The importance of Blockchain technology in the development of agricultural insurance – a review of applications and solutions

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Summary

The aim of the article was to analyse the benefits and risks associated with the use of Blockchain technology (blockchain) in the area of agricultural insurance. Literature analysis and case study method were used to evaluate the potential of blockchain. The analysis covered solutions and applications offered by private companies on commercial digital platforms and the insurance offer available or planned to be available on platforms created with the participation and financial involvement of the public sector. The conducted analysis allows concluding that solutions based on Blockchain, combined with additional functions of integrating and analysing data from the environment, may significantly improve insurance protection and risk management in agriculture. The reliance on the data registered and checked by all the nodes of the network increases the certainty and transparency of the transactions on the insurance market and at the same time leads to the reduction of the information asymmetry, which is the main reason for the market failure in the segment of agricultural insurance. Smart insurance contracts and solutions assuming automatic payments and indemnity payments (e.g. in stable cryptocurrencies) can further reduce transaction costs and improve contractual relations between insurers and insuring farmers. As a result, Blockchain can increase the pool of available insurance and coverage in the agricultural sector. In particular, this technology strengthens the potential to develop parametric insurance that focuses on weather and climate change risks. On the other hand, Blockchain technology is also associated with certain problems and risks (such as the risk of deliberate contamination of the blockchain with unverified data at the input or of low quality, the problem of a large carbon footprint of public P2P networks, or the still uncertain shape of regulations and legal solutions relating to smart contracts making payments in cryptocurrencies). Nevertheless, it is to be expected that the interest in digitizing agricultural insurance based on Blockchain technology will grow. This will be influenced by the increased frequency of disaster events caused by climate change and the rising costs of operating traditional insurance instruments for the risks involved in agriculture.

Keywords: Blockchain, digital agricultural insurance, smart insurance contracts, cryptocurrencies in insurance payments, parametric insurance.

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Introduction

Data and digital technologies are catalysts for profound change and transformation in various sectors and industries of the economy. They also significantly affect the functioning and development prospects of the insurance market. As a result of the increasing use of digital technologies, rapidly growing resources of operational and business data and data from the environment are opening up new opportunities for growth. Many companies and startups are using technological competencies in data analytics to create new insurance products and services or to support the activities of other companies and entities operating in the insurance sector. This segment, referred to as InsurTech (from the combination of the English words insurance and technology), is currently one of the main vehicles for innovation in the insurance market. The solutions and innovations proposed by companies in this segment improve both the protection and convenience of the insured and the efficiency of the insurance industry.

Particularly great needs to increase the efficiency of the insurance market are apparent in the agricultural sector[1]. Despite the growing threats and risks of weather and climate character and problems associated with the spread of infectious animal diseases in many countries of the world, including Poland, interest in insurance is limited[2]. An inefficient agricultural insurance market limits the ability to stabilize agricultural production. At the same time, it contributes to underinvestment in farms and petrification of the problem of low incomes in the sector[3]. Although in Poland insurance of crops and livestock is covered by statutory obligation and insurance premiums are subsidized from the state budget, still not many farmers decide to purchase insurance policies. In 2018, the area of agricultural crops covered by insurance amounted to only 3.2 million hectares, which accounted for 22.3% of the total area of agricultural land in Poland[4]. The percentage of livestock population

1. See. J. Kulawik, *Ryzyko i tradycyjne ubezpieczenia rolne – podstawy teoretyczne* [in:] *Ocena funkcjonowania ubezpieczeń upraw i zwierząt gospodarskich w polskim rolnictwie*, red. J. Pawłowska-Tyszko, Warszawa, Instytut Ekonomiki Rolnictwa i Gospodarki Żywnościowej, 2017, p. 24–34; *Identyfikacja podstaw przemian i problemów ubezpieczeń rolnych [Identification of the bases of changes and problems in agricultural insurance],* red. M. Soliwoda, Warszawa, Instytut Ekonomiki Rolnictwa i Gospodarki Żywnościowej, 2020, p. 663.
2. According to NatCatSERVICE, Eurostat and MunichRe, Poland – along with Greece, Portugal and Italy – is the EU country where climate change risks and damages remain almost entirely uninsured. O. Sushchenko, R. Schwarze, *Distributed Ledger Technology for an Improved Index-Based Insurance in Agriculture*, "Journal of Integrated Disaster Risk Management" 2020, Vol. 10(2), p. 69.
3. M. Castillo, S. Boucher, M. Carter, *Index insurance: Using public data to benefit small-scale agriculture*, "International Food and Agribusiness Management Review" 2016, Vol. 19(A), p. 94.
4. *Wspieranie środkami publicznymi systemu ubezpieczeń rolniczych. Informacja o wynikach kontroli*, Najwyższa Izba Kontroli, Departament Rolnictwa i Rozwoju Wsi, Warszawa 2020, p. 10, https://www.nik.gov.pl/plik/id,22251,vp,24920.pdf, access 28.07.2021.

covered by insurance has also remained very low for years. In 2018, only 9% of the poultry population, 0.5% of the swine population and 0.2% of the cattle population in Poland were insured[5]. It is therefore important to look for solutions and innovations that could increase farmers' participation in the insurance system. The issue of increasing the effectiveness of public spending in areas related to the functioning of agricultural insurance remains equally important[6].

One digital technology that can play a particularly important role in developing and strengthening the agricultural insurance system is Blockchain technology. Blockchain is both a type of digital, distributed database that uses advanced cryptography to ensure the safety, security, and reliability of the data and information stored in it, and a tool for creating new digital applications. It is increasingly indicated that digital agricultural insurance, based on Blockchain technology, can be an attractive alternative to classic insurance contracts. Blockchain-registered insurance products are already offered to farmers in some countries. Some products are based on the idea of index (parametric) insurance, which guarantees payment of fixed indemnity rates after the occurrence of an event described by a specified parameter, others use data recorded in the Blockchain for underwriting and determining the amount of indemnity after the occurrence of a disaster event. The need to provide more efficient and more widely available instruments for transferring risks associated with increasing disaster events caused by climate change may increase the popularity of parametric products and rapid claims assessment solutions for traditional insurance in the coming years. Although the use of Blockchain technology in the insurance sector is still relatively small, analyses of available literature and industry sources indicate a very high potential for future use of this technology[7]. Blockchain-based solutions, combined with better capabilities to integrate and analyze data from the environment, in fact, reduce the asymmetry of information in the insurance market. At the same time, they meet the growing need to streamline contractual relations between insurers and policyholders[8].

