Paper No: SC-05 **Smart Computing**

Technology-enabled online aggregated market for smallholder farmers to obtain enhanced farm-gate prices

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***Abstract* - Using scenario transformation methodology, we identified four scenarios that indicated a lack of trusted parties to sell harvest has forced smallholder farmers to sell the harvest to brokers who often collect the harvest at the farm gate at the lowest possible prices and sell in the market for large profits. As blockchain smart contracts provide a mechanism to reduce risk and establish trust between unknown trading partners, we transformed these into a scenario that establishes trust between farmer and unknown broker using smart contracts, generating a trust-enabled market. This scenario enables farmers to search for the optimum farm-gate price without relying on known brokers. The scenario is further enhanced to enable a Many-one-Many market linkage, facilitating automatic aggregated marketing. The paper presents the functional prototype of the scenario, explaining the functionality of the transformed system.**

Keywords – aggregated market, blockchain, farmer linkage, smart contracts, trust

I. INTRODUCTION

Of the 570 million farms around the world, 90% of them are considered smallholder farms [1]. 1.5 billion people around the world depend on smallholder agriculture for their livelihood and 75% out of that are the world's poorest people who live in developing economies [2]. They receive only one-third to one-half of the final price for their produce [3] [4] [5]. Although there is a possibility of getting a better price, if the harvest is taken to distant markets, due to cost and lack of storage and transport facilities, rural farmers often sell their produce to a middle man who generates higher profits by procuring harvest at the lowest possible prices. Even though farmers manage to transport the produce to distance markets, they may not be able to compete with dominating larger traders and auction-based sales [6].

A survey carried out in a developing country, Sri Lanka, reveals that while some farmers sell their harvest directly in the market, where selling price changes vigorously, 90% of farmers depend on a middle person or a shopkeeper to sell their harvest [7]. Similarly, in India, fruit and vegetable farmers mainly rely on middlemen who control the market although do not add much value, to sell their produce. Middlemen receive 50% to 71% of the price difference between farm-gate price and resale price [3]. Fafchamps and Hill (2005) affirm that Ugandan farmers tend to sell their produce in the market particularly when the market is close or the quantity of harvest is high, despite the less lucrative farm-gate prices [8]. A survey from Turkey reports that farmers have less bargaining power when it comes to selling the harvest due to the absence of apparent competition between commission agents [9]. Farmers from Perth, Australia have a major concern about the deductions done and margins received by the market agents [10]. Thus, the unavailability of organized markets and lack of buyers can be considered as some of the foremost reasons for less productive farm-gate prices, leading to poverty-stricken lives for smallholder farmers.

Muamba (2011) states that transformation of farmers' economic status from subsistent or semi-subsistent stage to specialized farmers who produce crops that have a comparative advantage, targeting their products to regional, national, and international markets, can be promoted by greater market participation [11]. Wealth stimulation can occur among farmers who have the potential to overcome the production constraints and the costs of market participation [12]. There are distinct types of markets associated with agriculture. The spot market is characterized by fewer barriers to entry, high transactions costs, and low returns. The contract productions to a known buyer for relatively undifferentiated crops are distinguished by potential barriers to entry, moderate risk of financial loss, and low transactions costs. The contract production to a known buyer for quality differentiated crops is similar to the former with a higher potential of financial returns as well as risks [12].

High marketing and transaction costs restrict smallholder farmers from market participation [3, 13]. Transaction costs can be classified into observable (pecuniary) and unobservable (non-pecuniary) transactions costs [14]. Observable transaction costs are visible when an economic exchange takes place such as transport, handling, packaging, storage, and spoilage. Unobservable transaction costs include information costs, negotiation costs, and monitoring costs [14]. Information Management Systems as an intervention approach have reported positive impacts in improving farmer's market participation and receiving higher farm-gate prices while lessening negative impacts [15] [16]. On the contrary, previous research reveals that there is no significant impact generated by the information intervention if markets are segmented [17] and the farmers have limited options to transport the harvest to the market [4] [17]. Thus, they are forced to sell to local middlemen. Research suggests encouraging farmers and new buyers into agribusiness because the limited competition for farmer's produce is the fundamental cause of lower farm-gate prices [4].

When new buyers enter into agribusiness, concomitant transaction costs arise in the form of information costs and negotiation costs from the farmer's perspective. While providing access to market information can result in reducing transaction costs, leading to higher market participation, facilitating the establishment of trust between farmers and buyers, targeting a trustworthy buyer-seller relationship can promote farmer's participation in markets [18]. Sako (1992) states that a smooth trading relationship requires contractual trust, expecting the promises to be kept, and competence trust, self-reliance in the trading partner's capability on carrying out the task [19]. Blockchain Technology, a distributed ledger platform that provides immutable, transparent, cheaper, faster, trustworthy, and secure transactions over a network with unknown users [20], together with smart contracts, executable code that facilitate execution and enforcement of the terms of an agreement between untrusted parties [21], has the potential of building trust between trading partners.

Thus, this research explores building trustworthy market linkages between farmers and buyers to obtain better farm-gate prices through enhanced market participation based on Blockchain smart contracts. Previous research claims that market linkages that support collective marketing have the potential of generating greater benefits for farmers [22] [23] [24]. Kumarathunga, et al (2020) analyses several online commodity market platforms, revealing most of them support one-to-one market linkages. Although some platforms provide many-to-one market linkages, this provision is implemented manually with the support of field partners who does the collection, limiting the scalability of the platforms [25]. Accessibility to markets depends on the extent of the production [26]. Thus, collectivization into cooperatives, self-help groups, or intermediary contracts is inspired due to the potential of reducing transaction costs for both farmers and the other trading party [13]. Therefore, in this paper, we present a functional prototype of a smart agricultural commodity market platform that supports aggregated marketing while enabling dynamic trust between farmers and buyers.

The remainder of the paper is organized as follows. In section II, we describe our research approach, leading to the functional prototype of the smart commodity market platform in section III and then the discussion in section IV. The conclusion is presented in section IV.

