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RATIONALE FOR THE NEED TO USE BLOCKCHAIN TECHNOLOGY TO RECORD AND CONTROL OPERATIONS FOR THE EXPORT OF GRAIN (THE EXAMPLE OF UKRAINE)

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ABSTRACT

Despite the steady export of Ukrainian grain growth, the net profit from its sales does not increase, and most times, even falls. That is why it became necessary to find out the reasons for the current situation and find ways out of it. The most common method for solving such problems in the modern world is the implementation of blockchain and related technologies (smart contracts, cryptocurrencies, etc.). This article is devoted to studying the economic need for the use of blockchain technologies to monitor grain for export in Ukraine and the analysis of foreign experience blockchain implementation to agricultural supply chains to adapt the best practices to Ukrainian realities. As a result of a theoretical study, the article identified problems in Ukrainian grain export, analyzed the results of using blockchain to solve similar problems in foreign countries, and also identified ways to use world experience in this area. In addition, the authors offered practical recommendations for changing and complementing the existing technological and logistic stages of grain export in Ukraine. It was also found that blockchain technologies, because of their properties such as decentralized control, security, *traceability, and control of transactions, could solve most of the problems that arise in the grain supply chain from grower to end consumer. The authors have proposed a generalized multilayer system that includes a "Data input layer", a "Data store layer", and a "User's layer", which most fully considers the peculiarities of agriculture in Ukraine. However, the question of these technologies introducing cost and the economic feasibility of their use for farms of various sizes remains is still unclear, and will be considered by the authors in their following works.*

Keywords: *Blockchain; Agricultural Supply Chain; Smart-Contract; Wheat Export; Ukraine*

1. INTRODUCTION

Conditions in the international grain market are becoming more dynamic and demanding, resulting in a challenging competitive environment. To adapt to this dynamic environment, grain supply chains must rely on cooperation, flexibility, and trust among the participants in the trading process. Thus, the importance of new technological solutions in supply chains has grown even more.

Blockchain technology has established itself as a necessary component of today's competitive environment. However, before introducing any new technology, it is necessary to analyse the success of its implementation in other countries to assess whether the technology is mature enough for its use in the realities of Ukraine. In addition, it is also necessary to identify the economic prerequisites for implementing this innovation.

2. LITERATURE REVIEW

2.1. Review of economic indicators of the grain export in Ukraine

According to foreign and international organizations such as UNITED STATES DEPARTMENT OF AGRICULTURE (USDA) and FOOD AND AGRICULTURE ORGANIZATION (FAO), for 5 years Ukraine has been one of the six largest producers and exporters of crops, with a large area of fertile land intended for growing grain and oilseeds. In 2021-2022, the USDA forecasts total grain production in Ukraine at about 74 million tons, up from about 65 million a year earlier. They estimate wheat production at 27.2 million tons versus 25.5 million, while corn production is projected to grow to 37.3 million tons from 30 million in 2020-2021.

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According to AGROCHART forecasts, the total grain export from Ukraine in 2021-2022 will be near 56 million tons, compared with 44 million tons a year earlier. They also project wheat export at 21 million tons in 2021-2022, up from 16.7 million in the previous year (+ 25.37%). Figure 1 illustrates the growth dynamics of Ukrainian wheat exports.

Besides, there is a tendency for the sales market to shift to the countries of Africa and Asia (Figure 2). This allows us to conclude that, in parallel with the acquisition of new sales markets, Ukraine is losing old ones. Thus, in the 2015-2016 marketing year, the European Union imported 2.03 million tons, and in 2020-2021 - about 0.68 million tons. Figure 3 shows that, on the back of approximately constant total imports of wheat by the European Union, imports from Ukraine have fallen considerably.