The purpose of this article is to discuss the benefits and risks associated with the use of Blockchain technology in the area of agricultural insurance, including the directions in which the InsurTech segment for agriculture is developing.

5. Op. cit.
6. M. Soliwoda, J. Pawłowska-Tyszko, A. Gorzelak, *Zarządzanie ryzykiem katastroficznym w rolnictwie – wybrane problemy. Perspektywa międzynarodowa i Polski,* "Finanse, Rynki Finansowe, Ubezpieczenia" 2017, nr 1, p. 688.
7. A.K. Kar, L. Navin, *Diffusion of blockchain in insurance industry: An analysis through the review of academic and trade literature*, "Telematics and Informatics" 2021, Vol. 58.
8. See P. Tasca, *Insurance under the Blockchain Paradigm* [in:] *Business Transformation through Blockchain*, eds. H. Treiblmaier, R. Beck, Cham, Palgrave Macmillan, 2019, p. 273–285.

The indicated topic has not been analysed more extensively in the literature so far. In the research on digitalization in the agri-food sector, including the analysis of possible areas of application of blockchain technology, the focus was mainly on agricultural production systems and the functioning of food supply chains. In the InsurTech segment and projects and activities initiated by public sector entities and financed or co-financed from public funds. The article ends with conclusions and a summary.

Blockchain technology – principles of operation

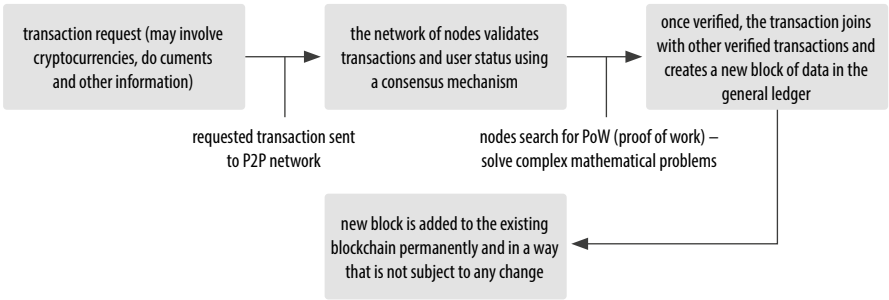
Blockchain (chain of blocks) technology is a relatively new digital technology. Its birth is related to the appearance on the Internet in early 2009 of an open-source program that allowed the generation of the first bitcoin block – a cryptocurrency that allows online payments directly between interested users, without the need for third parties (banks) to register transactions[9]. However, blockchain principles are not only used to create cryptocurrencies, but also to record data and transactions in many other areas. In fact, many types of blockchains are being developed, so it is indicated that Blockchain is more a collection of technologies than a single technology[10].

A common feature of Blockchain-based solutions is the use of distributed registries (a system of multiple cooperating nodes-computers) that do not require the involvement of a central operator or external control authority. With the consensus algorithms adopted, a network of p e e r - t o - p e e r (P2P) nodes creates a shared and fully synchronized digital database (general ledger) that does not allow the deletion or falsification of recorded transactions. Data and information are recorded as blocks. A single block groups multiple transactions and as such is added as another sequence to an existing blockchain using cryptographic hash functions (return functions). These functions create what is known as a unique fingerprint, which stores the recorded information as a string of characters and numbers. Each subsequent block contains a reference to the previous block (hash), the timestamp of the block creation, information about the transaction, the number assigned to the transaction

9. *Leksykon pojęć na temat technologii blockchain oraz kryptowalut*, red. K. Piech, Ministerstwo Cyfryzacji, Warszawa 2016.
10. V. Babich, G. Hilary, *Distributed Ledgers and Operations: What Operations Management Researchers Should Know about Blockchain Technology,* "Manufacturing and Service Operations Management" 2020, Vol. 22(2), p. 223–240.

(nonce) and other details necessary for the operation of the protocol[11]. The chain created in this way is copied and stored in all nodes of the P2P network. Thanks to this, Blockchain ensures a high level of security and data protection – even if one or several nodes stop working or fail due to a hacking attack, the remaining nodes will continue to provide access to data and system operation. Key steps and activities in the process of recording and validating transactions in the blockchain are presented in Figure 1.

Figure 1. Process of recording and validating transactions in the blockchain



Source: Own compilation based on PWC https://www. pwc. com/us/en/industries/financial-services/fintech/bitcoin-blockchain-cryptocurrency. html, access 13.07.2021.

Withdrawing or modifying data registered in the Blockchain is practically impossible, because any such operation would mean obtaining consensus for changes in each block from all nodes of the network[12]. The blockchain is thus protected against tampering and backward changes, both in the event that such changes are sought by third parties and by those directly involved in the transaction chain. Therefore, any online transaction involving digital assets from the past can be verified at any time in the future with confidence that it has not been altered after registration.

Blockchain can function as a public network (open, unpermissioned), in which no permission is required to record transactions (all interested parties can participate) or as a private network (closed, permissioned), which gives the right to record and verify transactions only to authorized entities. Open blockchain is used for cryptocurrencies (Bitcoin, Ether and others) among others. The recording of transactions involving data and business-sensitive information is most often done

11. A. Kamilaris, I. Cole, F.X. Prenafeta-Boldú, *Blockchain in agriculture* [in:] *Food Technology Disruptions*, ed. Ch. Galanakis, Academic Press, 2021, p. 267.
12. *Leksykon pojęć…*, op. cit. p. 8–9.

on private blockchains. The recording of transactions involving data and business-sensitive information is most often done on private blockchains. Private blockchains also create public sector institutions for state-citizen or state-business transactions. Three main categories of Blockchain applications can be identified: 1) execution of financial transactions and payments using cryptocurrencies; 2) the creation of distributed databases, and 3) the establishment and execution of smart contracts[13]. All the indicated capabilities and functions of Blockchain can significantly support the development of insurance system in agriculture.

