be directed to the farmer dashboard. The farmer dashboard mainly has 3 divisions, Resources, Assets and Activities (Fig. 4.15, Fig. 4.18 and Fig. 4.19). Farms and Plot relevant to that farmer is located in the Resources section. Relevant Products, Seeds, Fertilizers and Pesticides to the farmer are located in the Assets section. In the final section, relevant activities including Seeding, Watering, Manuring and Harvesting are included. In each section, items are sorted according to their emerging time in the farming process. For an example, as shown in Fig. 4.17, in the Activities section, as in the farming process activities are listed in the order of seeding, watering, manuring and harvesting.

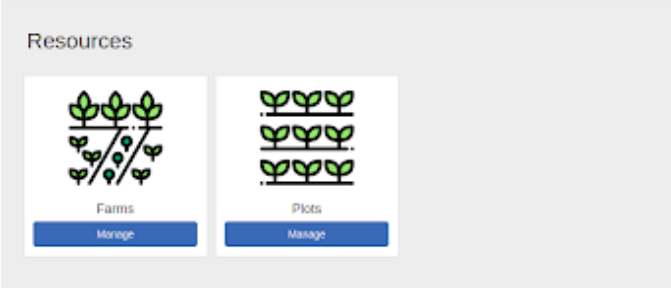

Fig. 4.15 Manage Resources

As in Fig. 4.15, from Resources section farmers can manage their resources including farms and plots. After selecting one of the resources they can update the details of it. As shown in the Fig. 4.16, farmers can only view their relevant farms but they can add, update and view their relevant plots. Each plot belongs to a specific farm and one plot cannot be registered with two farms. On the other hand, one farm can have multiple numbers of plots.

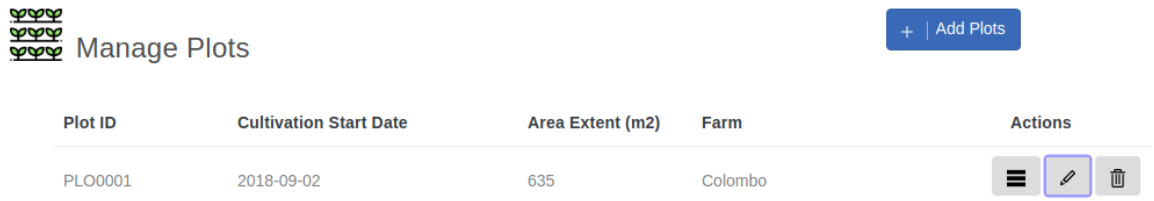

Fig. 4.16 Manage Plots

According to the requirements gathered from the case study, storing photos of the farms under different circumstances are really important for many supply chain stakeholders such as certification bodies and customers. To achieve this requirement, before storing in the blockchain, the uploaded photos are converted to base64 strings and then proceed.

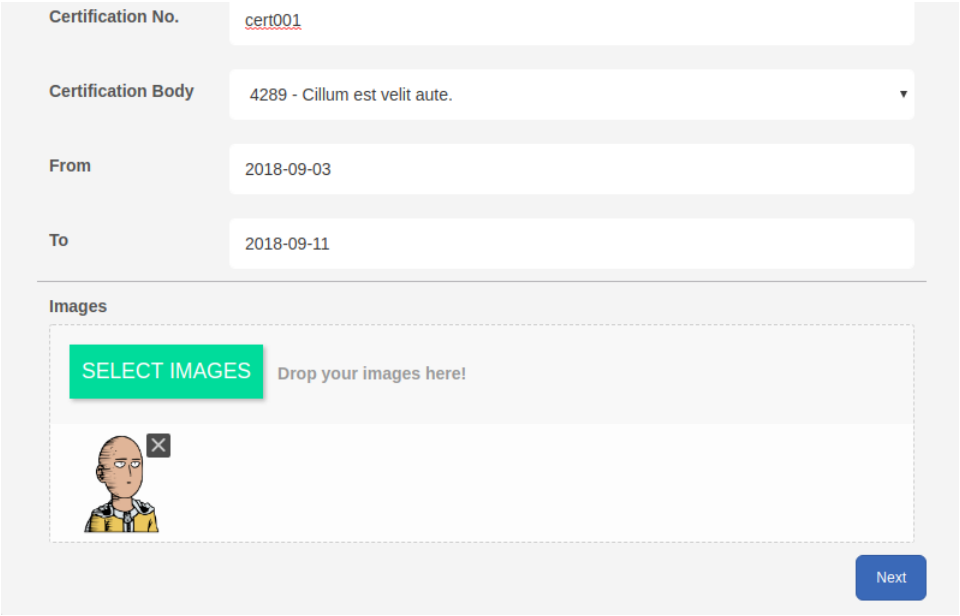

Fig. 4.17 Image Uploading

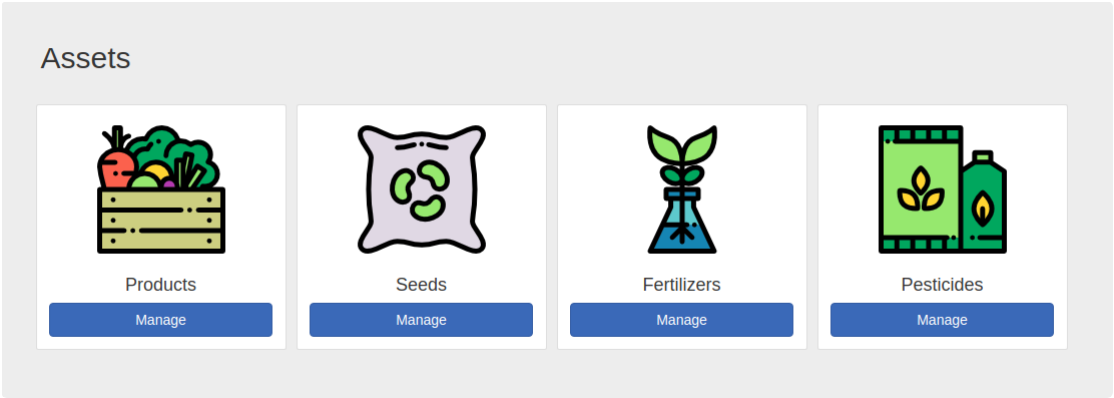

Fig. 4.18 Manage Assets

In the Assets section, as shown in Fig. 4.18, available assets to the farmer can be accessed. Under Products, a farmer can access his or her harvested products and under Seeds, Fertilizers

and Pesticides sections available seeds, fertilizers and pesticides quantities and other details can be accessed.

As mentioned, the 'Activities' section (Fig. 4.19) organizes the available activities to the farmer including Seeding, Watering, Manuring, Growth Progress, Harvesting and Diary Keeping. Under Seeding, Farmers are allowed to record seeding information in real time accordingly aligning with the physical seeding process and so as the harvesting process. In the seeding section, farmers can view all the available plots which are not seeded and already seeded plots (as in Fig. 4.20). Farmers can click the 'Seed' button and record seeding information to the relevant plot using available seed as shown in Fig. 4.21.