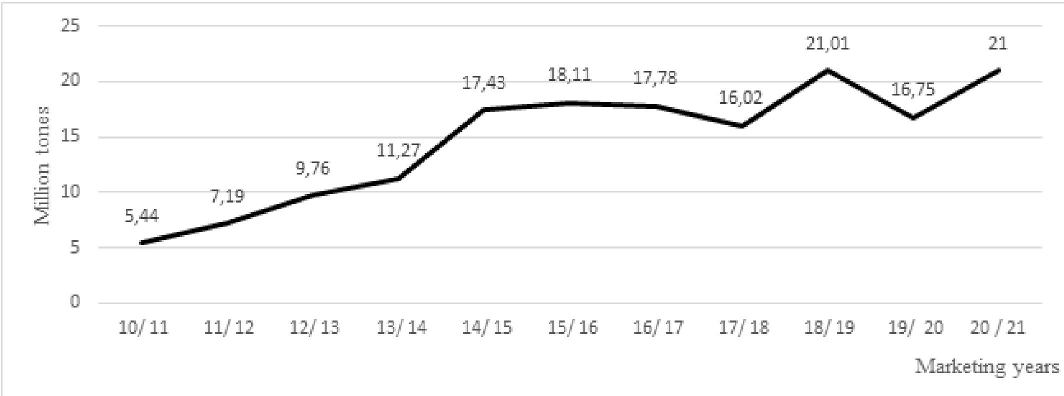

Figure 1: Export of wheat from Ukraine
Data source: created by the authors based on USDA data

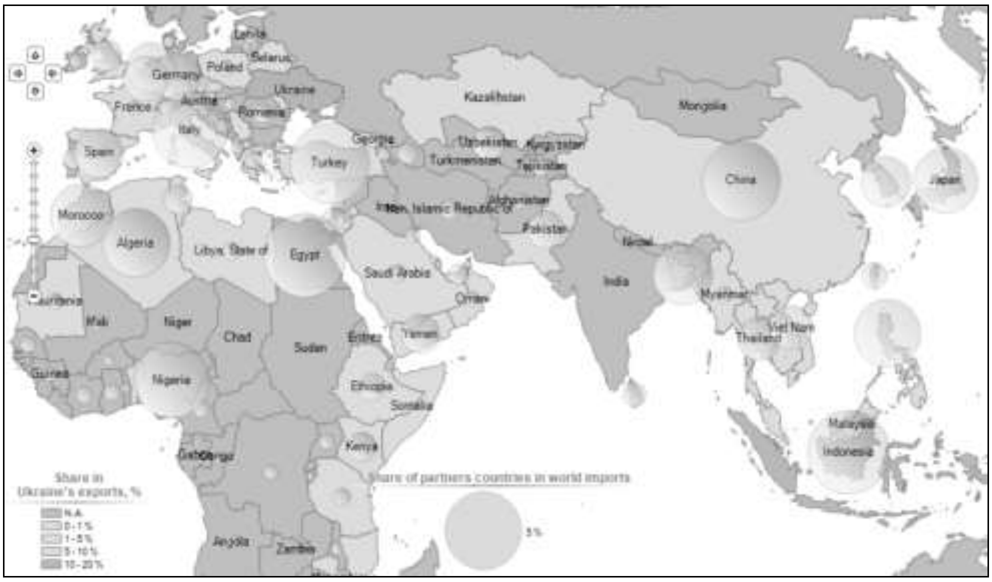

Figure 2: Shares of Ukraine's wheat exports by countries of the world
Data source: TRADE MAP.

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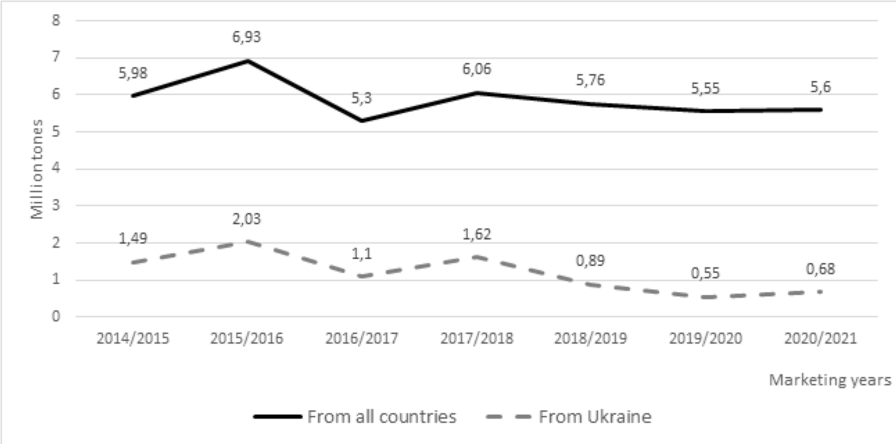