Benefits and risks associated with the use of blockchain technology in agricultural insurance

Progressive digitalization processes in the economy related to the use of the Internet of Things, sensors and artificial intelligence open new opportunities for the development of the agricultural insurance system. Although the pace of digital change in agriculture has been slower than in other sectors of the economy, it is estimated that the number of active connections to the Internet of Things will increase in agriculture to about 47 million in 2022 and about 70 million in 2025 (up from about 510,000 reported in 2016)[14]. The volume of available data relevant to the insurance industry, especially in the area of estimating climate, crop and livestock risks, can be expected to increase rapidly. It will also be influenced by public sector initiatives to improve access to Earth, environmental and climate data, including satellite and ground-based sensor data. Insurance companies will therefore face the challenge of developing new solutions for the effective use of data in the agricultural insurance system.

Blockchain is a technology that can support companies in the insurance sector both in the area related to the management and use of data from various sources and in the area related to the management of contractual relationships. The primary benefits of using blockchain technology in the agricultural insurance system include improved access to information and increased transparency of transactions between insurance market players. The problem of information asymmetry is still one of the main sources of unreliability in the agricultural insurance market. It leads to adverse

13. *Transformative Technologies and Jobs of the Future. Background report for the Canadian G7 Innovation Ministers' Meeting, Montreal, Canada 27–28 March 2018*, OECD 2018, p. 15–16.
14. *Number of Internet of Things (IoT) active connections in agriculture in the European Union (EU) in 2016, 2019, 2022 and 2025 (in millions),* https://www.statista.com/statistics/691880/agriculture-iot-active-connections-in-the-eu/, access 31.07.2021.

selection to the detriment of insurers, when insurance is abandoned by farmers with a low risk of an insured event and is mainly opted for by farmers aware of higher ex ante risks. At the same time, unequal access to information leads to moral hazard on the part of better informed market participants (in this case, farmers who may decide to engage in riskier behaviour once they have taken out an insurance policy)[15]. These phenomena translate into high costs of agricultural insurance and, as a result, into insufficient insurance coverage in agriculture. Recording data, information and all events covered by insurance policies in a distributed, non-tamperable and immutable database would significantly increase the transparency of insurance market relations and transactions. As such, Blockchain technology could therefore increase the level of security, credibility and trust in the processes involved in handling insurance contracts in the agricultural sector.

Another important benefit associated with the use of blockchain in the agricultural insurance system is related to the possibility of significant streamlining of contractual relations, lowering the costs of implemented transactions and increasing the operational efficiency of insurance sector companies. Currently, the main instrument of production risk management in agriculture are insurance policies that assume the need to assess the damage caused by an insurance event. Conducting a damage assessment involves the cost of engaging internal or external institutions and experts, and is usually spread over time (and may require multiple site visits). As a result, the indemnity is usually paid many weeks or even months after the insurance event occurs[16]. An important limitation of this type of insurance is also the uncertainty of the final amount of compensation that will be paid. This factor, along with the long waiting time for compensation payments, may discourage farmers from deciding to insure their production the following season. However, the above limitations do not exist in the case of index (parametric) insurance, where the payment of compensation depends exclusively on the indices (parameters) specified in the agreement. This type of insurance was introduced to the agricultural insurance system already in the 90s of the previous century. However, due to limited access to data and difficulties connected with verification of parameters written in contracts, parametric insurance has not been an attractive alternative to classic agricultural insurance for a long time. New information and communication technologies and the massive data influx observed in recent years are lifting these constraints[17].

15. H. Xiong et al., *Blockchain technology for agriculture: applications and rationale*, "Frontiers in Blockchain" 2020, No. 3, p. 2.
16. See for example G. Kowalczyk, *Susza rozgrzewa rolników i pcha do sporu z rządem*, "Dziennik Gazeta Prawna" 9.08.2021.
17. H. Xiong et al., *Blockchain technology*…, op. cit.

In particular, the development of Blockchain technology, including the use of solutions that allow Blockchain programs to communicate with non-Blockchain data, are opening up new and previously unavailable opportunities for the development of parametric insurance[18].

The primary application of Blockchain that can streamline contractual relationships between insurance market players, reduce insurance transaction costs, and simultaneously foster the development of parametric insurance in agriculture is smart contracts. These contracts, which are in essence computer programs, carry out the obligations and transactions enshrined in the contracts automatically and without the involvement of intermediaries, each time the conditioning event occurs. However, it is important to note that smart contracts can have a very different scope – they can perform only some or most of the activities written in the contracts. As such, smart contracts can therefore be applied to all types of insurance in agriculture, not just parametric insurance. In the case of the latter, however, Blockchain offers the most opportunities because it allows to automate the entire chain of activities in the insurance value chain – estimation of risks for different types of production, selection of indicators and parameters conditioning the payment of claims or calculations of insurance premiums and sums insured, monitoring and servicing of contracts, risk management and payment of claims (including with the use of cryptocurrencies)[19].

In the case of classical insurance, the use of smart contracts would be limited mainly to areas related to the estimation of risks and claims. The benefits of blockchain for this type of insurance would therefore include, among other things, the automatic recording of claims data and the ability to quickly determine the extent and type of losses. While these programs will not be involved in the automatic payment of claims, they may send notifications and other information to insurers and insureds related to the handling of the contract, including information regarding the need to settle a claim. Thus, blockchain technology and the smart contracts that operate within it can significantly streamline and improve contractual relationships for both parametric insurance contracts and more traditional claims insurance[20]. The basic possibilities of using Blockchain technology in the agricultural insurance system are presented in Table 1.

18. This mechanism of linking blockchain data with external data is provided by the Oracle software – an external service that allows, inter alia, for the implementation of smart contracts using weather data.
19. H. Xiong et al., *Blockchain technology…*, op. cit.
20. P. Adam-Kalfon et al., *Blockchain, a catalyst for new approaches in insurance*, PwC 2017, https://www.pwc.com.au/publications/pwc-blockchain.pdf, access 4.08.2021.