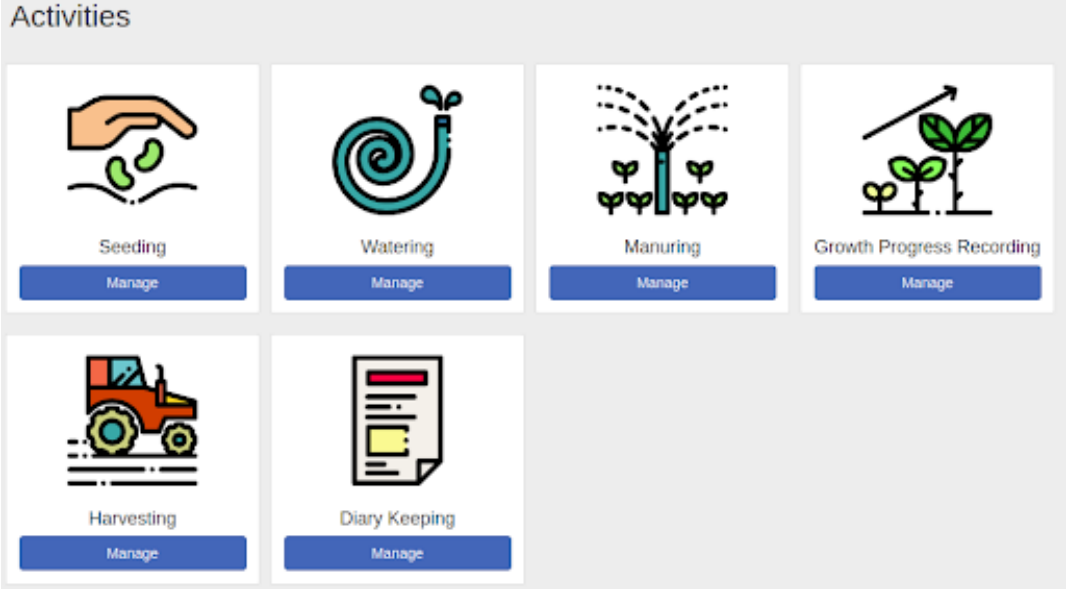

Fig. 4.19 Manage Activities

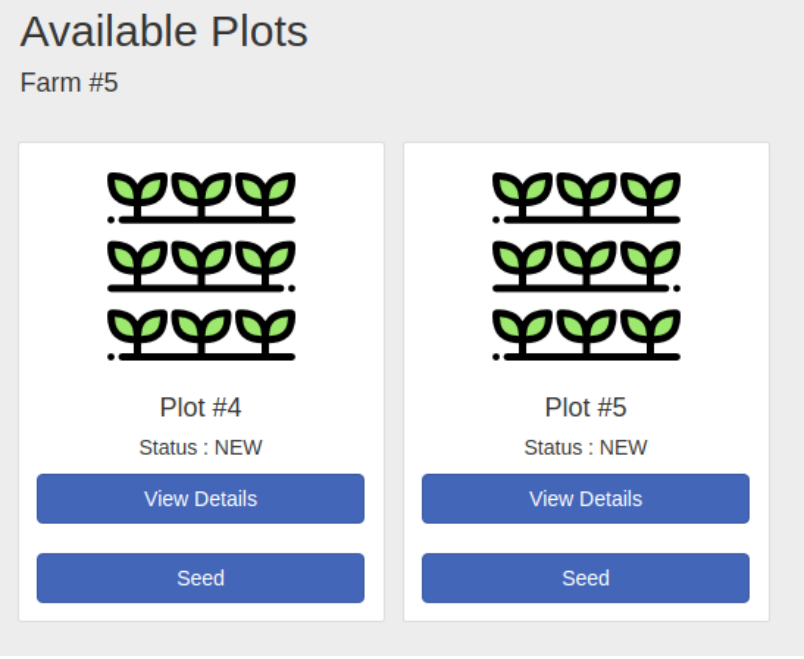

Fig. 4.20 Available Plots

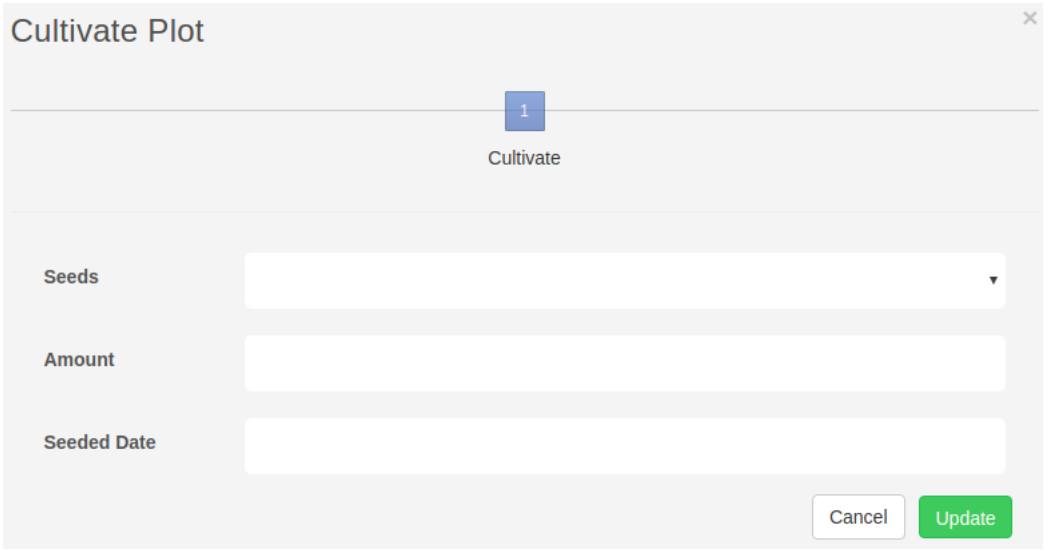

Fig. 4.21 Seeding Interface

After finishing the seeding process, the seeded plot will be automatically removed from available plots and added to the seeded plots interface (Fig. 4.22).

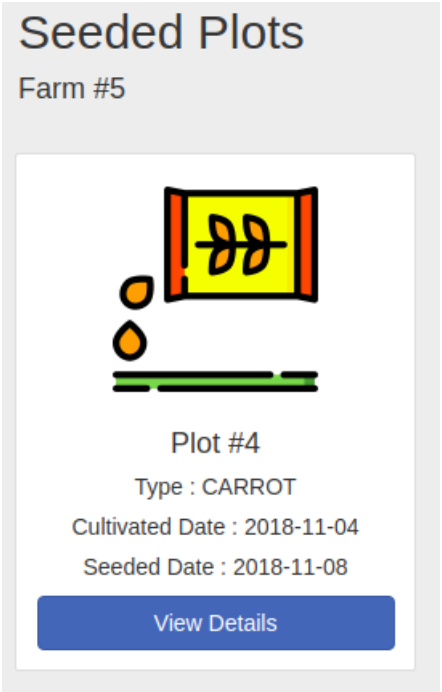

Fig. 4.22 Seeded Plot

Moreover, farmers can record watering and manuring information only for seeded plots in Watering and Manuring sections respectively. Under Growth Progress which will be elaborated in section 4.3.6, the growth progress of plants is recorded step by step in a plot-wise manner. In Diary Keeping, Farmers are allowed to record their day to day activities as they are currently doing in a manual way. In this study scope, the developed proof of concept only have these mentioned six activities, but it has the ability to scale up to the level of having more activities.

Customers

In this proof of concept customers' role is a bit different than other stakeholder interactions. Basically, organic food consumers don't have to log in to the system with their credentials to interact with the system. In order to get details of a certain product, customers only have to scan the QR code which is attached to that product or manually enter the product code in the search box. Here, other supply chain stakeholders also can use this feature in order to get details of a certain food item.

Consumers will be able to see the path of the product including all supply chain members. If there are any malpractices those will be shown with clear indications. Other than these all process information in the farm including applying of seeds, fertilizer, pesticides. Also, they can see the comments added by the certification bodies. Therefore they will be able to get a whole picture about the product in hand from the farm and decide whether products are genuinely organic or not.

4.3.2 Images, Icons and Colours

In the implemented proof of concept, always a multi-colour theme was used. When using colours, their relevance of use was considered in a higher priority. For an example, red was used for displaying errors, yellow was used for displaying warnings, green was used for displaying success messages and etc. Moreover, as the use of colours, when using icons, linear multi-colour icons were used.

When considering images, as elaborated earlier, the implemented blockchain based proof of concept supports image storing within the system. But as a special scenario, images are not stored in the blockchain in their original form to achieve a better performance measure. The relevant images are stored in the blockchain after converting them into base64 strings.

4.3.3 Assets and Identities

Each asset in the system has a unique identity. In all situations where a certain asset is retrieved or updated, the unique identifier of that asset is used. According to the system design, the creator of a certain asset has the privilege to use any desired string for the identifier of that certain asset. When considering "Product" asset type, with each product, there is a specific QR code which is generated in the asset creation stage and in this QR code, the unique identity of the product is stored. In operations such as product transfers and getting product historian details, this auto-generated QR code can be used by the relevant users.

Fig. 4.23 QR Code

4.3.4 Asset Transaction Process

The stakeholders including seed providers, fertilizer providers, farmers, distribution, packaging, warehousing, retailers can participate in the asset transaction process. In this process, basically, the ownership of a certain asset such as product, seeds and fertilizers is changed. As a safety measure, in the developed proof of concept, a certain transaction is always invoked by the new owner or the receiver of the transferred asset. For an example, when a product transferred from the farmer to the distribution, distribution peer has to invoke the transaction by scanning the QR code which is attached to the relevant product. In that case, the receiver can always counter check the details of the transferred product before accepting the transaction. In addition to that, in the Angular application, the receiver can invoke the transaction by manually entering a product id in the relevant field rather than scanning the product's QR code. Moreover, in the Transfer Product section, the products are listed under three categories; Owned Products, Submitted Requests and Pending Requests, as shown in Fig. 4.24.

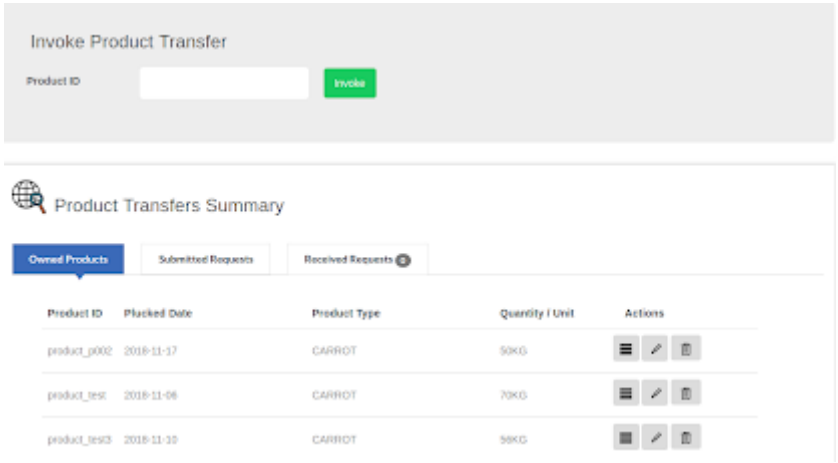

Fig. 4.24 Product Transfer Module

4.3.5 Track Product History

Proposed proof of concept offers the ability to scan a particular product and get all the information. As elaborated earlier, QR code which is generated in the asset creation stage and in this QR code, the unique identity of the product is stored therefore the user can simply scan this unique QR code and

automatically get all information or he can manually enter the product identity. All the information such as product details, farm details, plot details, certification details, product path, certification body comments and ph readings are displayed as shown in Fig. 4.25.

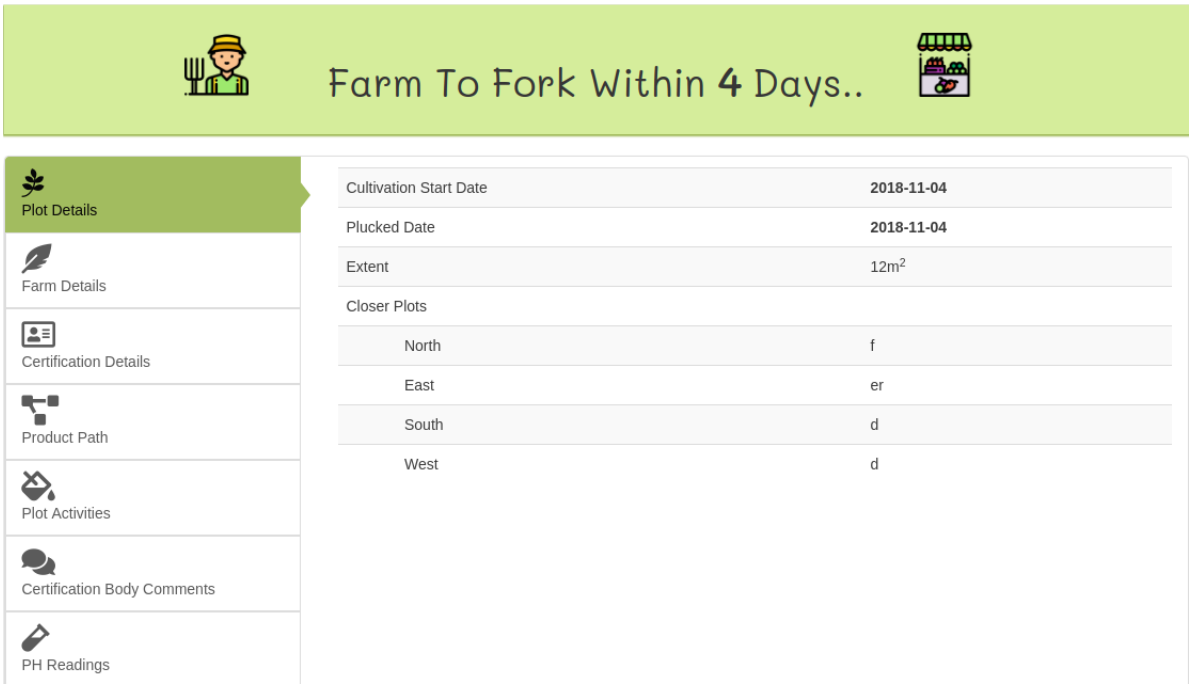

Fig. 4.25 Product Scan

4.3.6 Data Feeding

As elaborated, the integrity and genuineness of the data in the system are secured using the blockchain concept. But with the manual data feeding, there is a possibility of frauds and malpractices. Hence, the tackling malpractices in during data feeding are crucial whenever the main goal of the suggested infrastructure is to increase the transparency of the information flow in the organic food supply chain. The key facts to handle this situation in addition to validations are discussed under the following topics.

Plant Growth Progress

The implemented proof of concept can be considered as a decision supporter which provides relevant information as much as possible rather than a decision maker. Following this point 'Plant Growth Progress Recording' module of the system is a heuristic rule-based module which is supposed to provide progressive information on plant growth so that authorities like certification bodies can have insights whenever a malpractice is taken in the place. Even though this method will not secure the data feeding to the system 100%, it will provide the necessary information to identify frauds and malpractices. The heuristic rule which was followed in developing this module will be discussed in the Discussion chapter.