Figure 3: Wheat imports by the European Union
Data source: created by the authors based on USDA data

Such a change in the geography of sales markets affects the decrease in the profitability of wheat exports from Ukraine. It is because time and cost of delivery from Ukraine to Italy (from 1300 km) or to Spain (from 2600 km) by road or by rail will be much less than, for example, to Indonesia (over 10,000 km) by sea transport. AGRICULTURAL MARKETING SERVICE (2020) confirms this, where authors show that transportation of one ton of grain in Ukraine by truck costs from 8 to 19 US dollars, by rail - from 10 to 15, and by sea transport - from 14 to USD 38.

Analysing the current situation, we can identify several main reasons for such changes. First, it is the constantly growing requirements for food safety imposed by the European Union. You can see that in FOOD LAW GENERAL PRINCIPLES of the European Commission. However, increasing quality control is a worldwide trend. Figure 4 shows the number of requirements for wheat in the countries where Ukraine exports it.

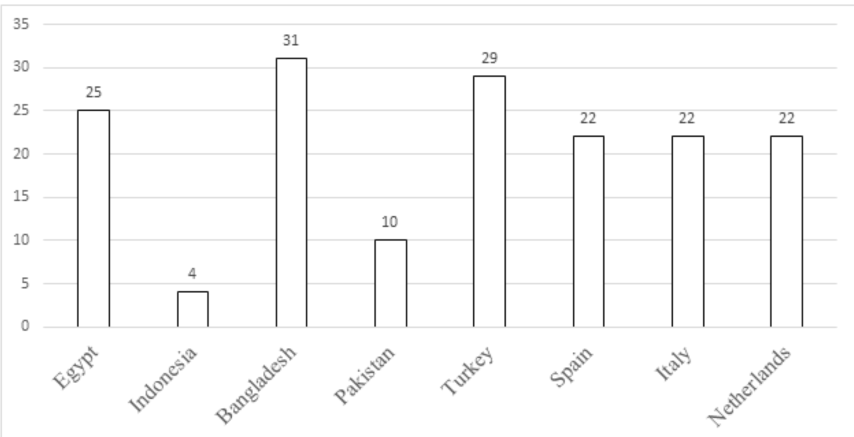

Figure 4: The number of requirements for wheat imported from Ukraine
Data source: created by the authors based on data from MARKET ACCESS CONDITIONS

Australian Export Grains Innovation Center (2021) released an analysis of the state of grain production in Ukraine. In this work, the authors point to a second reason. They believe that major Asian buyers remain wary of entering into direct contracts with Ukrainian companies for the grain supply due to widespread corruption and bribery in Ukraine. These buyers often contract with large traders (such as ADM, Bunge, Cargill, Louis Dreyfus) to reduce the risk of breaches.

Third, from the same analysis of the Australian Export Grains Innovation Center (2021), we can see that the banking system is sometimes dysfunctional and impedes the flow of foreign currency into and out of the country, restricting access to credit needed to finance grain production. In addition, most of the grain elevators in Ukraine remain technically outdated and very energy inefficient. As a result, the cost of their services is very high, but some of the grain does not go through post-harvest processing and is stored in conditions that cause damage, moisture, and contamination of the grain.

Fourth, COVID-19 has changed the strategy of many importers of Ukrainian grain. Many of them have started buying grain in advance because they are afraid that they will not have enough raw materials. Therefore, according to the USDA, China began buying grain in 2021 much earlier than usual - closer to the beginning of the harvest. Egypt's State Agency for General Authority for Supply Commodities did the same in 2021. It started buying wheat in a few months compared to usual terms and by August purchased most of the grain it needed. All this led to earlier purchases of Ukrainian grain because of its potential shortage. This once again shows that the global grain trading system is becoming less predictable.