II. RESEARCH APPROACH

This research is carried out following Design Science Research (DSR) methodology, which is a method of addressing important unsolved problems in unique or innovative ways or solve problems in more effective or efficient ways [27]. A good starting point for DSR is identifying and representing opportunities and problems in an actual environment [28]. Improving the environment by introducing novel artifacts and the process of building these artifacts is the desire of design science research [29].

Thus, to understand the selling mechanisms practiced by smallholder farmers, we based our research on Sri Lanka, a developing country in the South Asian region. We selected the area of Nuwara Eliya, which has the major productions of upcountry vegetables such as carrot, beet, leek, potato, and cabbage [30]. The distance between Nuwara Eliya and the Country's capital city, Colombo is 166.4 km. The manning market in Colombo is the wholesale market of fruits and vegetables grown across the country while Cargills is a supermarket network distributed across the country. Data for our research are gathered through discussions with about 30 smallholder farmers from different sub-areas: Palagolla, Kandapola, Kuda Oya, and Hawa Eliya. While the sub-areas are chosen randomly with the heuristic of representing the majority of the farming community, farmers are chosen according to the farm size, so the selected farmers are smallholders. The sample size of smallholder farmers is decided according to the Grounded Theory which emphasizes the flexibility of deciding the sample size as the research progresses. The researcher does the collection and analysis of data simultaneously, leading to real-time judgments on whether further data collection produces additional or novel contributions [31]. The sample size is decided when the researcher perceives that theoretical saturation is achieved [32]. Thus, the theories derived from the collected data are more likely to resemble reality [31]. According to DSR, the design cycle is the heart of any research project [28]. We chose the Scenario-based design method as the process of designing the artifact.

Scenario-based design is a family of techniques that uses to concretely describe how people will use a future system to accomplish tasks and activities at an early point in the development process rather than defining the system operations. A scenario is a story that describes actions and events that lead to a consequence. The goals, plans, and reactions of the people in the story are described as the actions and events [33]. Scenarios emphasize the people and their experiences, directing the user-appropriateness of the design ideas to the main focus. Design ideas can be refined from the feedback of the stakeholders about usage possibilities and concerns. Thus, the design will remain focused on users' needs and concerns since the scenario describes how the users will use the future system [33]. According to the discussions with farmers, we were able to develop 4 different scenarios on farmers' selling mechanisms as listed in Table I. The second step is analysing the scenarios to derive claims for each scenario, identifying the causal relationships. Next, each claim from each scenario is further analysed to derive positive and negative consequences [33]. The claims and consequences derived from the scenarios in Table I are listed in Table II. Deriving claims and their positive and negative consequences initiate originating some design moves with the heuristic of maintaining or even enhancing the positive consequences for the actors of the system while minimizing or eliminating the negative consequences [33]. Following this heuristic led us to perceive that farmers often choose a broker or buyer with pre-established trust, although they receive money later and the prices are low as illustrated in Table III. The level of trust reduces from top to bottom in the table. Thus, the process revealed the first design move of a future system.

- The system requires a mechanism to establish trust between farmers and unknown brokers to enable

TABLE I. SCENARIOS OF CURRENT SELLING MECHANISMS

Scenario 1
Bandara is a 45 years old farmer from Palagolla, Nuwara Eliya. He is a member of a farmers' society and has a farmer code given by the society. He grows carrot, leek, beets, and cabbage on his 2 acres' farm. He sells a certain amount of his harvest to Cargills supermarket who transfers the payable to a nominated bank account. He sells another certain amount of harvest to local brokers who pay within 2 or 3 weeks. Most of his harvest is sent to the manning market in Colombo in a truck. The truck driver (Sunil) comes to the farm. Bandara loads the harvest to the truck, writes a letter to the broker (Chinthaka) in Colombo, including the farmer code and quantities of each type of vegetable. Chinthaka decides the rates for each vegetable and the payable amount after deducting 2kg of vegetables for each 50kg bag as wastage. Chinthaka pays the transport charge to Sunil and reduces it from the payable amount. Then Chinthaka transfers the payable amount to a Bandara's nominated bank account after reducing a commission for selling the harvest from the payable amount.
Scenario 2
Nishantha is a 35 years old farmer from Kandapola, Nuwara Eliya. He grows carrots and leeks on a 1-acre farm. Nishantha sells his harvest to a local broker (Kamal) because Nishantha has trust in Kamal's paying back. In harvesting season, Kamal comes with a group of labours to help him with harvesting, but Nishantha does not have to pay for them. Kamal pays them. Nishantha and Kamal agree with a rate for the harvest, usually less than the rate in the Nuwara Eliya Dedicated Economic Centre. Nishantha does not know the rate Kamal sells. Usually, Kamal pays Nishantha within 2 or 3 weeks.
Scenario 3
Kalum is a 40 years old farmer from Kuda Oya, Nuwara Eliya. He grows leeks, carrots, and radishes on his ½ acres farm. He sells his harvest to a local broker (Namal) who pays Kalum within 2 or 3 weeks at an agreed rate. Sometimes he sells his harvest to an unknown broker for a lower rate because the unknown broker pays money on the spot.
Scenario 4
Ishan is a 50 years old farmer from Hawa Eliya, Nuwara Eliya. He grows carrots and potatoes on his ¾ acres farm. In harvesting season, he makes a call to a broker (Nadun) from the Nuwara Eliya Dedicated Economic Centre, asks him to collect the harvest, and makes an agreement with the rate. Ishan harvests the potato and makes them ready for selling. But Nadun harvests carrots with the help of his labours. Nadun transports them to the centre. After 2 or 3 weeks, Nadun transfers the payable amount to Ishan's nominated account.

farmers to choose any broker who offers comparative rates without relying on known brokers.

Next, we realised that the quantities produced by these farmers are little due to the small extent of the farmlands, thus the cumulative of both observable and unobservable transaction costs can result in lower margins for marginal and small scale farmers. However, research has demonstrated that trading collectively has the potential of reducing transaction costs with better coordination [24], leading to higher revenues for farmers [23] from better bargaining positions [22]. Thus, the second design move is generated to facilitate aggregated marketing.

- The system requires a mechanism to support a market linkage that facilitates aggregated marketing for farmers to obtain better rates.