When considering the module, users especially farmers are allowed to record information on plant growth progress under 3 categories; Sprouted Plant Count, Fruit Bearing Plant Count and

Destroyed Plant Count. In each category, users can add relevant counts and also add updated counts one after another, but they can't delete old records on plant counts as shown in Fig. 4.26.

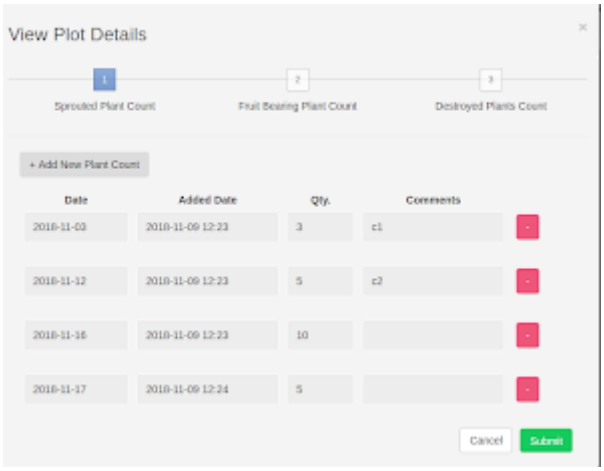

Fig. 4.26 Plant Count

All these growth progress recordings happen in plot wise. Therefore, users have to record these details considering each and every plot. Here, this recorded information can be retrieved by relevant authorities under plot details in a specific order. When considering this order the seeded amount, the sprouted plant count, the fruit-bearing plant count, the destroyed plant count and finally the harvested amount is ordered in the specified order (Figure 23). Here, the latest record date and amount are displayed in the tile, but users can view the fluctuation of the plant count in a chart as shown in Fig. 4.28.

Fig. 4.27 Plant Growth Display

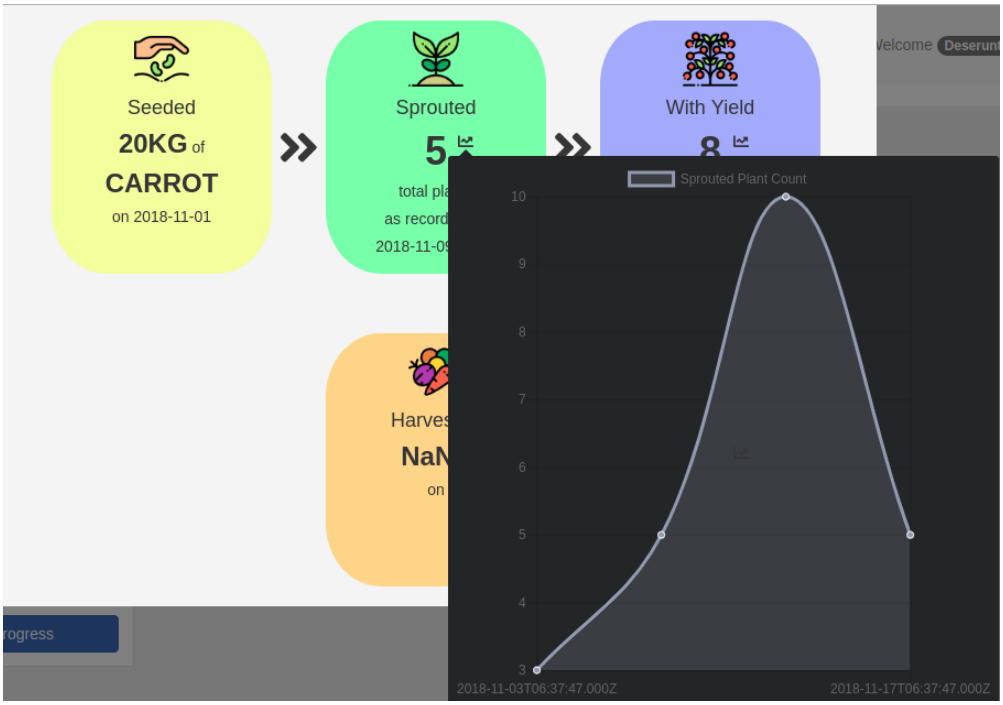

Fig. 4.28 Plant Count Variation Chart

Usage of IoT

Automated data feeding to the system using IoT devices paves the way to reduce the chances for happening malpractices in data feeding to the system is automating data feeding to the system using IoT devices and it helps to reduce the user intervention from the data feeding mechanism. But in this study scope, a such fully automated data feeding mechanism is not considered. But as a decision support infrastructure, in this study scope, minor use of IoT is proposed to have better insights while conducting the data feeding in a manual way. In this case, according to the results from the supply chain stakeholder case study and the consumer behaviour survey, some critical challenges were identified in the use of an IoT based data feeding mechanism.

- According to the results of the organic customer behaviour survey, organic food customers are only willing to pay 10% - 20% of the extra amount for the extra information they are provided. So that the IoT implementation should be cost effective and in here, do not focus on the economic feasibility of the solution which considered as a future enhancement for the organic food industry.
- Basically, in Sri Lanka, many large-scale organic farms can be identified. For an instance, the farm located in Attanagalla, Sri Lanka which was visited during the case study, has a land of 25 acres approximately. Therefore, the IoT implementation should have the ability to cover a larger area of land in a cost-effective and efficient way.
- Moreover, while interviewing the stakeholders especially farmers and farm owners, the possibilities of using IoT devices were discussed. But many of them were not comfortable in adapting to a new infrastructure.

- Furthermore, according to the field visits which were conducted in the supply chain stakeholder case study, many large-scale organic farms in Sri Lanka have a lack of required resources such as electricity and internet connectivity.

In this manner, in the study, the task of IoT devices is to record the variations of the soil texture, so that relevant authorities can study the variations with the manual data feedings and identify possible anomalies. Since this variation recording should be done in real time and on-premise without any lab testing, under above circumstances, from many possible areas including soil PH value, soil carbon to nitrogen ratio (C/N), leaf nitrogen concentration, soil moisture and soil temperature, soil electrical conductivity was chosen. The below facts were the key motives to choose electrical conductivity as the variation variable.

- Electrical conductivity is one of the simplest and less expensive method compared to other methods.
- Electrical Conductivity of soil can be measured using real time and on-premise sensors.
- Electrical Conductivity has correlations not only with soil texture but also with Water-holding capacity/drainage, Cation exchange capacity (CEC), Depth to claypan or rock outcropping, Porosity, Salinity and Temperature[67].

Following facts show how some of the variables correlated with soil electrical conductivity [67].

- Porosity: If the total soil porosity value is large then it more easily conducts electricity. Therefore sand has a low conductivity, silts have a medium conductivity, and clays have a high conductivity.
- Salinity: An excess of dissolved salts in the soil can be detected by electrical conductivity.
- Temperature: If the temperature decreases to the freezing point of water, soil electrical conductivity decreases slightly. Below freezing, soil pores become increasingly insulated from each other, and overall soil electrical conductivity declines rapidly.

According to the system design, the electrical conductivity of soil are recorded often with respect to each plot and those value fluctuations are illustrated in a chart and presented to the relevant parties alongside with the manually entered data such as daily diary records and manuring records. Here, users can easily identify anomalies by comparing these sensor reading fluctuations and manually entered log records.

- **Module Design**

In the study scope, the IoT segment was developed as a part of the implemented proof of concept in order to demonstrate the possibility of use of soil electrical conductivity for monitoring soil texture variations due to human or natural interventions. In implementing such a module for real business scenarios, its financial and other feasibilities should be assessed according to the results

derived from the supply stakeholder case study and consumer behaviour survey and have a proper base understanding. But in this study scope, did not consider about the financial feasibility of this module and developed for the sake of proving the concept of using soil electrical conductivity to indicate natural and human interventions to soil.

The implemented IoT segment is presented in Figure 4.29. As it shows, the electrical conductivity sensor probe is installed in the relevant plot and alongside with it, a NodeMCU microcontroller which is responsible for broadcast sensor readings to a client node of the blockchain network through a web server is connected. The client node at the farm retrieves sensor readings hourly from the web server and stores data in the blockchain network.

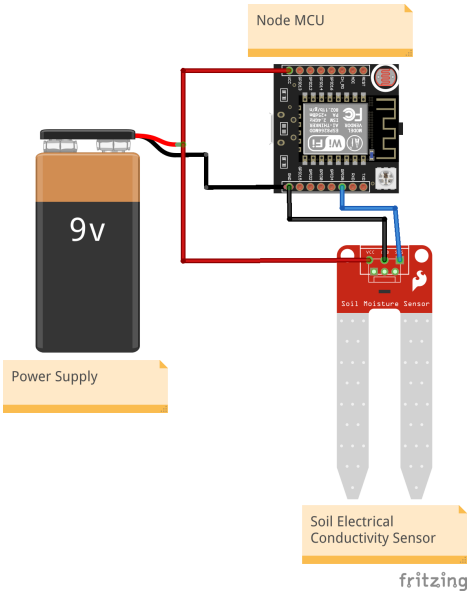

Fig. 4.29 IoT Segment

When presenting these data fluctuations to the user, a relevant user can get a graphical chart of sensor readings relevant to a specific date. According to the selected date, an hourly sensor reading fluctuation graph is generated alongside the manually entered log records as shown in Figure 4.30.

Then users can cross check these data fluctuations against the recordings of fertilizer or pesticides additions. According to that they can identify any unauthorized additions of fertilizers or pesticides.

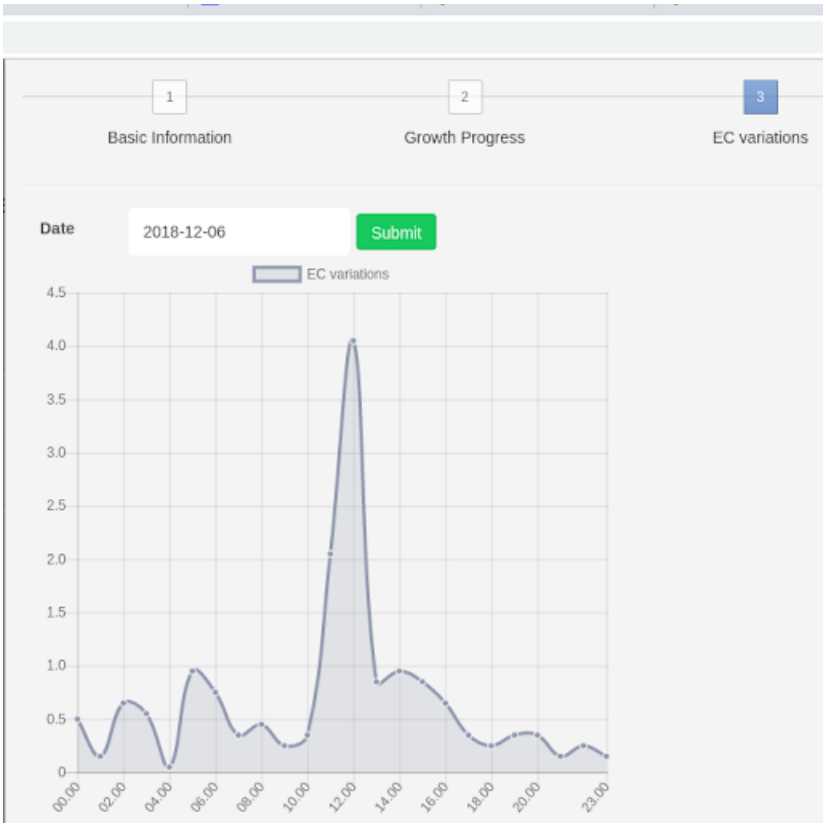

Fig. 4.30 Electrical Conductivity Variations within a day

4.3.7 A Complete Historian

The proposed system provides a complete historian about resources like farms, plots assets like products, seeds, fertilizers, pesticides and supply chain stakeholders. Under manage farms section, farm historian has a section called 'certification body comments' which displays all the comments regarding a particular farm made by certification bodies with inspection date and time. In the manage plot section, the historian has mainly four separate sections for plot activities, ph readings, farm details and certification body comments. When the user clicks 'historian' button in the action button panel he can get all the details under above mentioned sections regarding a particular plot as shown in Fig. 4.31.