The problem is also that, according to the Ukrainian Grain Association (2021), the number of claims for the content of ragweed seeds and other weeds in Ukrainian grain is growing every year. As a result, Ukraine's reputation as a supplier of high-quality grain suffers, and hence a decrease in prices and refusal of further cooperation. This is because the land market in Ukraine is still relatively young and many farmers have not developed a farming culture and are irresponsible for maintaining the quality of grain.

In addition, it should be noted that according to Chauhan (2019), besides reputational costs, weed contamination handles about 20% of the wheat crop lost. Therefore, we believe it makes sense to add a mandatory grain analysis of the quality indicators required by the importer in the logistics and pre-sale preparation of export grain. Moreover, the process of sampling and

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analysis should comply with anonymity and transparency and be carried out at various stages of transportation and storage of grain, since they can be very different in time.

2.2. Review of literature on blockchain technology and its use in agricultural production

2.2.1. Blockchain

Increasing transparency at all stages of the exported grain supply chain is certainly of great importance for Ukraine's further advancement in the world grain markets as a reliable trading partner. In this context, use of blockchain technology can play an important role. The generally accepted definition of a blockchain is a chain of linked and verified blocks, where each block contains some transaction data.

The author (or a group of authors), under the pseudonym Nakamoto (2008), had an enormous impact on the development of the blockchain. All basic principles of the Bitcoin cryptocurrency functioning were described in this work. Most of these principles are now used by many blockchain platforms. A unifying factor is that the block, besides other information, stores its address and the address of the previous block. These addresses are got by a special encoding of the block data (including the timestamp) using a hashing transformation into a constant-length string (usually 256 characters).

The addresses are called a hash. Decentralization of such data storage is ensured because each member of the blockchain (node) keeps a copy of the ledger. Adding all blocks except the first one (it is called a genesis block) is carried out only with the consent of most nodes (distributed consensus), and their deletion is impossible. And this ensures traceability, transparency, and reliability of information storage.

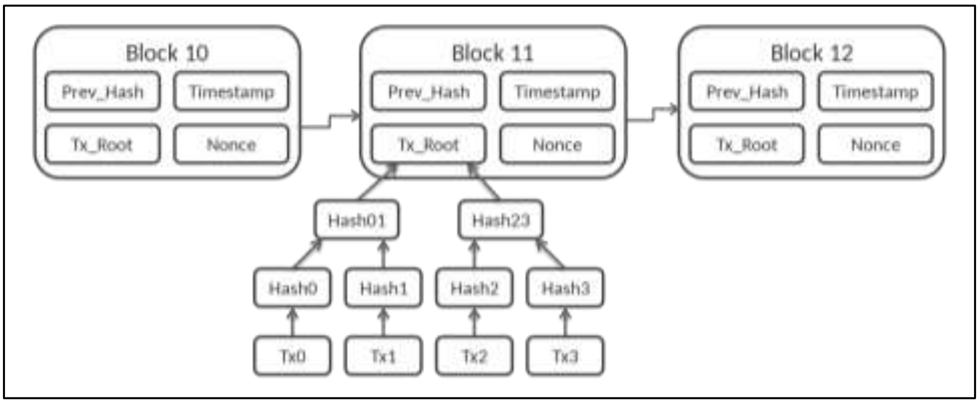

Figure 5: The structure of a typical blockchain
Source: Nakamoto (2008)

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Transaction data on the blockchain is usually represented as a Merkle tree, which is described in Merkle (1980). A transaction is a transferring of a data, for example, on the transfer of funds, between two addresses and its purpose may be the purchase of assets, services or goods, as well as the launch of smart contracts.

To protect network systems from abuse of block creation, the Proof-of-work (PoW) principle is commonly used, based on the need to perform some rather lengthy work on the client side (finding a solution to the task), the result of which is easily and quickly verified on the blockchain platform side. The key feature of the computations used is the asymmetry of the time spent - they are significant for finding a solution and very little for verification. Adding transaction records to the bitcoin blockchain is called blockchain mining; therefore, blockchain miners are computers, which validate the process.