Table 1. Possible areas of use of Blockchain technology (BCT) in the agricultural insurance system

Functions and services of BCTs in the insurance value chain	parametric insurance	insurance against damage
Estimation of crop and livestock risk pools from data recorded in the blockchain	+	+
Calculation of premiums and sums insured for individual holdings	+	+
Monitoring and servicing contracts, including drafting, signing, renewing and executing contracts	+	+
Risk management – monitoring of risks and threats, automatic alerts and notifications	+	+
Calculation of parameters and indicators relating to compensation payments	+	
Identification of contract forgery, detection of fraud and insurance fraud	+	+
Assessment and liquidation of damages caused by an insurance event		+
Smart contract with the function of recording the compensation due	+	+
Smart contract with automatic cryptocurrency compensation feature	+	

Source: Own study.

Undoubtedly, smart contracts coupled with cryptocurrency acceptance and payment carry the greatest transformative potential for the insurance system not only in agriculture but also in the economy more broadly. Through the use of cryptocurrencies, it is possible to streamline the processes of raising capital, as well as simplify, accelerate and reduce the cost of making online payments. Insurance based entirely on Blockchain would offer the possibility of using digital currencies both in the process of settling insurance premiums, in the payment of due claims, and in the execution of other financial transactions related to investments in the insurance market. Interest in the use of cryptocurrencies in the corporate sector has clearly increased in recent times, especially since the emergence of global stablecoins. These are cryptocurrencies backed by external assets (usually traditional currencies) and as such are less vulnerable to speculation and fluctuations in value. There are growing indications that stable cryptocurrencies have the potential to become a widely accepted medium of exchange[21]. Taking into account the difficulties of farmers in accessing sources of financing for production and investments, including the long

21. For example, Visa – one of the leaders in payment technologies – in 2021 began working with 50 leading crypto-asset platforms to develop cards that allow you to make payments using cryptocurrencies without the need to convert them. Zob. S. Peters, *Bitcoin. Płatności kryptowalutowe Visy przekroczyły miliard dolarów*, Money.pl, 12.07.2021.

waiting time for the payment of compensation under traditional insurance, the implementation of solutions based on crypto assets could significantly improve the financial liquidity of farms. Currently, regulations are being developed in the EU to enable and support the use of the potential of digital finance in the development of innovative digital services, alternative payment instruments and new sources of financing for enterprises, while reducing the risk[22].

Risks related to the use of digital finance in smart insurance contracts, e.g. with speculation in the cryptocurrency market, are one of the many risks that should be taken into account when assessing the potential of Blockchain technology in the agricultural insurance system. Like any innovation, blockchain technology is also burdened with problems that may limit its positive impact[23]. Although Blockchain does not allow the removal or falsification of recorded data, it does not guarantee that the data recorded in distributed databases is true, i.e. corresponds to actual facts and observations. This problem, referred to as g a r b a g e i n – g a r b a g e o u t, may be the result of dishonesty of blockchain participants from the very beginning, or the result of downloading data from unverified sources or sources collecting data of different quality. In the case of a private blockchain, these deficits can be overcome by means of a mechanism for verifying the activities of entities authorized to record data. Proper operation of the data entry system (e.g. weather data used in crop insurance) may also require the involvement of third parties (e.g. specialized search and collection companies). Thus, the benefits of eliminating intermediaries from blockchain based systems may not be achieved in all areas.

Another weakness of Blockchain technology is the high costs associated with power consumption – validating transactions across all nodes in the network requires a lot of computing power (this is especially true for public blockchains and cryptocurrencies). Since the processors of computers participating in P2P networks are typically powered by non-renewable energy, the operation of Blockchain technology contributes to a significant increase in global CO_2 emissions[24]. Paradoxically, technology, which has great potential to support sustainable agricultural development through a more effective risk management system, itself also generates environmental problems. Blockchain's development of digital agricultural insurance would therefore need to take into account parallel efforts to reduce the carbon footprint of the technology.

22. See *Proposal for a Regulation of the European Parliament and of The Council on Markets in Crypto-assets and amending Directive (UE) 2019/1937*, Brussels, 24.9.2020, COM(2020) 593 final 2020/0265(COD).
23. A. Kamilaris, I. Cole, F.X. Prenafeta-Boldú, *Blockchain in agriculture*…, op. cit., p. 270–275.
24. It is estimated that the production (mining) of Bitcoin alone generates between 22 and 22. 9 million Mt of CO_2 per year. Ch. Stoll, L. Klaaßen, U. Gallersdörfer, *The carbon footprint of bitcoin*, "Joule" 2019, Vol. 3(7), p. 1647–1661.

In addition to the risks and costs associated with the imperfections of the technology itself, the use of blockchain in economic practice may be limited by a deficient and inconsistent legal framework. The pace of development of digital technologies, including Blockchain technology, is very fast, therefore at the legislative stage, it is extremely difficult to take into account all potential applications, collisions, risks and threats[25]. In addition, the harmonization of legislative activities at the international level, which is particularly desirable in the case of digital platforms and blockchains, remains a major challenge. At the same time, there are risks and challenges in the area of managing data recorded in distributed databases, especially personal data that are permanently entered into smart contracts. The inability to delete records from Blockchain means that the problem may be, among others enforcing the "right to be forgotten" guaranteed by the EU regulation on the protection of personal data[26].

The third category of risks and problems is related to socio-cultural and economic barriers. The relatively low level of digital competences of farmers and a conservative approach to technological innovation may limit the possibilities of scaling the sale of Blockchain-based digital products and services. Agricultural insurance companies as well as insurance brokers and agents may also be reluctant to radical innovations, including the use of new computer programs and artificial intelligence in the process of risk assessment and compensation payment. Blockchain brings with it a great transformational potential for all participants of the insurance value chain. Implementation of some solutions on a larger scale (e.g. parametric insurance) may involve the necessity to change business models, including a new organization of work in the insurance sector. This is especially true in those areas where smart contracts and machine learning algorithms could take over human tasks.