Fig. 4.31 Plot Historian

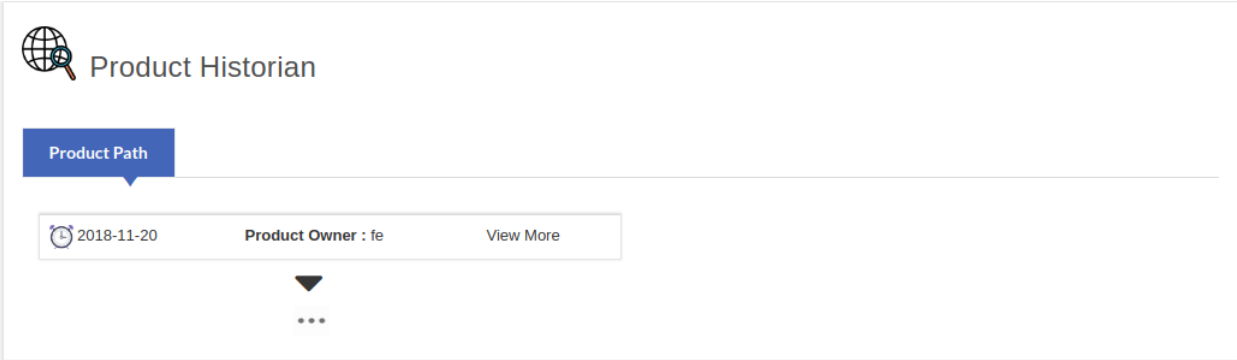

Fig. 4.32 Product Historian

Other than farm and plot historian, another important historian details section is product historian. In here, the user can get complete product path related historian details for a particular product as shown in Fig. 4.32 and it clearly shows the production stages and information in the supply chain process. Same as the product historian other assets like seeds, fertilizers and pesticides have their own product path historian. Moreover, each stakeholder has their own historian about tasks which they are done using the system.

4.4 Business Plan

This research has clearly mentioned a technical solution to increase transparency in the organic food supply chain after background study through case study and customer survey. But it needs a proper business plan to implement it successfully and keep it sustainable.

4.4.1 Foreign organic market

Sri Lankan organic farming industry not only focus on local buyers but also concerns about foreign consumers. Sri Lanka is exporting into a large number of countries with the intervention of Sri Lanka Export Development Board (EDB). However major organic food importing countries from Sri Lanka are USA, Germany, France, Japan, UK, Netherland, Sweden, Switzerland, Australia, Canada, Belgium and Austria[8]. Therefore this business plan not only focussing on gathered information through case study and consumer survey but consider the requirements of foreign customers as specified in foreign researches.

According to representatives from Saraketha, them and farmers involved with exporting process are earning a fair share of profit. Their main challenges are to improve demand for Sri Lankan organic foods compared to other countries and provide requirements requested by the foreign customers to create a competitive advantage over the other exporters.

As per a research done in Brazil, those consumers expect more transparency regarding the organic farming process and they are ready to buy more and pay a high price for that. [Analysis of value in organic food supply chain] Consumers in Ireland are interested to know the exported country and their buying decision is depend on that countries measurement to secure the quality of organic foods.[Ireland] Regular organic customers information seekers about product quality,

origins and processing, as well as ethical, social and environmental impacts of production [28]. However, currently, none of the retailers is able to provide all these details to their customers. Therefore these researches predict if a retailer is unable to provide these information, customer growth rate for organic may have an effect.

According to the above information, Sri Lankan exporters have a great chance to acquire a higher market share in the export market if they can provide what foreign customers ask which currently no one is providing. Sri Lankan exporters are looking to create a competitive advantage over the others exporters and this proposed blockchain solution will give the ability to provide information in a secured and trusted manner with the first mover advantage.

This solution will require a bit of training, the extra information recording and basic infrastructure such as smartphone. However, there were no researches done on the exact extra payment customers ready to pay for requested extra information requested whether they agreed to pay more.[Analysis of value in organic food supply chain]. Therefore, better to sell at the same price and use this extra information as a competitive advantage to attract more customers who are looking forward to this information. Another option is to provide extra information at an extra price. But at the initial stage, it is better to increase profit by attracting more customers for the Sri Lankan organic food rather than increasing price for the extra information. In this case, Sri Lankan organic exporters have to have a proper marketing campaign to educate foreign organic customers about the new information portal facilities Sri Lankans are providing.

4.4.2 Local Organic Market

According to the consumer survey, it is clear consumers want extra information to increase their trust in organic food and they are ready to pay 10%-20% extra payment for that information. On the other hand, according to the information collected through the case study, customer requested information such as processes followed in the farm, supply chain traceability and certification details are already entering by relevant parties. Therefore they do not have to put extra effort to record those. It's just a way of recording is changing from papers to a mobile phone.

Since case study and consumer survey provides all real information including prices following business plan is prepared after rounds of discussion with relevant supply chain stakeholders. However, the solution provided in research can be used for a vast number of vegetables and fruits. But for the explanation purposes business plan and financial feasibility will be considered for one vegetable; bitter gourd.

Usually from using one perch of land 60 kg of bitter gourd can be plucked as yield. The current average market price for organic bitter gourd kilo is Rs.380.

From 1 perch of organic bitter gourd = 60*380 = Rs. 22,800

Customers are ready to pay 10%- 20% extra amount for this additional information. But as a safety measure to protect the customer base who don't like to pay extra money to consider only price hike of 10%.

Extra payment = Rs. 22,800 *10% = Rs. 2,280

Therefore from the final product, they can make an extra net profit of Rs. 2,280 from 1 perch of bitter gourd. Therefore this is the maximum amount of money that can be invested for a one perch of the field. When the plan to spend on any IOT solution, should keep in mind this maximum extra amount of earning as a breakeven point.

This profit should be distributed among all the supply chain members according to the extra effort they put for the new solution. But since farmers are the one who is putting the biggest effort in recording most of this information he should earn the biggest chunk from this profit. During the case study, discussions held with supply chain stakeholders and they have agreed to divide shares of profit as follows.

Farmers - 70%

Wholesalers and Packaging centres - 10%

Seed fertilizer providers - 10%

Retailers - 10%

If farmers can have 70% of the extra amount customers paid, they can earn;

Extra profit = 2,280 * 70% = Rs. 1,596

For 1 Kilo = Rs. 1,596/60 = Rs. 27

Usually, farmers are selling one kilo of bitter gourd for Rs.200. Therefore this Rs.27 means a revenue increase of 13% for farmers. Almost all of the recording suggested for POC are already recording by farmers in their recording books. So, if there are no additional hardware investment for farmers this will be an extra earning for them without putting much extra effort.

Wholesalers, packaging companies, seed and fertilizer providers will have to just scan the barcode and check whether the seller's entered information are correct or not by cross checking with the physical goods. Therefore they don't have to put extra effort or provide extra information. But they can earn 10% of extra profit share and this leads them support suggested solution. Also, retailers are the most impressed party with this solution mostly because of their chance to impress and attract more customers. Other than that they can enjoy 10% extra profit margin. Some of the retailers even happy to contribute to the process without taking any share of profit if they can have this information to attract customers. Certification bodies also impressed with the solution due to their ability to get more on time information. Therefore most of the stakeholders we interviewed impressed with the proposed solution.

However, there can be stakeholders who reject to adapt to the solution. During the evaluation process, one such farmer is identified and all other stakeholders in our sample were happy with the solution. There can be more people who may reject to adopt the solution. But, stakeholders who get adopted to this will be able to build more customer loyalty and therefore, others will also have to adopt to this on one day to protect their market share.

Chapter 5

Discussion

5.1 Consumer Behaviour Survey

The current organic food market is targeted at upper middle class and upper-class families and most of the customers are rich and well educated. There can be two main reasons behind this. One can be, mostly the educated people will understand the harmfulness of conventional foods and therefore they are buying organic. But the most possible reason may be the high price of organic foods. Due to the high price of organic foods, customers can't move into organic foods whether they know the side effects of chemicals used for conventional foods.

There are families who buy organic foods with a low income. Most of them have babies who are less than 5 years old. It shows that parents are more concerned about their baby's health and tempted to buy organic irrespective of their poor economic condition. These customers main motive is healthiness and therefore they expect more information to assure these product really does not contain any harmful chemicals.

95% of customers buy organic food at least once a month. That shows most of the customers in Sri Lankan market are regular customers. Most of the countries in Europe like UK, biggest problem in enhancing the organic market is so many occasional customers that can't convert into regular customer [32]. But here in Sri Lanka, customers who buy organic are always frequently buying. But still, a number of organic food consumers are less than those countries. Reasons behind that may be the high price which prevent potential customers from trying it, lack of awareness and lack of trust in the organic procedure. Therefore to enhance organic food industry it has to attract new customers who never tried organic foods earlier.

Most of the customers have a general awareness that organic foods don't use synthetic chemicals and that seems to be the main expectation from the customer side. Only closer to 50% of them expect more things than that. But since most of them don't know about the qualities of organic foods such as not using genetically modified organisms or added hormones means their awareness about organic is not great. However, they refused the unsuitable definitions such as traditional food and herbal food shows that their awareness is enough not to mislead with false directions about organic foods.

There is a negative correlation between age and environment friendliness. It means younger people will consider the environment friendliness of organic foods as a reason to buy. But older people don't consider the fact that organic foods reduce environmental harm as a reason to buy organic foods. Also, there is a positive correlation between age prefer the taste. It means most of the elderly people think organic foods are tastier compared to conventional and they tempted to purchase organic because of that. However, younger customers do not believe so. These correlations show any marketing campaign to promote organic foods should be targeted at each age groups separately.

The main motive behind this consumer survey is to find out the extra information that customers are expecting to increase their trust in organic food genuineness. They mostly worried about the processes happening in the farm due to the risk of applying synthetic chemicals to crop. Then concerned about the supply chain members so they can take them all accountable for the quality of the food. Most of the customers don't know about organic certification. But customers who heard about the certification during the interview also interested in it. Customers want more transparency about the actions of certification bodies to verify whether they are working efficiently to reduce malpractices. Foreign customers expect information about the price paid to farmers since they believe it as their social responsibility. But Sri Lankan customers seem to be selfish and they don't want those.