2.2.2. Smart contracts

Using blockchain, we can confidently refuse intermediaries, but if we want to automate actions, for example, checking the conditions without which a transaction is impossible, we cannot do without smart contracts. Like traditional contracts, a smart contract is also a set of organizational terms that govern the trust between the parties involved in that contract. The only difference is that the smart contract is a code developed using a programming language.

A breakthrough in this area was the work of Szabo (1997), based on his White paper published in 1996. In this article, the author noted that the rules, terms and conditions are implemented in smart contracts through programming, which reflects the exact agreement approved by all parties. According to the author, the primary purpose of smart contracts was to embed contractual clauses in a combination of hardware and software so that breach becomes difficult and the cost of contract breach becomes prohibitive. This approach ultimately increases the security of the contract and reduces the possibility of contract violation.

The idea of smart contracts was popularized and implemented in 2016 on the Ethereum blockchain platform. Tikhomirov (2017) described Ethereum as a decentralized blockchain that includes a Turing-complete programming language. The language theoretically allows all practical calculations to be expressed in smart contracts - pieces of code that are permanently stored in the blockchain and capable of responding to user requests. Therefore, since Ethereum is itself a blockchain, storing a contract within the blockchain makes it extremely difficult to hack and tamper with the contract.

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2.2.3. Use of blockchain and smart contracts in agricultural supply chains

Mirabelli and Solina (2020) reviewed the application of blockchain technology to enable traceability in the agricultural industry. They concluded that blockchains could solve the vast majority of existing problems.

However, the agricultural supply chain is very complex and is not inclined to implement blockchains for the following reasons:

1) technological knowledge of many interaction participants is at a low level;
2) products along the entire chain undergo many transformations;
3) roles and actions of numerous stakeholders are extremely heterogeneous;
4) agricultural supply chain is spread over vast geographic areas, even across different continents of the globe, creating significant barriers to interoperability and deployment.

Galvez, Mejuto, and Simal-Gandara (2018) note that providing food traceability through blockchain technology looks very promising. At the same time, some restrictions remain: 1) the blockchain does not have a mechanism for verifying the data entered into the system, and if you interfere with the sensor, the blockchain cannot detect the substitution; 2) it is difficult to estimate the cost of implementing and maintaining the functioning of blockchain technology with a really large number of participating nodes and transactions.

Kamilaris, Fonts, and Prenafeta-Boldύ (2019) also recognize blockchain as a foundation for creating transparent and more sustainable food production and distribution and integrating key stakeholders into the supply chain. The key problems they highlighted include 1) low availability of the blockchain associated with the high complexity of the accompanying technologies; 2) there is no assessment of the long-term impact of the blockchain on economic sustainability and social aspects; 3) the necessary policy and regulation rules are missing; 4) technical problems (delays in transactions, low confidentiality when using public keys, not all parameters of food quality can be controlled using analytical methods); 5) it is necessary to bridge the digital divide between developed and developing countries.

Pranto, Noman, Mahmud, and Haque (2021) proposed a system that uses blockchain as a basis, while sensors equipped with built-in means to interact with each other and the external environment (this technology called Internet of Things - IoT) collect data, and smart contracts govern the interactions between all of these parties involved. However, they note the following difficulties in such systems implementation: 1) if at any stage someone does something by mistake, it will be impossible to change or update the data in the blockchain; 2) after the deployment of a smart contract within the blockchain, it will no longer be possible to change it; 3) initial setup of the blockchain environment requires a monetary investment; 4) if devices for collecting data are damaged, the operation of smart contracts that depend on them is impossible.

Wang et al. (2021) propose smart contract algorithms for implementing agricultural food supply chain tracking based on the Hyperledger blockchain platform in Shanwei County (China). However, the authors also believe that now there are scalability, privacy, and regulation issues of the blockchain, and there is no decentralized payment mechanism.

Malik, Kanhere, and Jurdak (2018) have developed a generalized conceptual framework that comprises product supply chain units jointly managing the permitted blockchain. The proposed concept provides: 1) a holistic platform for process participants and administrative authorities, which allows monitoring of developments in relation to product quality; 2) a multi-tier architecture for managing read and write access to the blockchain, including the use of separate parallel blockchains; 3) a technique for collective management of read and write access.