Both design moves are used to develop the transformed scenario. We presented the transformed scenario and the conceptual model for an online agricultural commodity market platform in a previous conference paper [25]. In this paper, we present the modified conceptual model to develop a functional prototype for a smart agricultural market platform. For simplicity, when explaining the market platform, we have used buyer for both buyer and broker.

III. SMART AGRICULTURAL COMMODITY MARKET: THE FUNCTIONAL PROTOTYPE

The modified conceptual model of the smart agricultural commodity market platform is illustrated in Fig. 1. It has 5 major components.

A. Digital agribusiness ecosystem (DAE)

Digital Agribusiness Ecosystem, previously known as Digital Knowledge Agribusiness Ecosystem [34], consists of a database that has quasi-static information about crops, pests and diseases, land preparation, and growing and harvesting methods. It provides this information as actionable information to farmers through mobile apps. Two mobile apps called "Govi Nena" and "Gayankisan" are already being deployed and used by farmers in Sri Lanka and India respectively. When the farmer feeds what to grow and when to grow to the system through the mobile app, DAE provides a detailed cost of cultivation for each crop and crop calendar outlining essential tasks he should carry out to optimize yield as well as to manage pests and diseases better, leading to optimal output. DAE has the capability of predicting the expected harvest and expected harvesting date for each crop for each farmer according to the season and location [34].

B. Web site

Since DAE is capable of predicting the expected harvest for each farmer for each crop, the harvest can be aggregated based on geographical proximity, crop type, and expected harvesting date. Thus, many farmers can be clustered into one group according to the same parameters and made available to many buyers, forming Many-one-Many market linkages between them, enabling aggregated marketing. This market linkage is demonstrated in Fig.2. While the crops are still in the growing stage, the aggregated harvest according to the farmers' group is made available for buyers through the website in advance as displayed in Fig. 3. The harvest aggregation can be done according to administrative divisions in a country. For example, the administrative divisions in Sri Lanka are province, district, divisional secretariat division (DS Division), and Grama Niladhari division (GN Division – the lowest grass-root level division) [35]. Thus, for the buyers in Sri Lanka, aggregation can be carried out up to the GN division level. The buyers can fill in a bid form in the website as in Fig.4, entering the crop type he expects to buy, grade, the expected buying period, location, quantity, and the offered price.

C. Mobile app

Mobile App will be developed as an extension to existing apps in the ecosystem. When a buyer submits a bid, the bid is sent only to the mobile apps of a certain group of farmers as displayed in Fig.5. This filtration is executed against the geographical proximity, crop type, and expected harvesting date so that the buyer is facilitated with easy coordination and collection of the harvest during the harvesting period. When a farmer receives the bid, he has three options to correspond as displayed in Fig. 6.

TABLE II. ANALYSING THE FOUR SCENARIOS

	Claim	Consequences
1	has 2 acres farm	- produces small quantities of harvest
	sell the harvest to the Cargills supermarket.	+ has an agreed price and trust of paying
		- farmer has to do cleaning, grading, and packing
	sends the harvest to manning market in Colombo in a truck	+ gets his money transferred into his bank account + able to discharge his excess productions
		- does not know the rate which the buyer is going to sell his vegetables and the rate he will get - has to agree with any rate the seller decides because the harvest is already given - broker reduces 2kg for each 50kg as wastage. It is 4% of the total value. - transporting the vegetable-packed in a truck increases the wastage - broker reduces a commission for selling the vegetables. - farmer gets a little profit at the end when all deductions are made
2	Has1 acre farm	- produces small quantities of harvest
	sells the harvest to the local buyer	+ no harvesting cost + no transporting cost + has developed mutual trust between farmer and buyer
		- receives the money within 2 or 3 weeks - rates are little less than in the economic centre
3	has 1/2 acres farm	- produces small quantities of harvest
	sells the harvest to a broker	+ gets money on the spot + no need to build trust between the farmer and the buyer
		- rates are low
4	has 3/4 acres farm	- produces small quantities of harvest
	local broker does the carrot harvesting and transports them to the economic centre	+ farmer does not have to bear a cost for harvesting carrot + farmer does not have to pay the transport charge + vegetable that goes to the market is fresh + farmer does not need storage for vegetable + harvesting labours may be experienced in harvesting, so the wastage is little
	sells the harvest to the local broker	+ has developed trust between farmer and broker + receives money to his bank account
		- receives the money within 2 or 3 weeks - rates are little less than the rates in the economic centre

1) Accept the offer

If a farmer is pleased with the price offered by the buyer, he can accept the bid by entering the amount of harvest he expects to sell at that price. The bid has an expiry date. Therefore, the farmer can accept it until the expiry date. However, if other farmers who received the same offer, accept the offer before him, the offer quantity can be saturated before the expiry date, supervening the expiration.

2) Provide a counteroffer

If the farmer is not content with the price, he is facilitated with the option of providing a counteroffer, entering a new price, and the amount expected to sell at that new price. Farmers can choose this option if the bid price is very low. In this case, the farmer is supposed to wait for the particular buyer's acceptance or rejection.

3) Reject the offer

The third option is to reject the offer if the price offered is not satisfactory enough. However, the farmer can anticipate more bids with different prices since the bids are for the expected harvest, not a ready lot.

When a farmer chooses one of the above three options, it is sent to the Contract Negotiator Module.

D. Contract negotiator module (CNM)

Contract Negotiator Module (CNM) is a server-side software module that maintains the coordination and communication between the farmer and buyer. CNM stores the bids offered by buyers and responses from the farmer in a database. Once an offer is saturated or expired, CNM analyses all the responses received from the farmers against the buyer's bid. This analysis can produce one of the following two results.

1) The amount in total accepted offers = buyer's requirement

TABLE III. FARMERS' CHOICE ORDER

Scenario 1	Scenario 2	Scenario 3	Scenario 4
Cargills Super Market (Agreement)	Local Broker	Local Broker	Broker from Nuwara Eliya Trade Center
Local Broker		Unknown Broker	
Manning Market in Colombo			

Since the buyer's requirement is fulfilled, CNM sends a notification to the buyer mentioning that his offer has been accepted by farmers, and requests his confirmation on whether he is intended to continue to the next step of establishing a contract.