Anyone would like to have more information about the whole process. But the problem is to enter those details supply chain members have to put an extra effort. Therefore to keep this model sustainable they should get some compensation for the extra effort. Customers are willing to pay an extra amount of money for the extra information. According to the results, the average price increase could be closer to 20%. But that means closer to 30% of customers can lose because of the price hike. It won't be good for the stability of the industry. Therefore the most suitable increase in price seems to be 10%.

5.2 Supply Chain Stakeholder Case Study

5.2.1 Farmers

Farmers are not bringing their record books to farm and not recording their activities day by day. This has lead to revocation of farmers organic certification. Before giving a solution for this we have to understand the problem step by step.

Their certifications get revoked because they are not maintaining proper records and inspection officers can identify some mismatches in the way of recording and actual surrounding of the farm. This incomplete records created just because they are recording those approximately once a fortnight and then they can't remember the exact things happened in the farm. This happens because of they are not recording it while they are on the field and when they come home they don't record it because they feel tired.

Then the important thing is to know why they are not recording it on the field. According to farmers, they are in fear of misplacement of the record book. If the record book is misplaced

then farmers certifications will be revoked and that's the main reason not to bring record book into the farm. They usually put short notes of what they did on a separate notebook or on a piece of paper. There is another reason not to record it directly on the record book. Farmers believe clear handwriting will give them an edge to accept the record.

When providing a solution, the main 2 factors should be avoidance of misplacement of the book and provide a method to record them in a clear manner. Since farmers should use it in the farm solution should support mobile devices. On the other hand, to stop misplacements, increase availability and to stop data tampering it should have a secured distributed database. When considering all these factors best solution seems to be an online mobile app which saves data in a distributed database.

5.2.2 Wholesalers

Wholesalers work as the main intermediary in this industry. They are the ones who convey the requirements of customers to farmers. From the customer's point of view, their biggest problem is lack of trust on the genuineness of organic foods. Currently, only scientific method available for that is organic certification. But according to the consumer survey half of the customers never heard about organic certification. Therefore they measure the genuineness of foods using methods such as the appearance of the food including size and colour.

Wholesalers are the one who is responsible for the packaging of products. Usually, they buy the full quota of product from farmers. But retailers are requesting products according to the perspective of customers like size and colour. Therefore they can't sell large size products.

Wholesalers biggest requirement is to create a system which will change the perspective of customers from assessing products from appearance to a more scientific way. Customers tempted to measure genuineness using appearance just because they don't have any other method. If an information system can provide information about the whole farming process and supply chain then customers will be tempted to use that information to clarify the product genuineness. Since this is a solution to increase customer trust, this solution should be a trustworthy one which has accurate information and can securely transfer the information.

5.2.3 Exporters

Exporters biggest concern is the traceability. Most of the countries including the USA is asking traceability of a product as a legal requirement. According to exporters, Importers of those countries not just expect paper documents for that, but also expect to enter all supply chain members with the geo location. Currently, they gather all those as paper documents and submit it to the importers' system later. But this blocks the ability to attach a geolocation by the supply chain member himself which reduces the reliability.

Therefore a system which enters all information with geolocation by supply chain members themselves will be important for them to convince to the end consumers in the foreign countries this

information is real. This will increase the competitiveness of the products among the competitors from other countries who currently use these technologies to prove their product provenance.

5.2.4 Retailers

There are two main types of retailers. They are raw food retailers and processed food retailers. Raw food retailers can also be divided into two as supermarkets and specialized organic food retailers. However, the raw food retailers common problem is some customers require more information such as manufacture date and provenance of product which they don't have currently. Retailers fear that organic customers will move away from the industry due to lack of trust. If customers can see all the information through a mobile app they will tempted to believe those information instead of size or colour of product.

Processed food retailers face this problem more than the raw food retailers. It's because raw food retailers mainly win the trust of the customers using their retail brand name. All the supermarket chains have a well known brand name in the country and therefore customers tempted to trust them. Specialised organic raw food retailers also established themselves in the industry at the moment and have a brand reputation. But the problem with processed food retailers is organic processed food industry is new and they don't have a known brand name to win the customers trust. Therefore they want a proper system to prove for their customers that they are using only organic raw materials.

If a system can connect from organic farmer to raw food retailers and show that these foods are genuinely organic then processed food retailers also can register in that system and show all the purchases they have done is through this system. Then processed food retailer's customers can check retailer's purchasing behaviour and assess the genuineness of processed organic food.

5.2.5 Certification Bodies

Organic certification is the only scientific way of assessing the genuineness of organic products. But they use mainly four methods to prove the genuineness of organic products. Those are informed farm visits, uninformed farm visits, check record book and transaction among supply chain members.

It is very difficult to identify any malpractices during informed visits. Because farmers are ready for the visit and they create environment accordingly. Then uninformed visits are the most suitable visit to check their genuineness. But to plan such a visit, certification bodies want more information. If they have on time information about what is happening on the farm when they see any anomaly they can visit the farm. This will enhance the productivity of the inspection process.

Checking record books also not that efficient since farmers do not record it daily. When inspectors from certification body visit the farm for uninformed visits farmers don't have record books on their farms. They keep them home. While they go home and bring back the book they have the chance to change the records accordingly. But if farmers are provided an information system which can't tamper the data then this problem will be solved.

Certification bodies have to check all the supply chain members from seed/fertilizer providers to retailers. But sometimes all of them are not registered under one certification body. In such

cases, it will be difficult for certification bodies to check the real amount of sales by cross check with each supply chain member. Therefore if a full ecosystem is provided to connect all members of the organic industry then certification bodies can easily gather that information and assess the genuineness of those transfer information.

5.3 Prototype - Traceability System

As elaborated, the traceability system was planned to implement as a proof of concept in order to justify and present the derived information from the consumer behaviour survey and the supply chain stakeholder case study. In designing the system, user experience and processing performance were considered in a higher priority since the supply chain stakeholders have relatively less computer literacy and there is a need of having an efficient system with accurate processing power in relatively lower costs. Furthermore, the proposed system's sustainability in the technical, economic and social aspects plays a crucial role in this study.

5.3.1 System Design Considerations

Initial Data Feeding

In the study scope, the main goal was to figure out a sustainable way to increase the transparency of the organic food supply chain. In this case, the study has suggested to increase the transparency of the information flow within the organic supply chain using blockchain's key features; data immutability and chronological data storage. Even though blockchain can tackle the transparency considerations, still there is a possibility of happening malpractices in the initial data feeding stage. To address this issue, in this study scope, below stated possible solutions have been considered.

- Use of IoT devices to automate data feeding

The optimal way to terminate malpractices and frauds in initial data feeding is cutting off the human intervention in the data feeding process. It can be achieved through a fully automated data feeding mechanism using IoT devices. Even though this data feeding part was not considered thoroughly in this study scope, the ability to use IoT devices was considered. In this case, according to the results from the supply chain stakeholder case study and the consumer behaviour survey, some critical challenges were identified in the use of an IoT based data feeding mechanism.

1. According to the findings derived from the consumer behaviour survey, organic food consumers are only willing to pay a 10% - 20% average extra amount of money for the extra information that is delivered using the proposed traceability system. This amount might not be sufficient and worth to develop an IoT based infrastructure.

2. From the site visits conducted during the case study, many sustainability issues related to an IoT implementation including lack of electricity and lack of internet connectivity were identified. Hence, designing a sustainable IoT platform is a challenge.

3. Basically, in Sri Lanka, many large scale organic farms can be identified. For an instance, the farm located in Attanagalla, Sri Lanka which was visited during the case study, has a land of twenty five acres approximately. Therefore, the IoT implementation should have the ability to cover a larger area of land in a cost effective and efficient way.

4. Moreover, while interviewing the stakeholders especially farmers and farm owners, the possibilities of using IoT devices were discussed. But many of them were not comfortable in adapting to a new infrastructure.

- Use of heuristic rules (progressive method) to tackle malpractices

As mentioned above, IOT devices can be used to automate the initial feeding of data. But due to high cost and practical difficulties, it will be difficult to automate all the initial data feeding. Therefore this research proposes a method to tackle malpractices while entering data manually. This method will mainly try to tackle malpractices by farmers. Farmers have to record the following events within a given period of intervals. Events measured for that will be as followed;

1. When farmers cultivate they have to record how much of seeds they used for each plot. Plot size is recorded early in the process.

2. Then they should record the number of plants come up from those seeds in each of the plots.

3. The next indicator farmer should mark is the number of plants which has flowers.

4. Finally, they can record the total yield from each of the plots.

5. Due to any natural disaster or pest attack plants get destroyed significantly, it should be recorded by farmers before removing those signs from the field.

Since farmers are recording these actions, all stakeholders have knowledge about the current situation of the field. They are recording all these progressively. Therefore they can't suddenly add extra yield. As an example, if this sort of progressive recording is not there they can cultivate using a very small amount of seeds and finally add conventional yield to it and change the early records accordingly.

But with this system you can't suddenly add extra yield since, they can't tamper those later and all other stakeholders including certification bodies will see on time information. Certification bodies can plan uninformed visits on dates farmers update those records. Then if they can see any difference between the records and the actual situation in the farm certification bodies can take disciplinary actions and record those as a comment in the blockchain which will communicate to all other stakeholders.

- Use of exchange measuring method to stop adding conventional yield

When one stakeholder is passing to the next stakeholder, the second one should scan the product and they can accept or reject the details in the package. This will stop the prior stakeholder of the supply chain from adding the wrong amount of yield or other inputs. But most importantly this will help to identify additions of conventional foods.

As an example wholesaler can buy 100 kg of carrot from different organic farmers and then add 20 kg of conventional carrot into it and sell 120 kg of carrot to different retailers. Since there is a number of different individuals involved with one wholesaler certification bodies will have a hard time of detecting real in and out amounts. But with the proposed system all these will be tracked and in a case of out is more than the amount of in that will be indicated in the system to all stakeholders.

- Use of intervention of Certification and Accreditation bodies to minimize malpractices

As the main goal of the study is to increase the transparency of organic food supply chain, it is believed to provide the access to all information in data feeding to relevant authorities such as certification bodies, accreditation bodies and also consumers. Under this point, identifying anomalies in the data feeding process are expected to handle by these authorities. The loophole of this point is that it is a high trust based mechanism on authorities. But according to the observations of the case study, since even authority bodies do malpractices, the effectiveness of this method has doubts.

User Experience and User Interfaces

In the system design phase, user experience (UX) and user interface (UI) considerations played a major role throughout the whole designing process, because supply chain stakeholders such as farmers have relatively less computer literacy. Following are some of the key design considerations and principles used when developing the blockchain based proof of concept.

- Aligning Interface Flow with Supply Chain Process

One of the most important design consideration is bridge the gap between system design and application area in the real world otherwise it occurs huge problems for system users. As early mentioned stakeholders have relatively less computer literacy. If system design totally different from their real life activities then it is difficult for users to adapt to the new system therefore much as possible we developed the proposed system flow align with the supply chain process.

- Consistent User Interfaces

In proposed POC, each stakeholder has their own dashboard which contains separate sections like resources, stakeholders and activities. All these sections in the dashboard are customized according to stakeholder responsibilities and tasks but look and feel similar in design including elements such as colours, shapes, layout and buttons. Other than the dashboards all the inner tables, buttons and layout also maintains the consistency across the system design.