3. RESULTS

After analyzing the opinions of scientists from section 2.1, we made a fairly confident conclusion that many of the problems listed there that led to a change in the market situation can be solved using blockchain and related technologies. Table 1 provides the most important of these problems and the technologies and methods that we propose to solve them or reduce their impact.

Table 1: Some problems of the Ukrainian grain export market and means for their solution

Problem	**Solution tool**
Strengthening quality control of imported products	Adding mandatory grain quality control at all stages of logistics
Distrust of Ukrainian traders	Use of smart contracts, which will be automatically concluded only when all the conditions of all parties are in fact fulfilled
Problems with banking infrastructure	Using the payment capabilities of the blockchain
The global grain trading system is becoming less predictable because of the COVID-19 pandemic's impact	Thanks to the transparency of the blockchain, all real current resources will be visible, which will make it possible to quickly respond to market changes
Insufficiently responsible attitude of some farmers to the contamination of the supplied grain	Photographing fields to create a map of weed infestation in the field

Data source: created by the authors

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From the table 1, you can see that one of the most specific for the Ukrainian grain export market is weed contamination. Therefore, to identify batches of grain from fields prone to infestation with ragweed and other quarantine weeds, it is necessary, at least at the stage of the formation of farming culture among farmers, to introduce the practice of mandatory photography of fields to create a map of weed infestation of the field. Now, the most affordable way of such mapping is the use of unmanned aerial vehicles.

Low shooting heights and high-resolution images allow creating a map that can distinguish crops from weeds. Sometimes, it even turns out to identify a specific variety of a pest plant (cruciferous, dicotyledonous, etc.) and select the optimal type of herbicide. Such monitoring can be done prior to harvest. Using the images, you can also determine the timing of harvesting and predict the yield.

Figure 6 shows an example of a zone map, where each zone corresponds to a weediness level of 1 to 5 points.

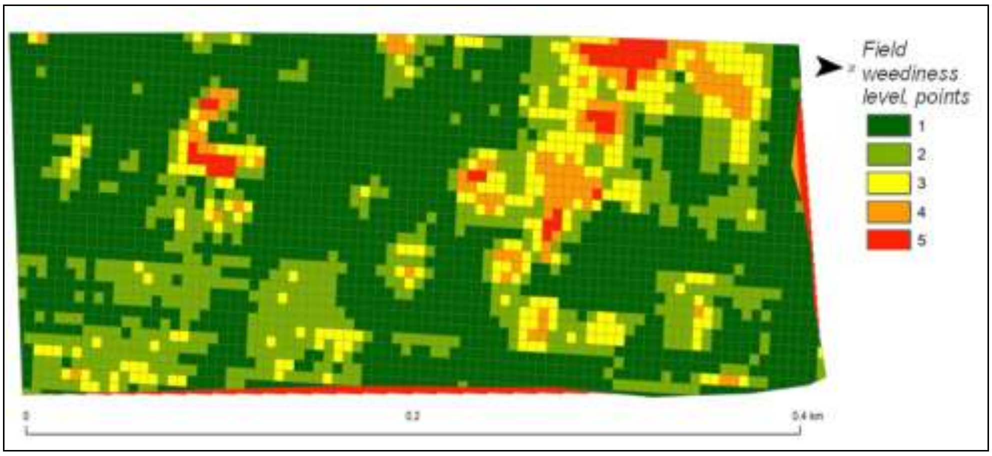

Figure 6: Map of field infestation with quarantine weeds
Source: drone.ua

However, judging by the data from section 2.2, blockchain technology (in the context of its application to the grain export chain in Ukraine) currently has some significant drawbacks. The following are those that can be leveled to one degree or another by changing the structure and approaches to the system being developed.

Table 2: Some problems of using blockchain in agricultural supply chains

Problem	**Solution**
The roles and actions of many stakeholders are extremely heterogeneous	Creation of a multi-level system, at one level of which users are assigned roles that determine their rights
Transaction delays	Using blockchain without Proof-Of-Work (PoW) consensus
Scalability issues	Use several zonal blockchains, separated, for example, by geography (region, region, etc.)