2) The amount in total accepted offers < buyer's requirement, but there are some offers from farmers with a higher price

In this case, the CNM sends a notification to the buyer, stating that only a portion of his offer is accepted by farmers for the offered price. It also mentions that his requirement can be fulfilled at a higher price if he accepts the counter offers submitted by the farmers. If the buyer consents to the counteroffer price, that price is applicable for all the farmers who accepted that offer, not only for the farmer who submitted the counteroffer.

Once the buyer confirms his willingness to continue with the purchasing process, the next step is to establish a contract between the farmers and buyer. Thus, CNM asks each farmer to deposit 10% of the agreed total amount and the buyer to deposit 10% of the agreed total amount. These amounts are required as an honor to the contract that will be established between them. The buyer will be provided three options to pay the balance 90% of the total price according to the farmer's choice:

- deposit it in the system at the point of establishing the contract, so when the harvest is collected, the money is sent to the farmer, otherwise sent back to the buyer
- organize a cash payment at the time of collecting the harvest
- pay 3 days/ 1 week/ 2 weeks after collecting harvest (this depends on the buyer's rapport) – this can be done directly or through the system

The buyer and the farmers can do the deposit in the form of fiat money either via mobile money or e-banking. Once the deposits are done, the amount is converted into a unique type of cryptocurrency and sent into a blockchain network along with farmer's and buyer's data to establish a contract in the form of a smart contract. When the expected buying period approaches, the CNM requests confirmation from both parties whether the harvest delivery is performed, before sending an invoke message to the blockchain platform to execute the smart contract to transfer the money accordingly. When the smart contract is executed, the cryptocurrency is converted into fiat money and transferred to the relevant financial account: mobile money account or bank account.

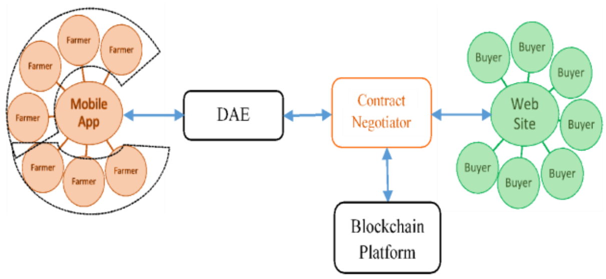

Fig.1. Conceptual model of the proposed platform

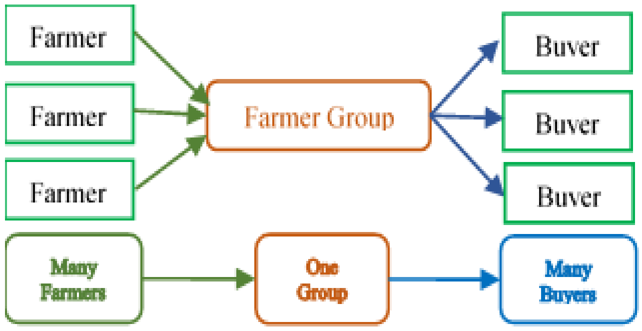

Fig. 2. Many-one-many market linkage

All the transactions are stored in a database to produce ratings and rankings for both farmers and buyers according to their behavior of honoring the contracts. The rank of the buyer or farmer will be calculated according to the number of successful transactions and the total number of contracts, while the rating is established according to the reviews received. When a farmer receives the offer, he can tap on the unique buyer id listed in the offer to see the buyer's rank and the ratings received from previous transactions. Similarly, when the buyer receives acceptance from a farmer, he can tap on the farmer's unique id to view the farmer's rank and ratings. This feature generates the possibility of establishing online trust between farmers and buyers.

E. Blockchain network

A Blockchain network is integrated into this platform to facilitate the process of contract establishment. When it receives a deploy message from CNM with the required data: farmer's data, buyer's data, the amount of cryptocurrency sent by both farmer and buyer, crop type, grade, expected harvesting period, agreed price, and amount of harvest for the particular crop, it deploys a new smart contract. Once it receives an invoke message from the CNM, it releases the cryptocurrency stored in the particular smart contract's account and let the CNM aware that the smart contract is executed.

IV. DISCUSSION

According to the scenarios derived from the discussions with farmers, we observed that farmers are in a trust bubble with a small number of brokers. They prefer selling the harvest to a known broker even at a lower price due to pre-established trust of getting paid although they receive money after 2/3 weeks. However, as farmers do not step out of their trust bubble, they miss the opportunity of