Prototypes and examples of using Blockchain technology in agricultural insurance system in the world

Technology startups and InsurTech companies play a key role in the development of digital agricultural insurance. InsurTech is a new segment on the insurance market – it includes companies and entities that use advanced technologies and digital solutions to create products and services that increase the protection and convenience of the insured and increase the efficiency of the insurance industry. There are

25. P. Adam-Kalfon et al., *Blockchain*…, op. cit.
26. M.Finck, *Blockchain and the General Data Protection Regulation. Can distributed ledgers be squared with European data protection law?* European Parliamentary Research Service, Scientific Foresight Unit (STOA), 2019, p. 74–75.

three basic categories of companies in this segment – challenging companies, i.e. 1) introducing new products and business models in the insurance sector (also known as full carriers); 2) enablers, offering specialized services at every stage of the insurance value chain, and 3) online insurance intermediaries or providing information on new insurance products (distributors)[27]. The analysis of the data available on the Crunchbase platform, one of the largest databases collecting information on innovative enterprises and startups in the world, shows that recently there have been entities on the market that have developed or intended to develop insurance programs for agriculture using Blockchain technology[28]. At the same time, the number of startups and enterprises specializing in the use of satellite technologies, data provision, modeling and assessment of insurance risks in various areas is growing. Industry reports indicate that this market has a great transformational potential, especially in the area of weather, catastrophic and climate change risk management[29]. Large enterprises and insurance companies that are interested in expanding the offer of insurance products and services or purchasing specific innovations that improve the process of assessing insurance risks in the agricultural sector also cooperate with technology startups. After all, the digital agricultural insurance market is still embryonic in nature. Product prototypes and insurance products created using Blockchain are offered only on a few platforms in the world. The most advanced and innovative platforms for digital insurance products in agriculture include the Arbol platform from the USA, the Qoldau platform from Kazakhstan and the Beacon platform developed in Europe. A closer presentation of the indicated platforms and undertakings will highlight the possibilities and ways of using Blockchain technology in insurance in the agricultural sector.

Arbolmarket platform: Ethereum network and digital parametric insurance

Start-up Arbol was founded in 2018 in the United States with the aim of improving access to weather risk insurance for a variety of entities, including specifically entities and businesses operating in the agri-food sector[30]. The result of Arbol's

27. *World InsurTech Report 2020*, CapGemini and EFMA 2020, www.worldinsurtechreport.com, access 10.08.2021.
28. At the same time, it should be noted that agricultural insurance is still not one of the most frequently developed products. Searches on the Crunchbase platform identified 1,417 entities attributed to the InsurTech segment, with only 119 of them identifying agricultural insurance as one of their areas of focus,https://www.crunchbase.com, access 26.07.2021.
29. *How insurance can help combat climate change*, MacKinsey and Company, 6.01.2021, https://www.mckinsey.com/industries/financial-services/our-insights/how-insurance-can-help-combat-climate-change, access 26.07.2021.
30. *Arbol – summary information,* https://www.crunchbase.com/organization/arbol-markets, access 4.08.2021.

work is the ArbolMarket platform, which provides access to tools and solutions that facilitate and support transactions and contracts between weather-exposed agricultural producers and capital providers – insurers and asset managers (banks, hedge funds, investors and others interested in making profits from financing weather derivatives)[31]. The platform common to farmers and insurers is to reduce the problem of information asymmetry and, as a result, help lower the prices of premiums for weather risk insurance. The main product and service offered on the ArbolMarket platform is parametric insurance, which makes the payment of compensation dependent on strictly defined indices related to weather and natural phenomena, not on the calculation of damage and losses in production.

Arbol's insurance is offered in the form of smart contracts, which automatically pay out compensation if the indices indicated in the contracts are reached. These contracts act as decentralized applications directly on the Blockchain – in the Ethereum network, in which each computer (node) stores a copy of all contracts and verifies transactions related to the payment of compensation. The decision to base the Arbolmarket platforms on the public Ethereum network was dictated by the desire to provide farmers and insurers with the easiest-to-use applications. Ethereum operates slower than other decentralized networks, however, it allows for solutions that release end users from having the knowledge and skills to use private keys that give access to Blockchain. Thus, users can log in to the service on the Arbolmarket platform with a password protected, as is the case with standard web applications. The developers of the platform expect this solution to encourage more traditional agri-food customers to use smart insurance contracts[32].

Currently, the Arbolmarket platform offers farmers and entities interested in investing in the insurance market several parametric products – insurance against the risks associated with excessive or insufficient rain and snowfall, protection against excessively high temperatures and protection against weather phenomena that prevent fertilization. In accordance with the rules of the platform, the farmer, after logging in, may submit a willingness to conclude a smart contract (selecting the type of risk insured, the period of protection, the areas covered by the protection, the amount of the premium). The reports are visible to the investor insurers who can agree to or reject the proposed contract. Both the interested investor and the farmer pay a certain amount to the smart contract (in the Ether cryptocurrency) in order to receive tokens in return (certificates of the signed contract). They give the farmer the right to compensation, the investor the right to profit. If an insurance event occurs (described in a strictly adopted parameter), the farmer automatically

31. Informacje z platformy Arbolmarket, https://www.arbolmarket.com/, access 4.08.2021.
32. B. Andre, *Which blockchain is right for your DApp?*, 14.02.2019, https://arbolmarket.medium.com/which-blockchain-is-right-for-your-dapp-89966f4dc515, access 4.08.2021.

receives all the funds assigned to the smart contract (in the Ether cryptocurrency). If the data analyzes do not show that the parameter specified in the contract has occurred, the smart contract allocates the entire sum of Ether to the insurer (investor)[33].

Some products cover all countries of the world, other products are available only to farmers in the United States. In the case of insuring certain types of risks, additional information is required to be added to the platform, e.g. the operation of a parametric product protecting maize crops during the pollen season against too high temperatures during the day and at night requires farmers to provide information on planting dates. There are also parametric products on the platform that do not use weather-related indices. One such product is the SmartYield Program, which uses an index based on the amount of yields. The source of data are sensors located in agricultural equipment[34]. If the yield index falls below a certain limit, farmers automatically receive compensation. For this product, as with weather insurance, farmers do not have to submit claims for compensation. They also know the amount of compensation in advance. Thus, the basic limitations of traditional insurance – bureaucracy related to the submission of applications, long processing times related to the claims assessment process and the uncertain amount of compensation – are eliminated. The creators of the platform indicate that the simplicity of parametric insurance, combined with much better access to the technology of processing large amounts of data, will allow to achieve economies of scale and reduce costs for insurers and insurance prices for farmers[35].