Data source: created by the authors

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We offer a multi-level system for controlling access to reading and writing information at all stages of the delivery of Ukrainian grain for export (Figure 8). We consider the Data store layer to be the basic level of this system. This layer is a permitted blockchain (that is, it allows only identified participants to perform actions) and comprises two elements - the Zone blockchains group and the Shipment ledger.

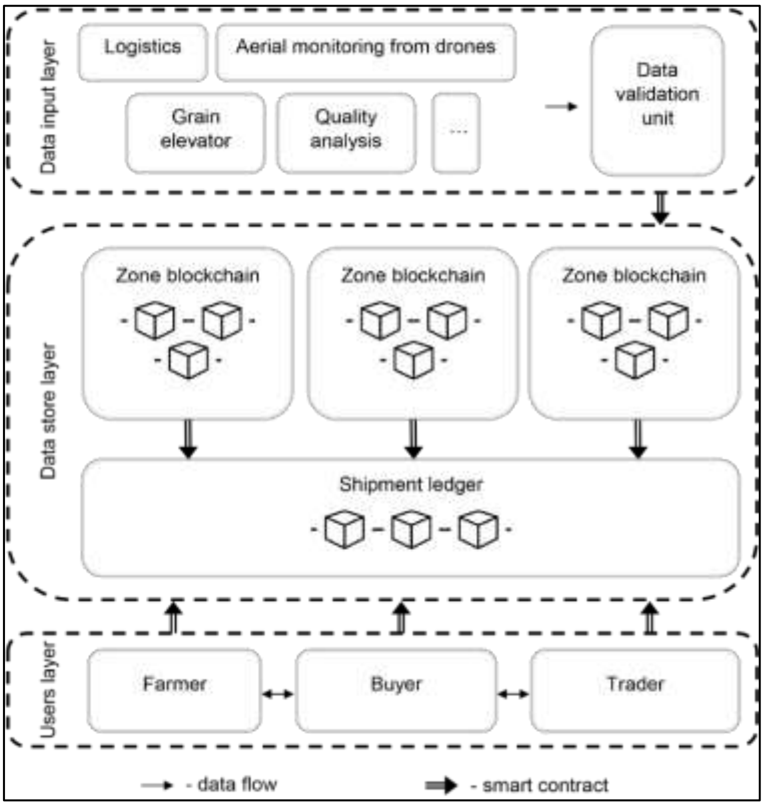

Figure 8: Structure of the control system for export grain in Ukraine
Data source: created by the authors

An important issue with the permitted blockchain is that it can only scale to a few hundred Li et al. (2017), which, with the growth of nodes and activity in the blockchain, causes a delay in transactions and reduces the network bandwidth. To solve this problem, we propose to use the concept of sharing a single blockchain ledger.

As a result, several Zone blockchains are formed, separated, for example, by geography (region, district, etc.). They contain blocks with information about individual grain deliveries from the producer, which comes from another layer of the system - the Data input layer.

Data input layer includes grain data sources and Data validation unit. By data sources, we mean both information about the grain got through direct analyzes and by evaluating photo data from the air, as well as field coordinates, data on the time and conditions of storage at the elevator, temperature during transportation, etc.

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Data validation unit is a software based on Data Science and Artificial Intelligence that evaluates the input data and, if a potential error is found, sends it for rechecking or makes a request for re-analysis. For example, if according to the map of weed infestation of the field, the infestation level is 4 points, and the analyzes did not show this deviation, then additional analysis may need to be done.

When a trader or a buyer forms new batch of grain, a new block, which contains links to individual shipments from farmers from Zone blockchains and other necessary data, appears in a blockchain called Shipment ledger. As a result, the buyer can find out from which fields and in what conditions the purchased grain was stored.

The Users layer is software that allows users to log into the system under a specific role that grants specific rights. Here, the farmer can put up his grain for sale, and the buyer can enter contracts.

In our further work, we plan to consider in more detail all layers, their practical implementation and economic feasibility of using, depending on the size of the farm.

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