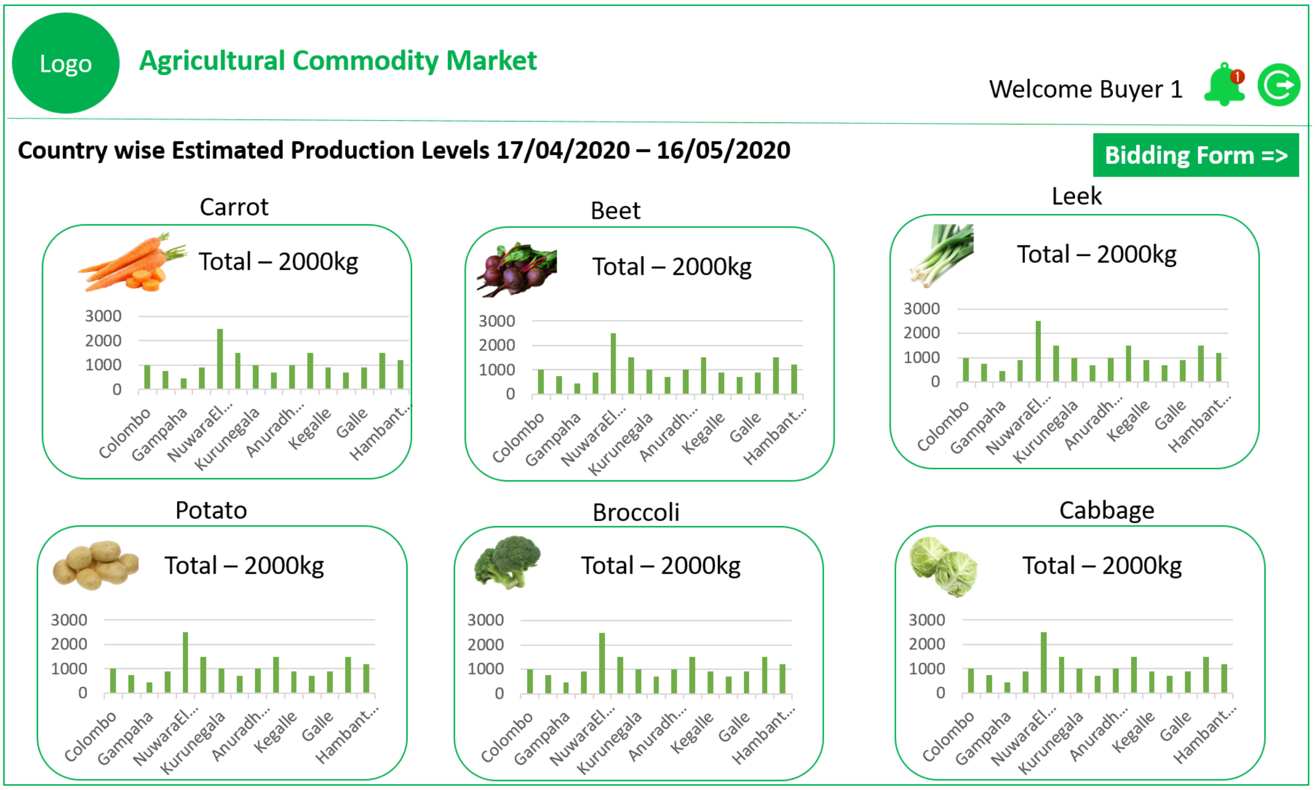

Fig 3. User interface for logged in buyers

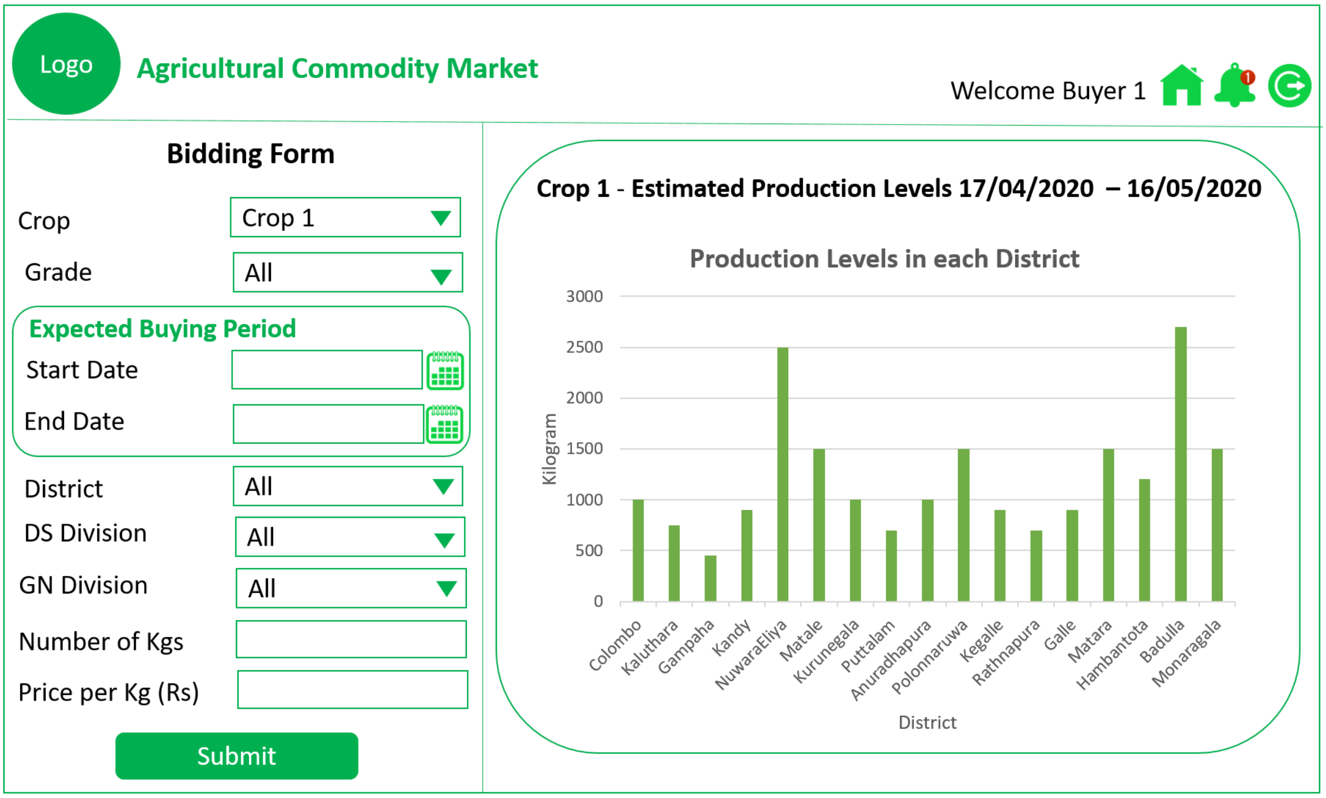

Fig 4. Bidding form

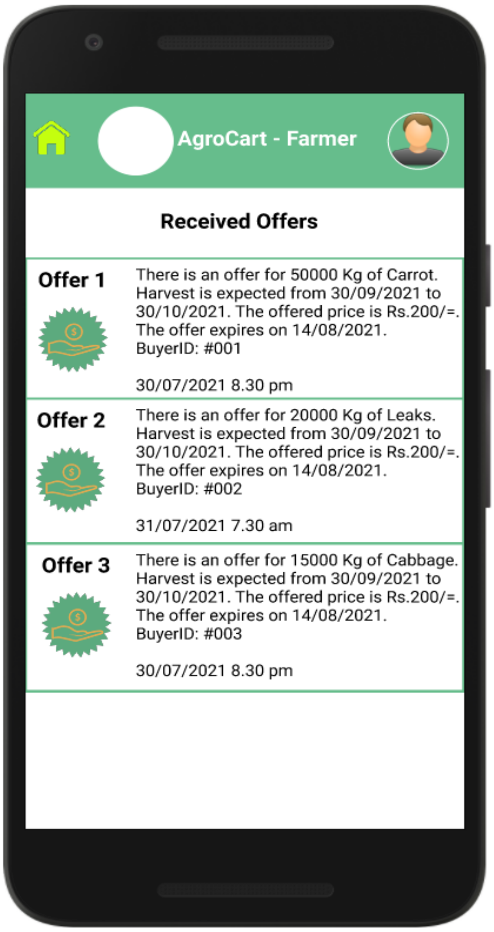

Fig. 5 (a). Received offers for the farmer

selling their harvest at a competitive price to an unknown broker. They do spot selling to unknown brokers only when they need instant money because on-the-spot buying brokers attempt to procure at the lowest possible price targeting higher margins. These findings correlate with research done by Batt (2003) among farmers in Perth, Australia. The researcher states that although farmers expected to transact with a market agent who offers the highest price, the highest price does not assure being paid. He further declares that farmers are paid after 14-21 days once the goods are received by the market agent [10].

The proposed smart agricultural commodity market platform provides a strategy for farmers to step out from their trust bubble for better price determination. While they receive a competitive price for their produce as a reward, they confront the risk of not being paid since the broker is now unknown, and there is no pre-established trust. To mitigate this risk and build trust, the proposed platform generates a Blockchain smart contract which executes by itself when the predefined terms are met. Thus, farmers can choose any broker who offers better rates. Once a broker agrees to buy harvest from the farmer at a specific rate, they can enter into a contract with agreed terms. The contract will ensure the payment is transferred to the farmer according to contract terms. Thus, this enables farmers to select any broker, guaranteeing an optimal price while assuring payments because the smart contract deployed on Blockchain is secure from vagaries from both farmer and the broker. The 10% deposit is proposed to compensate the victim party if the other party did not follow the contract conditions.

Therefore, the static relationship between farmer and the known broker has transformed into a trust-enabled dynamic relationship between farmer and unknown broker

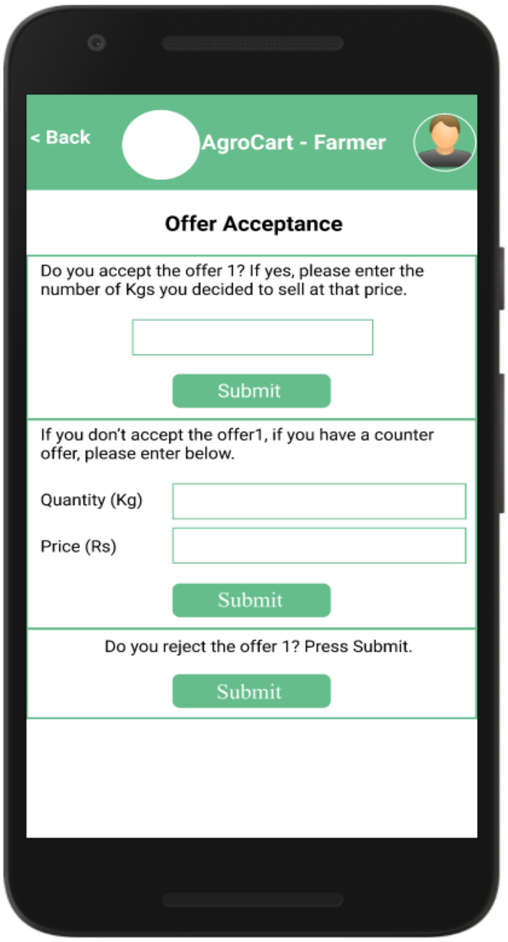

Fig. 5 (b). The three option farmer gets

since farmers are not bound to sell their harvest only to known brokers.

While eliminating the middleman and selling the harvest directly to buyers seems to be effective in reducing costs and getting better prices, transportation, storage cost, and wastage can negate these benefits. Besides, the middlemen can lose their source of revenue. Therefore, facilitating a dynamic trust-enabled relationship between farmer and broker is preferably more realistic for underprivileged farmers with no transportation or storage facilities, maintaining the existing nature of their agribusiness while increasing the number of brokers that a farmer can choose. While the existence of multiple brokers in the system can influence the farm-gate prices, it also eliminates