- A Simple Single Scan Approach for Invoking Transactions

In the proposed system, all the details of a particular product reside in a QR code attached to a product, therefore, each stakeholder can invoke a transaction using a simple single scan of QR code. As an example, when transferring a product from one stakeholder to another, the receiver party has to proceed the scan of the product and confirm whether the transaction is correct one or incorrect one. If it is correct one, then the receiver can confirm it as the correct one and it is added to the blockchain. If it is incorrect one then the receiver can reject it and it is not added to the system. This process helps to avoid entering incorrect information to the system because always the receiver party has the authority to take the decision.

- Call to Action Buttons

As previously mentioned, each dashboard consists with simple large buttons attached with an image to indicate the relative importance of a call to action with respect to other actions, therefore, system users can easily identify the task which is going to do. Fig. 5.1 is an example of a large button called 'manage farms'.

Fig. 5.1 Manage Farm Button

- Obtain User Attention with Size

In most of the systems, size of an element relative to other elements indicates its importance than other ones. That means the larger the element is, the more important it is. Therefore in the proposed system, we used different sizes for titles, buttons based on their importance.

- Progressive Disclosure

It is a system design principle used in human computer interaction to maintain the focus of a user's attention by giving things when it is needed. This technique presents only the minimum features required to complete a task. The following figure shows an example of using progressive disclosure in the proposed system. In here, four action buttons: view, view historian, edit and delete will only display when a new plot is added to the system, therefore, it makes the system simple.

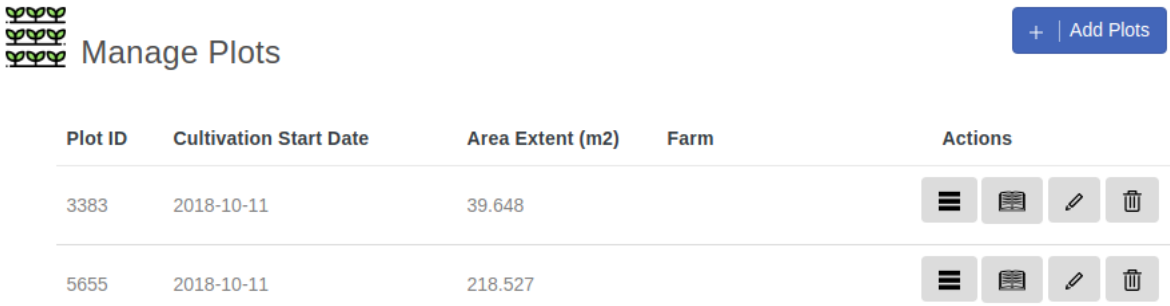

Fig. 5.2 Manage Plots

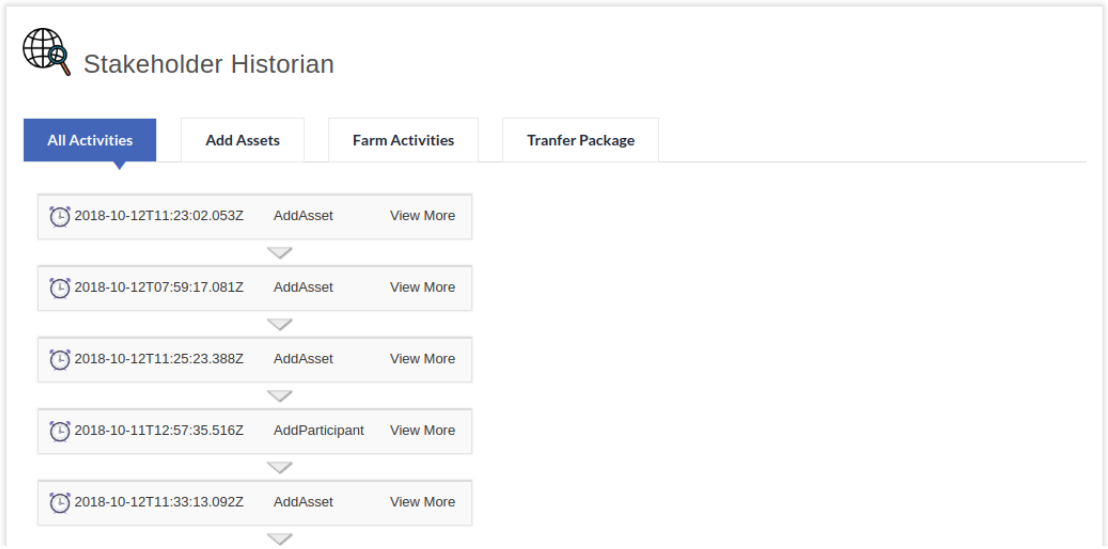

Fig. 5.3 Stakeholder Historian Details

Figure 5.3 shows another example of using progressive disclosure. In here rather than giving all the information at once it includes a 'view more' button for more information therefore if someone wants more details he can proceed the view more feature. This feature maintains simplicity and user friendliness in the design.

- User Friendly Forms

In the proposed system, it contains the stepwise wizard as forms to be completed by users. The main reason behind is there is a large number of input fields to be filled in some forms, therefore, it is not a good design practice of adding all the input fields into one form and make scrolling to fill those fields. In here, users can easily fill all the input fields in the first step and then go to the second step without scrolling the form or using a separate form.

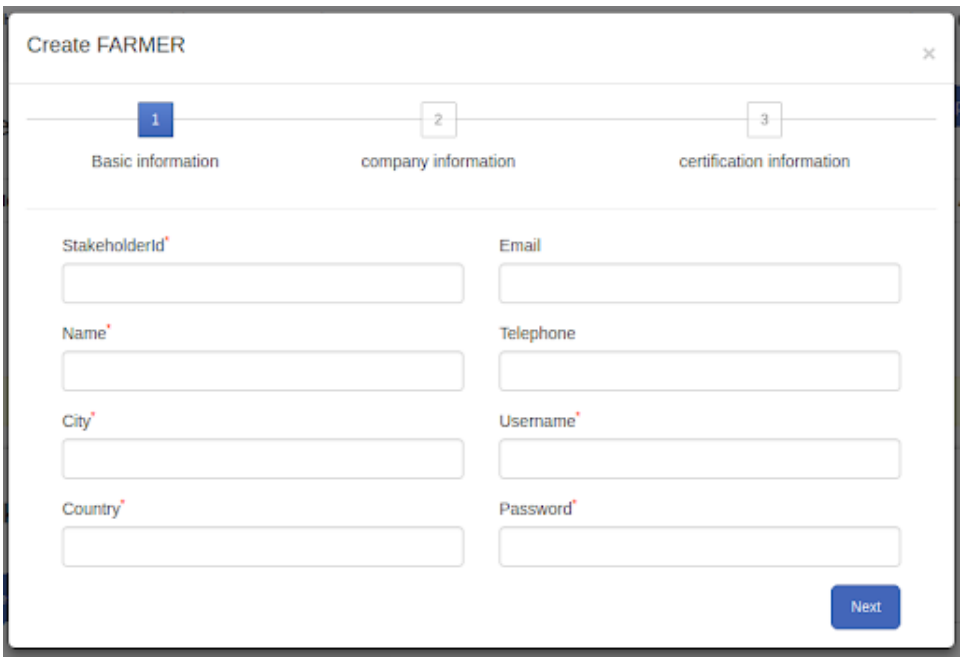

Fig. 5.4 Stepwise Wizard

- Single Interface for all Historian Details

In here, we used a single horizontal tab panel to show all the historian details of a particular asset or stakeholder. Users can easily move between relevant tabs and get all the details without any problem, therefore, it increases the usability of the proposed system for users. The following figure shows an example of historian details of a particular asset (plot).

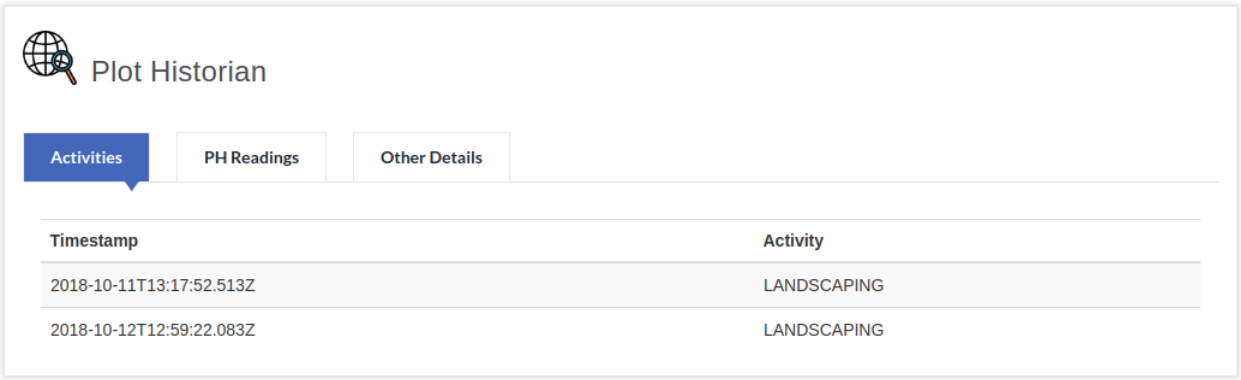

Fig. 5.5 Plot Historian Details

- Images and Icons

Images and icons are very important considerations when coming into the system design process. The proposed system often uses large images for buttons and titles to increase understandability of users about the functionality, therefore, it directly shows the purpose of a particular functionality. Other than images it uses icons to increase the memory of users corresponding to system features because icons are fast to recognize at a glance.

Furthermore, as elaborated in the system design, the system allows users to upload relevant images at certain points. Basically, through this feature, users are provided with a convenient and effective way of retrieving and expressing information within the system at hard to understand situations.

5.4 Evaluation

This research has generated a Proof of Concept to increase transparency of organic food supply chain. Required information for those was taken by consumers and certification bodies. Then the design of the web application and mobile application has done according to the specific requirements of the supply chain stakeholders including farmers. After developing the PoC it was given to each of the stakeholders in organic food supply chain and took their feedbacks. Other than that we have done a performance evaluation on backend blockchain runtime.

5.4.1 User and process evaluation

For evaluation purposes, we have contacted a farmer (Aththanagalla farm) and a wholesaler (Sanilma) who are selling products to Keels supermarkets. These 3 members were used to create the supply chain from farm to retail shop by passing a selected food product (bitter gourd). Other than this farmer there were plans to contact 3 more farmers to get the usability of the system. However, one of those farmers reject to corporate with us and therefore only capable to contact 2 more farmers to check the usability of the system. Also 'Sri Cert' certification body corporate for this evaluation process.

Before handing over the mobile app or web application into the hands of the supply chain members we have done a full demo in front of them. After that ask them to record required data through the app and given a few scenarios like delete and edit information to check whether they can do it easily. While they were entering details they were helped when it was required to provide advice.