Satellite data and data from ground meteorological stations are used in the assessment and monitoring of parameters (indexes). Data is collected from reliable sources (NASA and the National Oceanic and Atmospheric Administration) and then logged using the IPFS (interplanetary file system) protocol. While IPFS itself is not a blockchain technology, it does take advantage of its principles. It is a decentralized and p e e r - t o - p e e r system for storing and sharing files, websites, applications and data[36]. In order to ensure the stable operation of the platform, Arbol develops cooperation with entities specializing in data delivery and with companies

33. S. Jha, B. Andre, O. Jha, *ARBOL: Smart Contract Weather Risk Protection for Agriculture*, 2019, https://vdocuments.mx/reader/full/arbol-smart-contract-weather-risk-protection-for-agriculture-2019–08–08-arbol, access 8.08.2021.
34. S. Evans, *Arbol taps machinery sensors for parametric crop insurance triggers*, 24.02.2021, https://www.artemis.bm/news/arbol-taps-machinery-sensors-for-parametric-crop-insurance-triggers/, access 8.08.2021.
35. *Parametric insurance revisited – insights from Arbol*, Insureblock Podcast (episode 145), 24.01.2021, https://insureblocks.com/ep-145-parametric-insurance-revisited-insights-from-arbol/, access 10.08.2021.
36. As such, IPFS – like Blockchain – increases the security of data storage (possible attacks on specific servers do not block access to data, as is the case with centralized databases controlled by a single entity) and at the same time eliminates the problem of data manipulation or removal of inconvenient information. IPFS also facilitates the day-to-day processes of aggregating, synchronizing, and distributing huge amounts of data. See *What is IPFS,* https://docs.ipfs.io/concepts/what-is-ipfs/#decentralization, access 11.08.2021.

producing equipment that allows data collection[37]. In parallel, Arbol is developing a new ecosystem for climate data (dClimate) – an open source toolkit for standardizing and building weather data resources from various sources based on IPFS, i.e. using paths (addresses) to content, not addresses to specific locations data storage[38]. This solution is intended to encourage various entities (including scientists, university staff, government agencies and smaller companies dealing with data collection) to engage in efforts to build distributed weather databases. As such, this project may contribute to further strengthening the role and importance of parametric solutions and products in the agricultural insurance market.

Qoldau platform and digital agricultural insurance in Kazakhstan

In December 2017, the Government of Kazakhstan announced the "Digital Kazakhstan" strategy, which entails a broad program of digitization in the economy and public administration[39]. Digitalization of agriculture is one of the areas particularly supported by the government of Kazakhstan. The emphasis on using new digital technologies in this area stems from the large role agriculture plays in Kazakhstan's economy. In 2016, the share of agriculture in Kazakhstan's GDP was 4. 6% with 18% of the economically active employed in this sector. Although agricultural production in Kazakhstan is growing and the country remains one of the world's largest cereal producers and exporters, increasing adverse weather events, in particular recurrent droughts, pose a serious threat to the sustainability of agricultural production levels and agricultural incomes. Many problems also result from an ineffective farmland management system and insufficient protection of agricultural soils. One of the main goals of digital investment is therefore to improve the ability to analyze and predict problems in the agricultural sector, including improving the monitoring of agricultural soils and reducing the impact of unfavorable weather conditions on production and agricultural income.

The government in Kazakhstan started implementing the digitization strategy in the agricultural sector by digitizing information on farmlands and pastures. It was also decided that the digitization process in agriculture would be supported by a single digital platform that would combine the database function with the function of comprehensive services for the entire agri-food sector. The government obligated

37. S. Evans, *Arbol taps machinery*…, op. cit.
38. *Case study: Arbol*, https://docs.ipfs.io/concepts/case-study-arbol/#the-story, access 11.08.2021.
39. *State programme "Digital Kazakhstan"*, approved by the Decree of the Government of the Republic of Kazakhstan of December 12, 2017, No. 827, https://digitalkz.kz/wp-content/uploads/2020/03/ГП%20ЦК%20на%20англ%2003,06,2020.pdf, access 27.07.2021.

farmers to actively participate in the construction of the platform – farmers were obliged to register information on farms and fields, their production (including types of crops) and the agricultural equipment used on the platform. Thanks to the idea of crowdsourcing, in one year, it was possible to create a digital database covering 25 million hectares of arable land (100% of the total area of arable land) and 55 million ha of pasture (over 80% of the total area of pastures)[40]. Managed by the Ministry of Agriculture, the platform called Qoldau (meaning "support" in Kazakh) currently has 172,000 registered users[41]. It includes online business-farm (B2F), farm-state (G2F) and farm-state (F2G) relationships and transactions. The available applications and services are used by farm owners, government agencies and many other entities operating in the agri-food-industrial complex (financial institutions, suppliers of means of production, storage warehouses, traders). Thanks to the integration with government databases, spatial data repositories and electronic payment systems, the offered solutions are comprehensive. At the same time, the certainty and credibility of data and transactions is ensured by the integration of Qoldau with the Blockchain-based QazChain database[42].

Among the functions and services available on the Qoldau platform you can find, among others state electronic register of component evidence – e-Cereals, the Agromonitor service, thanks to which farmers have access to electronic maps of arable fields and can monitor their own and/or leased plots using remote sensing data and data from specialized sensors, Agroanimals service that allows you to track the state of the herd, including automatic identification of sick animals based on data from sensors sent every 5–30 minutes, or advisory services and recommendations on the use of precision farming techniques (AgroConsultant). The platform also offers electronic subsidy application, e-application processing and approved subsidy payment services[43]. One of the key services offered on the platform

40. *Qoladu.kz,* Zerde – Digital International Partnership, https://zerde.digital/en/qoldau-kz, access 25.07.2021.
41. *WSIS Prizes Contest 2020 Nominee – Digital platform for business Qoldau,* https://www.itu.int/net4/wsis/stocktaking/Prizes/2021/DetailsPopup/15742745315624085, access 25.07.2021.
42. The use of Blockchain technology in the registration and execution of transactions in the agricultural sector reflects the assumptions of the government's digitization strategy. It declares support for the widest possible use of this technology in the economy. It is worth noting that Kazakhstan is currently the fourth market for the mining of Bitcoin, a Blockchain-based cryptocurrency, after China, the US and Russia. At the same time, the government in Kazakhstan declares its willingness to further popularize the use of Blockchain and cryptocurrencies in various areas and sectors of the economy, including banking, healthcare and agriculture. See. *Government considers development of cryptoindustry and blockchain technologies*, Official Information Source of the Prime Minister of the Republic of Kazakhstan, 11.05.2021, https://primeminister.kz/en/news/v-pravitelstve-rassmotreli-voprosy-razvitiya-kriptoindustrii-i-blokcheyn-tehnologiy-1141139, access 25.07.2021.
43. Na platformie dostępnych jest wiele innych usług. Dodatkowo, planowane jest uruchomienie nowych aplikacji dla rolników. Zob. https://www.qoldau.kz/en#resources, access 25.07.2021.