the vulnerability of farmers, who have limited outside options, being abandoned by brokers. If brokers relinquish their business in some rural regions, farm-gate prices tend to decline dramatically as farmers have to adapt to available options. However, the exit of few brokers will not affect farmers since the platform facilitates farmers to choose any broker/buyer who offers comparative rates. Furthermore, the farmers will not have to rely only on brokers if they possess a transport advantage since the trading can occur directly between farmer and buyer, eliminating the middleman. This feature also can lead to generating higher profits for farmers with better prices.

Following features are supported in the platform generating benefits not only for the farmer but also for the broker.

- forming automatic farmer groups enabling many-one-many market linkages, facilitating aggregated marketing

Thus, the farmer is enabled to achieve better prices with high bargaining power and low transaction costs, while provided access to bigger markets, enabling them to target regional, national, or international markets. Meanwhile, the buyer can collect the harvest with the least transaction costs due to better coordination between them.

- establishing contracts between farmer and buyer in advance in the form of smart contracts, reducing contract establishment costs

With an established contract, the farmer has an option to secure trade with a buyer who offers better rates, even the crop is still in the growing stage to reduce future market risks. Similarly, the buyer gets to secure a business opportunity. The pre-harvest and post-harvest wastage are minimized due to enhanced coordination with prior knowledge of buying period.

- enabling dynamic trust through blockchain smart contracts and rating and ranking system

The farmer is empowered to choose any buyer with comparative rates without relying on the known brokers from his trust bubble due to the dynamic trust enabled by the system. The rating and ranking system along with blockchain smart contracts contributes to building trust and reducing the risk of not getting paid. Since both parties deposit 10% of the total agreed amount as an assurance to honour the contract, in a case of breaching the contract, the victim is paid that deposit. Thus, the loss is minimized.

- Empowering both farmer and buyer to manage risks through disaggregation and aggregation

The farmer can disaggregate his production according to the grades and sell to different buyers at different prices. This process has the potential of reducing the overall risks by breaking down the risk into several parts since there is less probability for all the buyers to act unfaithfully at once. Similarly, from the buyer's perspective, he is enabled to aggregate the harvest from several farmers according to his requirement. Thus, risks are disaggregated in the cases of contract breaching from the farmer's side.