Stakeholders

- Farmers

This process evaluation is based on bitter gourd. Evaluation process was started from the farm and purchased seeds, fertilizers and pesticides were entered into the system manually by us. Farmers' process started from accepting or rejecting those information. Then these farmers have to record applying of seeds, fertilizer, pesticides and water. We have specifically selected a date where that farmer was starting a new plot. So, it was able to track those seed applying procedure. Fertilizer, pesticides and water applying and those data entering processes were done with relevant to other matured bitter gourd plots.

Closer to days proceeding, wholesalers came to the farm. At that time vegetables were plucked including bitter gourds and then packaged them in boxes. Then farmers entered the details about

quantity from each type and to whom they are selling. A unique QR code pasted on the bitter gourd box and all entered information were assigned to that. Then the box is hand over to the wholesaler's representative and ownership is transferred to wholesaler via the mobile app.

- Wholesalers

Wholesaler's representative took all the boxes and cross-checked the mobile app details such as quantity and type of vegetable with the real vegetable boxes and then took the accept or reject decision. When he accepted it ownership transformation to wholesaler will be completed. When there are mismatches between farmers quantity and wholesaler measured quantity, wholesaler's representative reject it and farmer have to do the required changes to get accepted.

Then this packages transferred into packaging centres. Within the packaging centre, bitter gourd box was opened and distributed those bitter gourd among small weighted packets that can be sold in the supermarket. A QR code was pasted on each of the small bitter gourd packets. By using the proposed system in this research, each packet is assigned to the relevant big bitter gourd box for tracking purposes. Then wholesalers delivered those small packets to keels warehouse and transfer the ownership to the supermarket.

- Retailers

The supermarket will check the products and accept it by scanning the QR code as similar to earlier transfers. If there are rejections wholesalers have to edit their entries to correct the amounts. However, whether the edits have done any of the stakeholders can check the history and identify initially entered amounts. Evaluation process covered up to this stage.

Operational Feasibility

- Complex form structure

According to the user feedback which had been taken during the user evaluation process, some changes had been done to the system design. In the beginning, we have developed all the forms in the system in a way that, all input fields in one single interface as in figure 5.6. In here it is difficult for a user to fill in the input fields because of its complex structure and also user doesn't know the importance of filling each data input because it does not prioritize the input fields according to its importance. Furthermore, if the form has many input fields then it doesn't show all fields in one single frame, therefore, users have to scroll and fill those input fields.

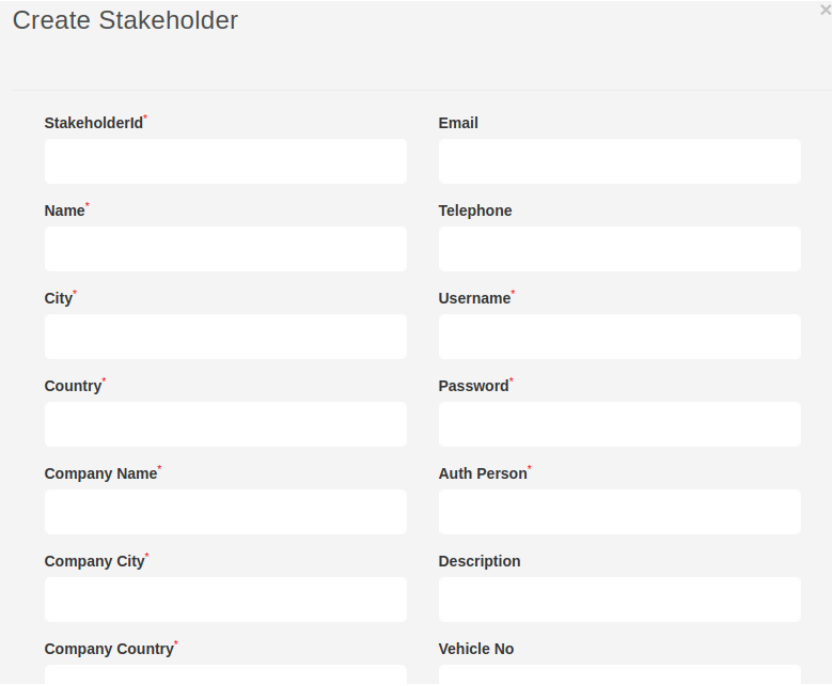

Fig. 5.6 Traditional Form

Figure 5.7 shows the proposed input form which solves the above-mentioned user friendliness problems and mainly in here it categorizes all the input fields and put those into labelled sections in the form, therefore, it helps the user to clearly identify the importance of each section based on the flow of tabs. As an example create farmer form developed as a single interface with three main tabs (step wise wizard) : Basic information, company information and certification information.

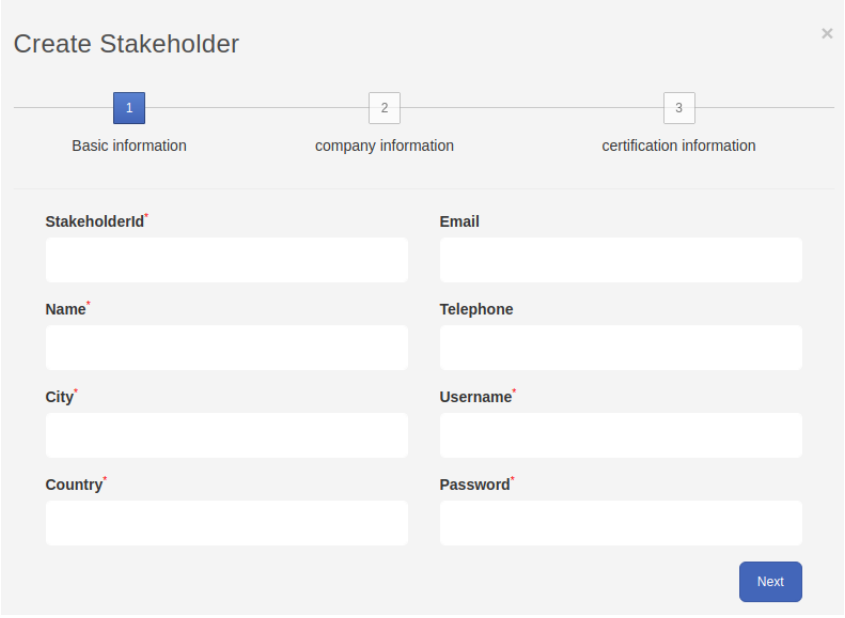

Fig. 5.7 Step Wise Wizard

- Registration process feel bit longer

Farmers have to fill very long and detailed registration forms regarding their own details and for each plot even. These registration forms seem to be too long since they are not much familiar with typing using smartphones. However, according to the requirements of the certification bodies, it is a must to fill all these forms. But new system makes it easier for them to fill those by auto-filling whenever the same field is repeated in 2 forms. This feature is appreciated by the farmers.

- Parts of the farm with less signal

When we reached to some areas of the farm signal strength was not that good to enter data using the app. In such instances, the farmer has to record it on a piece of paper, as usually he does in the current process. when he reached an area with proper internet coverage he has to update the information. This sort of procedure may lead farmers to the habit of later recording which is inefficient and open gaps to malpractices.

- Time wasting when the record on time

According to farmers, recording in the app took extra time compared to the sketch notes they put in the rough papers. They accept the fact that they do not have to reenter those details when they enter the recordings then and there using the mobile app. However, they also made the point that when they get used to the app time spent to record will be reduced closer to the level of recording on rough papers. If so that won't be a big problem. However, until they get used to it their processes will get late due to this.

- Ownership Transfer

Initial system design was to transfer ownership of the asset by the seller. As an example when wholesaler marked set of products as transferred to retailer and retailer scanned those, the system is updated in a way that retailer as the new owner of those products with relevant attributes such as product type, quantity and price. But during the evaluation phase, buyers suggest that it is better if they have an method to accept or reject before changes the ownership of the product. This is required because buyers want to cross-check prices and quantity of the system with physical goods. Therefore in the improved system, it is provided with the facility to accept or reject the transaction from buyers side after scanning the product QR code. Until they accept transaction product ownership remains with the wholesaler according to this example scenario.

Financial Feasibility

Customer survey has shown that customers are ready to pay an extra 10% to 20% for the extra information they required. Also, there is no new infrastructure investment for the basic transparency system other than daily using types of equipment such as a smartphone. Within the business plan, it is described a profit distribution plan according to the effort each of the stakeholders has to put for

extra information delivery. All stakeholder agreed with this profit distribution plan and therefore basic developments of the transparency system should be financially successful.

However financial feasibility problems can occur if the extra IoT platform is introduced. During preparing the business plan it is identified, for a 1 perch of bitter gourd, extra amount that farmers can earn is limited to around Rs. 1,600 per year. But if we are going to introduce IoT devices to enhance transparency and enable automated data feeding, one of those will cost around Rs.10,000 according to our selected sensors. If farmers are planning to come to breakeven point within a year they can only occupied one sensor for six perches according to profit they earn from this. If we are planning to put a sensor for a 2 perch area, breakeven point can be achieved within 3 years. But the practical way to going forward with this is those IoT sensors should be sponsored by government or retailers. Then those invested parties can have higher percentage of profit share. However, during the discussion none of the farmers were ready to invest that much of a significant amount on IoT devices.

System Acceptance

As mentioned in the introduction of evaluation, all of the stakeholders participate in the evaluation session and give their suggestion to improve. They were happy with the system if it is implemented with the suggested improvements expecting the financial benefits and growth of customer base both locally and internationally.

However there was an exception. One farmer was sighting this system as a useless system. Reasons for him to reject the system was he believe that this sort of transparency will not give any difference to local customers. He believed that whether the consumer survey has shown an extra payment for extra information this won't work in real world. On the other hand he believe no point in revealing daily farming details to customers. He believes this can create misbeliefs among customer due to misinterpretations about the delivered information. However since his ideas are abnormal compared to others, we have contacted his relevant certification body and inquired details. According to certification body whether they have not confirmed him as a user of prohibited substances, there were few suspicious scenarios reported about him and his record book keeping is weak.

5.4.2 Performance Evaluation of Backend Blockchain Runtime

To evaluate the performance of the implemented underlying blockchain runtime, Hyperledger Caliper benchmarking tool was used as elaborated in the methodology chapter. For the evaluation purposes, a blockchain network was deployed in a docker network installed in a computer equipped with 8GB of RAM, Dual-Core Intel® Core™ i5-6200U CPU @ 2.30GHz processor and 1TB of hard disk. Elementary OS 0.4.1 (Loki) 64-bit version has opted as the operating system in which the blockchain network was deployed. The Hyperledger Fabric based blockchain network was deployed as a 2 peers network with two organizations. Furthermore, it has 1 certification Authority

node, 1 Orderer node and 2 CouchDB database instance nodes as each database instance belongs to a single organization.

When considering the performance evaluation, it was conducted in 4 main test rounds. All these test rounds have followed the exact same scenario but each differed from other test rounds according to the number of transactions invoked in a second and the number of assets created during that test round. In each test round, performance results were gathered in two categories; Performance and Resource Consumption. Under Performance, transaction success/fail ratio, transaction send rate (transaction per second - tps), minimum latency, maximum latency, average latency and throughput were measured. Under Resource Consumption, maximum average memory usage, maximum average CPU usage, traffic in and traffic out were measured. As the common test scenario, in each test round, as participants, a farmer, a certification body and as assets, a farm and a plot had to be created respectively. Then according to the test round input, a certain amount of products was planned to be generated. Finally, a number of product transfer transactions had to be invoked according to the passed test round arguments.