is also agricultural insurance. The AgroInsurance service – offered to farmers and participants of the insurance market – allows you to submit an e-application for an insurance contract, conclude an online insurance contract, pay the insurance premium, register an insurance event and pay compensation[44]. Farmers can also use online calculators to calculate the insurance premium due, both for subsidized and under-premium insurance. At the same time, a common access portal to data and related digital services reduces the problem of information asymmetry and allows for better risk management in the agri-food sector. Thanks to the data, it is possible to more accurately assess the pool of insurance risks, which translates into lower costs of reinsurance fees for insurers[45].

The Qoldau platform is still under development. Electronic agro-insurance services are also being developed, currently divided into four sections – plant production insurance, livestock (cattle) insurance, real estate and agricultural equipment insurance, and third party liability insurance for grain storage entities. In the recent period, the most innovations concerned the insurance of field crops. After severe production losses due to the 2017 drought, the government of Kazakhstan supported a project to develop new insurance instruments in this area. One of such products was developed jointly by the Insurance Association for Agriculture in Kazakhstan, Swiss Re – a Swiss insurance company with extensive experience in the development of innovative insurance products and risk reinsurance, and the Dutch startup VanderSat dealing with the provision of satellite-based products and services, including data on soil moisture and temperatures[46]. As a result, already in 2020, digital index (parametric) insurance, based on the new Soil Moisture Deficit Index (SMDI), appeared in the offer on the Qoldau platform. This indicator was considered to be a more accurate measure of water availability than the indicator based on rainfall (e.g. due to the fact that the latter did not take into account additional factors affecting the amount of yields – water runoff, evaporation and groundwater level)[47]. The distinguishing features of the new insurance product are daily satellite measurements of soil moisture and data logging in a tamper-resistant distributed database based on a blockchain. The solutions adopted ensure transparency, credibility

44. *Электронный Сервис «Agroinsurance»*, https://agro-insurance.qoldau.kz/en/info-start, access 25.07.2021.
45. R. Cekuta, K. Cheriegate, B. Wilcox, *The Computer and the Farmer. The role of information technology in boosting agricultural productivity in Kazakhstan*. Special Policy Brief. Caspian Policy Center, https://www.caspianpolicy.org/wp-content/uploads/2019/10/CEEP-REPORT-computer-and-the-farmer.pdf, access 26.07.2021.
46. *Drought insurance for Kazakh farmers,* https://vandersat.com/cases/drought-insurance-for-kazakh-farmers/, access 27.07.2021.
47. *Strengthening risk resilience: 2020 highlights. Soil moisture deficit index*, https://reports.swissre.com/sustainability-report/2020/solutions/strengthening-risk-resilience-2020-highlights/soil-moisture-deficit-index.html, access 27.07.2021.

and certainty of the parameters underlying the payment of claims. If the soil moisture deficit indicator reaches a predetermined level, the contractual compensation is paid. It is not required to carry out a claim settlement, as in the case of classic insurance[48]. At the same time, however, the description of the insurance product in question indicates that the farmer should report online waiting for the payment of compensation[49], which means that the platform is not yet fully operational with intelligent contracts that register insurance events on their own. Nevertheless, the relatively simple structure of the insurance, clear rules for the payment of compensation, great convenience resulting from the implementation of all transactions on the platform, as well as subsidizing index insurance premiums by the state, make the interest in this product grow[50]. Currently, in addition to several versions of insurance based on SMDI, the Qoldau platform also offers insurance based on the Soil Moisture Excess Index (SMEI). In 2020, the area covered by index insurance amounted to 115 thousand hectares, in 2021 it increased to almost 145 thousand hectares[51].

BEACON project – improving crop damage detection and estimation based on Blockchain technology and Earth observation data

The huge opportunities that data and Blockchain technology offer for the improvement and development of the agricultural insurance system are well illustrated by the work carried out under the BEACON project. The BEACON project is one of the innovative activities financed by the European Union's Horizon 2020 program. Its implementation began in January 2019, and the end of activities is scheduled for January 31, 2022. The project involves companies from the insurance sector, consulting companies and university employees. Etherisc is also involved in the implementation of the project – one of the startups of the InsurTech segment, specializing in creating protocols for decentralized insurance applications stored on Blockchain.

48. M. Andriesse, *Drought is insurable*, 16.06.2021, https://www.swissre.com/risk-knowledge/mitigating-climate-risk/drought-is-insurable.html, access 27.07.2021.
49. *Index insurance in plant farming*, https://agro-insurance.qoldau.kz/en/index-start, access 27.07.2021.
50. Insurance based on SMDI is also used in Russia, Ukraine, Kenya, Brazil and some European countries – France, Slovenia, Serbia, Croatia, Bulgaria, Lithuania and Latvia. The introduction of such insurance is also planned in Australia, Tanzania, Belgium, the Netherlands, Switzerland, the USA and Zimbabwe. See *Satellite-based soil moisture records for increased access to financial services,* 17.09.2020, https://g4aw.spaceoffice.nl/files/files/G4AW/webinar/Session%201%20-%20VanderSat%20-satellite-based%20soil%20moisture%20records%20for%20increased%20access%20to%20financial%20services.pdf, access 29.07.2021.
51. *Статистика по типам страховых продуктов – 2021 [Statistics by types of insurance products] год*, https://agro-insurance.qoldau.kz/en/index/statistics/all-products?Year=2021, access 29.07.2021.