- facilitating buyers to pay the balance of 90% of the total agreed amount in three options

Since the buyers are getting three options to pay the balance, they can manage their finances according to their financial status.

Since a survey done in Sri Lanka reveals that 90% of farmers depend on brokers or shop keepers to sell their harvest [7], we can reach an implication that the developed scenarios represent the majority of the farming community in Sri Lanka. According to MEAS 2014 report, the most accessible market for the majority of smallholder farmers in developing countries is the informal market where the price is discovered through arbitrary combinations of supply and demand, trader cartels, and customer loyalties for a particular buyer. However, 80-90% of agricultural products are traded in such informal markets, including farm gate sales, roadside sales, village markets, rural assembly markets, and urban wholesale and retail market sales [2]. All the harvest sales in the 4 scenarios we developed can be positioned in one of the above-mentioned informal markets. Thus, it enables the generalisation of the proposed commodity market platform for different types of crops in different areas, not only for Sri Lanka but also for other developing countries in the future. During this generalisation phase, there will be a step to identify the administrative divisions for the particular country to effectuate the farmer groups and production aggregation according to geographical proximity.

Although this is still in the functional prototype stage, we compared the proposed commodity market with existing blockchain-enabled markets for agricultural commodities with similar approaches. Liao, et al (2020) have presented an integrated market platform for contract production called BeIMP, targeting small-scale farmers [36]. One of the main differences between BeIMP and the proposed commodity market platform in this paper is the market linkages supported by both markets. While BeIMP supports one-to-one market linkage between farmers and buyers, the proposed market supports Many-one-Many market linkages, enabling aggregated marketing. A decentralized agricultural platform called KHET is being proposed to encapsulate the whole agricultural process, eliminating all the intermediaries from land renting to harvest selling. The markets in the KHET platform establish pre-contracts with farmers to buy farmer's produce [37]. Thus, KHET does not support aggregated marketing for farmers. A Community Supported Agriculture (CSA) model is proposed in the context of Vietnam, targeting small and tiny businesses. In this model, the end consumer directly pays the farmer in advance, sharing the risk with the farmer. However, this model has integrated blockchain for traceability option only and farmers do not have access to bigger markets through aggregated marketing [38]. Therefore, the proposed commodity market platform is distinguished from markets with similar approaches due to the aggregated marketing feature.

However, there is a possibility that farmers do not honour the contracts due to reasons beyond their control such as natural disasters and scarcity of Agri inputs. In such cases, farmers have to face the loss from both the harvest loss and the deposit loss due to the nature of the contract established. Thus, in the future, we expect to integrate the system with harvest insurance providers to ensure that the farmer is secured from such massive losses.

The initial proof-of-concept prototype of the market is developed as a website using HTML, CSS, and Typescript in frontend and node.js and MySQL in the backend. The prototype is evaluated to test the feasibility with the participation of experts in the Agri industry. According to DSR, generated design alternatives must evaluate against the requirements until a satisfactory design is achieved [29]. Thus, based on the feedback from the experts from the Agri industry, the second prototype is decided to be developed as a mobile application, instead of a website. Furthermore, the feasibility of farmers paying 10% of the total agreed amount as an honour to the contract will be evaluated with the implementation of the second prototype.

V. CONCLUSION

High transaction costs, poor physical and institutional infrastructure, absence of market information, and insufficient markets inhibit smallholder farmers from market participation. We perceived that due to a lack of trusted buyers, farmers often choose the same brokers with pre-established trust although the rates they offer are low and receive money after 2/3 weeks. They sell the harvest to unknown brokers only if they receive money on the spot due to the risk of not getting paid and lack of trust. Thus, we present a functional prototype that supports a strategy to transform the static trust between farmers and known brokers into dynamic trust between farmers and unknown buyers. The prototype generates more options for farmers, enabling them to choose any buyer with comparative rates, generating competition among buyers that lead to better prices for farmers' harvest. Furthermore, supporting aggregated marketing through Many-one-Many market linkages results in reducing transaction costs for both farmer and buyer, facilitating farmers to generate higher profits with greater bargaining position. Thus, the proposed smart agricultural commodity market has the potential of uplifting the economic status of smallholder farmers, enabling them to receive better prices while reducing the transaction costs in market participation. Once the validity and feasibility is tested, the implementation of this platform will contribute to alleviating poverty among smallholder farmers and uplift their livelihoods.

REFERENCES

[1] Food and Agriculture Organization. (19/06/2021). "Smallholder Family Farms". Available: http://www.fao.org/economic/esa/esa-activities/smallholders/en/

[2] S. Ferris *et al.*, "Linking Smallholder Farmers to Markets and the Implications for Extension and Advisory Services," in "Modernizing Extension and Advisory Services," United States Agency for International Development05/2014 2014, Available: https://www.agrilinks.org/sites/default/files/resource/files/MEAS%20Discussion%20Paper%204%20-%20Linking%20Farmers%20To%20Markets%20-%20May%202014_0.pdf, Accessed on: 19/06/2021.

[3] I. Somashekhar, J. Raju, and H. Patil, "Agriculture Supply Chain Management: A Scenario in India," Research Journal of Social Science and Management, RJSSM, vol. 4, no. 07, pp. 89-99, 2014.

[4] S. Mitra, D. Mookherjee, M. Torero, and S. Visaria, "Asymmetric Information and Middleman Margins: An Experiment with Indian Potato Farmers", Review of Economics and Statistics, vol. 100, no. 1, pp. 1-13, 2018.

[5] (2020). AgStat. Available: http://doa.gov.lk/SEPC/images/PDF/AgStat2020.pdf

[6] R. Ranjan, "Challenges to Farm Produce Marketing: A Model of Bargaining between Farmers and Middlemen under Risk", Journal of Agricultural and Resource Economics, vol. 42, no. 3, pp. 386-405, 2017.

[7] P. Di Giovanni *et al.*, "User centered scenario based approach for developing mobile interfaces for Social Life Networks," ed, 2012, pp. 18-24.