The considered 4 test rounds in the evaluation process are stated below and with each test round, respective Performance Metrics and Resource Consumption tables are presented (Table 5.1 to Table 5.8). In each Resource Consumption table (Table 5.2, Table 5.4, Table 5.6 and Table 5.8) memory usage, CPU usage, traffic in and traffic out were calculated for each blockchain node established in the deployed blockchain network.

1. Generate 30 products and invoke product transfer transactions in a 5tps send rate.

Name	**Success**	**Fail**	**Send Rate**	**Max Latency**	**Min Latency**	**Avg Latency**	**Throughput**
backend	30	0	5tps	10.88s	1.10 s	4.81s	2tps

Table 5.1 Performance Metrics for Test Round 1 (30 Transactions in 5tps Send Rate)

Type	**Name**	**Memory (Max)**	**Memory (Avg)**	**CPU (Max)**	**CPU (Avg)**	**Traffic In**	**Traffic Out**
Docker	dev-peer0.org2. example.co....0.20	104.6MB	102.9MB	17.29%	5.65%	605.5KB	487.5KB
Docker	dev-peer0.org1. example.co....0.20	105.9MB	104.6MB	28.97%	7.43%	838.0KB	580.7KB
Docker	peer0.org2. example.com	333.5MB	320.1MB	15.54%	8.31%	2.1MB	3.9MB
Docker	peer0.org1. example.com	285.8MB	263.8MB	25.69%	10.19%	2.6MB	4.3MB
Docker	ca.org1. example.com	8.9MB	8.9MB	0.03%	0.00%	572B	0B
Docker	couchdb.org2. example.com	127.3MB	122.6MB	86.36%	48.90%	597.7KB	1.1MB
Docker	orderer. example.com	13.6MB	12.5MB	2.80%	1.09%	481.4KB	973.2KB
Docker	ca.org2. example.com	9.2MB	9.2MB	0.03%	0.00%	572B	0B
Docker	couchdb.org1. example.com	130.7MB	124.9MB	108.53%	53.03%	693.7KB	1.3MB

Table 5.2 Resource Consumption for Test Round 1 (30 Transactions in 5tps Send Rate)

2. Generate 30 products and invoke product transfer transactions in a 100tps send rate.

Name	Success	Fail	Send Rate	Max Latency	Min Latency	Avg Latency	Throughput
backend	30	0	10tps	4.42s	2.62s	3.30s	5tps

Table 5.3 Performance Metrics for Test Round 2 (30 Transactions in 10tps Send Rate)

Type	Name	Memory (Max)	Memory (Avg)	CPU (Max)	CPU (Avg)	Traffic In	Traffic Out
Docker	dev-peer0.org2.example.co....0.20	104.6MB	102MB	23.23%	7.86%	597.2KB	479.9KB
Docker	dev-peer0.org1.example.co....0.20	105.9MB	103.6MB	20.46%	10.55%	913.6KB	790.5KB
Docker	peer0.org2. example.com	277.2MB	240.7MB	18.38%	10.26%	2MB	4.1MB
Docker	peer0.org1. example.com	282.3MB	250.6MB	19.40%	13.05%	2.9MB	5.1MB
Docker	orderer. example.com	14.6MB	12.6MB	3.31%	1.26%	475.4KB	943.7KB
Docker	ca.org2. example.com	8.8MB	8.8MB	0.02%	0.00%	1.1KB	0B
Docker	couchdb.org2. example.com	128.8MB	120.5MB	103.68%	58.54%	613.3KB	1012.0KB
Docker	ca.org1. example.com	8.8MB	8.8MB	0.03%	0.00%	1.1KB	0B
Docker	couchdb.org1. example.com	132.9MB	124.2MB	111.51%	67.87%	755.9KB	1.4MB

Table 5.4 Resource Consumption for Test Round 2 (30 Transactions in 10tps Send Rate)

3. Generate 100 products and invoke product transfer transactions in a 5tps send rate.

Name	Success	Fail	Send Rate	Max Latency	Min Latency	Avg Latency	Throughput
backend	100	0	5tps	10.85s	1.66s	6.06s	4tps

Table 5.5 Performance Metrics for Test Round 3 (100 Transactions in 5tps Send Rate)

Type	Name	Memory (Max)	Memory (Avg)	CPU (Max)	CPU (Avg)	Traffic In	Traffic Out
Docker	dev-peer0.org1.example.co....0.20	111.5MB	108.9MB	41.37%	13.58%	2.6MB	1.9MB
Docker	dev-peer0.org2.example.co....0.20	109.4MB	105.5MB	29.6%	10.37%	1.8MB	1.4MB
Docker	peer0.org1. example.com	296.2MB	280.8MB	40.83%	14.78%	7.6MB	13MB
Docker	peer0.org2. example.com	332.8MB	287.9MB	20.82%	11.78%	5.8MB	11.5MB
Docker	orderer. example.com	22.3MB	19.7MB	3.56%	1.35%	1.3MB	2.7MB
Docker	couchdb.org2. example.com	161.8MB	143.2MB	112.82%	66.03%	1.6MB	2.7MB
Docker	ca.org1. example.com	8.8MB	8.8MB	0.02%	0.00%	572B	0B
Docker	couchdb.org1. example.com	160MB	141.8MB	129.93%	73.69%	2MB	3.7MB
Docker	ca.org2. example.com	8.9MB	8.9MB	0.02%	0.00%	572B	0B

Table 5.6 Resource Consumption for Test Round 3 (100 Transactions in 5tps Send Rate)

4. Generate 100 products and invoke product transfer transactions in a 5tps send rate.

Name	Success	Fail	Send Rate	Max Latency	Min Latency	Avg Latency	Throughput
backend	100	0	10tps	12.71s	7.98s	9.71s	5tps

Table 5.7 Performance Metrics for Test Round 4 (100 Transactions in 10tps Send Rate)

Type	Name	Memory (Max)	Memory (Avg)	CPU (Max)	CPU (Avg)	Traffic In	Traffic Out
Docker	dev-peer0.org2.example.co....0.20	109.9MB	105.9MB	37.81%	10.87%	1.7MB	1.4MB
Docker	dev-peer0.org1.example.co....0.20	113.3MB	108.8MB	58.48%	14.64%	2.6MB	1.9MB
Docker	peer0.org2. example.com	292.6MB	264.9MB	24.10%	12.15%	5.7MB	11.6MB
Docker	peer0.org1. example.com	284.1MB	266.7MB	41.77%	16.11%	7.6MB	13.6MB
Docker	orderer. example.com	26.9MB	22.3MB	7.49%	1.46%	1.3MB	2.6MB
Docker	couchdb.org2. example.com	155.7MB	137.7MB	134.21%	63.29%	1.8MB	2.7MB
Docker	ca.org1. example.com	9.1MB	9.1MB	0.02%	0.00%	572B	0B
Docker	ca.org2. example.com	9.7MB	9.7MB	0.01%	0.00%	572B	0B
Docker	couchdb.org1. example.com	151.9MB	135.9MB	124.12%	76.64%	2.1MB	3.8MB

Table 5.8 Resource Consumption for Test Round 4 (100 Transactions in 10tps Send Rate)

In Table 5.9 and Table 5.10, a summary of performance of the network in different transaction send rates are presented. In Table 5.11, average performances of the whole system is presented. Finally Table 5.12 is used to present average resource consumption of the overall system.

Name	Send Rate	Avg Max Latency	Avg Min Latency	Avg Latency	Avg Throughput
backend	5tps	10.865s	1.38s	5.435s	3tps

Table 5.9 Summary of Performance for 5tps Send Rate

Name	Send Rate	Avg Max Latency	Avg Min Latency	Avg Latency	Avg Throughput
backend	10tps	8.565s	5.3s	6.505s	5tps

Table 5.10 Summary of Performance for 10tps Send Rate

Name	Avg Max Latency	Avg Min Latency	Avg Latency	Avg Throughput
backend	9.715s	3.34s	5.97s	4tps

Table 5.11 Average Performances of the System

Type	Memory(avg)	CPU(avg)	Traffic In(avg)	Traffic Out(avg)
Docker	113.417MB	19.187%	1.663MB	2.804MB

Table 5.12 Average Resource Consumption of the System

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Appendix A

Consumer Survey Questionnaire

1 - Totally disagree 2 - Disagree 3- Neutral 4 - Agree 5 - Totally agree

1. What do you mean by organic food products?
   (a) Natural food
   (b) Foods does not use chemical fertilizer/ pesticides
   (c) Traditional food
   (d) Foods without Hormones
   (e) Not Genetically modified
   (f) Herbal food
2. Do you purchase / consume organic foods?
   (a) Yes
   (b) No
3. If no, What are the reasons?

	1	**2**	**3**	**4**	**5**
High price					
Lack of trust about genuineness					
No extra benefits					
Lack of availability					

4. If Yes, Why do you choose organic products?

	1	2	3	4	5
Healthy / nutritious					
Environment friendly					
Prefer the taste					
Quality of product					

5. what are the organic food types you consume?

   (a) Vegetables

   (b) Fruits

   (c) Spices

   (d) Grains, Cereal

   (e) Livestock(meat/ egg/ Fish/milk)

   (f) Honey

6. How often do you buy organic products?

   (a) Once a week

   (b) Several times a week

   (c) Once a month

   (d) Several times a month

   (e) Few times a year

7. Do you know about any organic certificates in Sri lanka ?

   (a) Yes

   (b) No

	1	2	3	4	5
8. Do you believe these organic standards and certificates ?					

9. How do you verify or know that the foods you are buying / consuming are organic?

	1	2	3	4	5
By checking the organic food product brands					
By keeping trust on the retailer					
By checking appearance of the product (colour and size)					

10. What is the maximum extra amount you would like to pay for the expected extra information?

    (a) 0%

    (b) 0% - 10%

    (c) 10% - 20%

    (d) 20% - 30%

    (e) 30% - 50%

11. What kind of information will be more valuable to know about organic foods?

	1	2	3	4	5
Farmer details (location, employee details)					
Farming details (Fertilizer, seeds, water applying,manufactured date)					
Path of the product					
Price they pay for each member in supply chain					
Certification details including certification bodies remarks					

12. Your age range

    (a) 18 - 25

    (b) 26 - 35

    (c) 36 - 45

    (d) 46 - 55

    (e) 56 and over

13. Your gender

    (a) Male

    (b) Female

14. Your residence (Hometown)

15. How many people currently live in your household?

    (a) 1 - 2

    (b) 3 - 4

    (c) 5 - 6

    (d) 7 - 8

16. Marital status

    (a) Single

    (b) Married

17. Children under 5 years old

    (a) Yes

    (b) No

18. What is your household income?

    (a) Less than 50,000

    (b) 50,000 - 100,000

    (c) 100,000 - 150,000

    (d) 150,000 - 200,000

    (e) Above 200,000

19. Highest educational qualification

    (a) O/L

    (b) A/L

    (c) Undergraduate

    (d) Graduate

    (e) Master degree holder

    (f) PhD degree holder

    (g) Professional qualification