[8] M. Fafchamps and R. V. Hill, "Selling at the Farmgate or Traveling to Market," American Journal of Agricultural Economics, vol. 87, no. 3, pp. 717-734, 2005.

[9] S. Lemeilleur and J.-M. Codron, "Marketing cooperative vs. commission agent: The Turkish dilemma on the modern fresh fruit and vegetable market," Food Policy, vol. 36, no. 2, pp. 272-279, 2011.

[10] P. Batt, "Building trust between growers and market agents," Supply Chain Management, vol. 8, no. 1, pp. 65-78, 2003.

[11] F. Muamba, "Selling at the farmgate or travelling to the market: A conditional farm-level model," The Journal of Developing Areas, vol. 44, no. 2, pp. 95-107, 2011.

[12] D. Boughton et al., "Market participation by rural households in a low-income country: An asset based approach applied to Mozambique," Faith Economics, vol. 50, pp. 64-101, 2007.

[13] P. S. Birthal, A. K. Jha, and H. Singh, "Linking farmers to markets for high-value agricultural commodities," Agricultural Economics Research Review, vol. 20, no. conf, pp. 425-439, 2007.

[14] G. Holloway, C. Nicholson, C. Delgado, S. Staal, and S. Ehui, "Agroindustrialization through institutional innovation Transaction costs, cooperatives and milk-market development in the East-African highlands," Agricultural economics, vol. 23, no. 3, pp. 279-288, 2000.

[15] P. Courtois and J. Subervie, "Farmer Bargaining Power and Market Information Services," American Journal of Agricultural Economics, vol. 97, no. 3, pp. 953-977, 2015.

[16] E. Nakasone, "The Role of Price Information in Agricultural Markets: Experimental Evidence from Rural Peru," IDEAS Working Paper Series from RePEc, 2013.

[17] M. Fafchamps and B. Minten, "Impact of SMS-Based Agricultural Information on Indian Farmers," The World Bank Economic Review, vol. 26, no. 3, pp. 383-414, 2012.

[18] H. Lu, J. H. Trienekens, S. W. F. Omta, and S. Feng, "Influence of guanxi, trust and farmer-specific factors on participation in emerging vegetable markets in China," NJAS - Wageningen Journal of Life Sciences, vol. 56, no. 1, pp. 21-38, 2008.

[19] M. Sako, Price, quality and trust: Inter-firm relations in Britain and Japan (no. 18). Cambridge University Press, 1992.

[20] S. Underwood, "Blockchain beyond Bitcoin. (other applications of blockchain technology) (News," Communications of the ACM, vol. 59, no. 11, p. 15, 2016.

[21] M. Alharby and A. van Moorsel, "Blockchain-based Smart Contracts: A Systematic Mapping Study," Fourth International Conference on Computer Science and Information Technology, 2017.

[22] D. Roy and A. Thorat, "Success in high-value horticultural export markets for the small farmers: The case of Mahagrapes in India," World Development, vol. 36, no. 10, pp. 1874-1890, 2008.

[23] E. Fischer and M. Qaim, "Linking Smallholders to Markets: Determinants and Impacts of Farmer Collective Action in Kenya," World Development, vol. 40, no. 6, pp. 1255-1268, 2012/06/01/ 2012.

[24] H. Markelova, R. Meinzen-Dick, J. Hellin, and S. Dohrn, "Collective action for smallholder market access," Food policy, vol. 34, no. 1, pp. 1-7, 2009.

[25] M. Kumarathunga, R. Calheiros, and A. Ginige, "Towards Trust Enabled Commodity Market for Farmers with Blockchain Smart Contracts," in Proceedings of the 2020 Asia Service Sciences and Software Engineering Conference, Nagoya, Japan, 2020, pp. 75-82.

[26] A. Ali, A. Abdulai, and D. B. Rahut, "Farmers' Access to Markets: The Case of Cotton in Pakistan," Asian Economic Journal, vol. 31, no. 2, pp. 211-232, 2017.

[27] A. Hevner and S. Chatterjee, "Design science research in information systems," in Design research in information systems: Springer, 2010, pp. 9-22.

[28] A. R. Hevner, "A three cycle view of design science research," Scandinavian journal of information systems, vol. 19, no. 2, p. 4, 2007.

[29] H. A. Simon, The sciences of the artificial. MIT press, 2019.

[30] D. P. B. Dharmasena. (2017, 29/07/2019). High Input Vegetable Cultivation in Central Highlands of Sri Lanka. Available: https://www.academia.edu/34274054/High_Input_Vegetable_Cultivation_in_Central_Highlands_of_Sri_Lanka.

[31] A. Strauss and J. Corbin, Basics of qualitative research techniques. Citeseer, 1998.

[32] D. Silverman, Doing qualitative research: A practical handbook. Sage, 2013.

[33] M. B. Rosson and J. M. Carroll, "Scenario-based design," in Human-computer interaction: CRC Press, 2009, pp. 161-180.

[34] A. Ginige et al., "Digital Knowledge Ecosystem for Achieving Sustainable Agriculture Production: A Case Study from Sri Lanka," in 3rd IEEE International Conference on Data Science and Advanced Analytics, Montreal, QC, Canada, 2016, pp. 602-611.
[35] Wikipedia. (25/08/2021). Administrative divisions of Sri Lanka. Available: https://en.wikipedia.org/wiki/ Administrative divisions of_Sri_Lanka
[36] C.-H. Liao, H.-E. Lin, and S.-M. Yuan, "Blockchain-Enabled Integrated Market Platform for Contract Production," IEEE Access, vol. 8, pp. 211007-211027, 2020.
[37] S. Paul, J. I. Joy, S. Sarker, S. Ahmed, and A. K. Das, "An Unorthodox Way of Farming Without Intermediaries Through Blockchain," in 2019 International Conference on Sustainable Technologies for Industry 4.0 (STI), 2019, pp. 1-6: IEEE.
[38] D. H. Nguyen, N. H. Tuong, and H.-A. Pham, "Blockchain-based Farming Activities Tracker for Enhancing Trust in the Community Supported Agriculture Model," in 2020 International Conference on Information and Communication Technology Convergence (ICTC), 2020, pp. 737-740: IEEE.