The aim of the BEACON project is to use data from Earth observation, advanced weather analysis and information and communication technologies (including Blockchain technology) to develop a package of commercial tools and services that strengthen the possibilities of operation and development of enterprises in the insurance sector. The proposed services are in particular to mitigate the impact of uncertainty regarding the weather on the assessment of risks for insurance products in agriculture, reduce the number of visits to the scene of the incident to verify the insured's claims, reduce operating and administrative costs related to monitoring contracts and indices used in insurance, reduce the problem of insurance fraud. and enable the development of more precise and personalized insurance products[52]. Smart contracts are also an integral part of the project – automated programs run on Blockchain, which are to accelerate the payment of compensation and reduce the costs associated with their service. The project also provides for measures to improve risk management in the agricultural sector. It is planned to launch an early warning service – a digital application through which insurance companies will be able to inform farmers about upcoming weather threats and recommend taking necessary actions to limit the negative impact of weather on crops[53]. The developed solutions are to be tested as part of the pilot phase of the project in the operating environments of 10 selected companies in the insurance sector. After validation of the adopted models and confirmation of the commercial value of the BEACON platform, it is planned to prepare a business model allowing the sale of the offered products and services[54].

The services of the BEACON platform are to be distinguished by reliable and credible methods of detecting damage and estimating losses in agricultural crops caused by hail, floods, fires and droughts. For this purpose, different types of data from Sentinel satellites are used, as well as a whole range of detection and monitoring techniques for changes on the Earth's surface. The first phase focused on the selection of appropriate Earth observation methodologies and techniques, and on qualitative damage assessments. In the second phase, the work focused on the development of machine learning algorithms that are to allow quantification of losses for individual types of crops. The crops included in the models tested included wheat, barley, corn, soybeans, sunflower seeds and cotton. Following additions and corrections, especially in relation to the services for calculating losses caused by hail,

52. See https://beacon-h2020.com/concept/, access 1.08.2021.
53. Ibidem.
54. *Boosting Agricultural Insurance based on Earth Observation data. Beacon Project Information,* https://cordis.europa.eu/project/id/821964, access 2.08.2021.

drought and floods, the developed methods and calculators were incorporated into the BEACON pilot toolkit[55].

Ultimately, the BEACON package will include five different services supporting insurance companies in the areas related to the creation, conclusion and performance of crop insurance contracts against selected weather risks. They will be:

1) crop monitoring application – crop data, yield estimates, profiling of insurance contracts;
2) loss estimation calculator – damage assessment after hail and storms, spatial distribution and assessment of flood damage, mapping, assessment and classification of fire damage severity, detection and assessment of damage to crops caused by drought for the entire growing season;
3) fraud control application – a service that allows for automatic verification of the legitimacy of claims for compensation;
4) application for estimating the probability of weather risk occurrence – the use of Copernicus seasonal meteorological and climate forecasts to create maps showing the probability of extreme weather events in a given area and to assess the potential impact on crops;
5) damage forecasting and prevention application – early warning system with alerts sent to insurance companies and their customers (weather warnings, pest and disease alerts)[56].

Only insurance companies registered on the platform will have access to the indicated services. From one place, insurers will be able to view aggregated information on policies and areas insured – the number of policies (areas) affected by an extreme weather event, a register of types of extreme weather events for individual contracts (areas), the number of policies (and areas) at risk of extreme weather events, and the number of policies (and areas) that may suffer from the emergence of diseases and pests of crops. Integration of the BEACON platform with Blockchain technology will ensure the security of information and data regarding contracts and insured areas. Blockchain components, however, will not be included in the data collection process itself, their role is to be limited to the processing of data collected or produced by other elements and tools of the BEACON platform. As intended, only a small part of the data is to be processed in the blockchain. These will be, in particular, data necessary for the proper functioning of smart contracts, processed in accordance with the requirements of the GDPR – pseudonymised data about

55. *Beacon Newsletter*, Issue no 7, May 2021, https://beacon-h2020.com/newsletter-7/, access 6.08.2021.
56. E. Lekakis et al., *Redefining Agricultural Insurance Services Using Earth Observation Data. The Case of Beacon Project* [in:] *International Symposium on Environmental Software Systems*, Cham, Springer, 2020, p. 90–101.

customers and assigned plots and fields, provisions in contracts (period of validity, insured area and types of crops, insurance value). The exact scope of data stored in Blockchain's distributed database, however, will depend on the types of insurance products that will be offered to farmers. The created blockchain is to be private – only selected entities (nodes) will have the right to register and validate data in blocks, including generating new contracts. Other entities will be able to enter the database and view the registered records. Activities related to the preparation of policies, including amendments to them, are to be automatically saved in the block chain, which will eliminate the problem of possible abuse or fraud against the interests of insured farmers. The smart contract feature will inform insurers of a claim for compensation as soon as the insurance events specified in the contract are registered on the blockchain. However, the payment of compensation will require approval of the claim by the insurer. After the claim is accepted, the platform will send a notification to Blockchain about the need to pay compensation.

Summary

Blockchain technology offers many solutions that can facilitate the assessment of insurance risks and risk management, and at the same time improve the processes related to the conclusion and execution of insurance contracts. The need for improvement in the indicated areas is particularly great in the case of insurance in the agricultural sector. The possibilities of Blockchain technology to improve the functioning of the agricultural insurance system will largely depend on the proper use of opportunities related to the rapidly growing resources of digital data. These data, generated by various devices and systems (including satellite remote sensing systems, weather data recording stations, programs for geospatial data and digital maps, or drones and sensors recording data on yields and parameters affecting agricultural production performance), require appropriate security, security and access procedures. Also other categories and types of data used in insurance contracts require appropriate security systems. It is particularly important for insurance companies and insurers to ensure the reliability and correctness of data and information that constitute the basis for the calculation of insurance premiums, sum insured and the amount of compensation. Such protection, thanks to the use of distributed registers and consensus algorithms, is offered by Blockchain technology. Blockchain, however, not only ensures safe and reliable access to data used in the insurance value chain, but also opens the way to the development of new products and services in the insurance system.

Presented case studies show that businesses, governments and public sector institutions recognize the various opportunities associated with the use of blockchain technology in agricultural insurance. At the same time, they show that Blockchain can increase competition in the agricultural insurance market by expanding the pool of available insurance and a new system of organizing relations between policyholders and insurers. One of the most innovative elements of the digital agricultural insurance platforms currently under development is smart contracts. Blockchain-based smart contracts have great potential to reduce the costs associated with transactions on the insurance market. They can also facilitate and accelerate the conclusion and execution of insurance contracts. These are the benefits that distinguish the analysed platforms, both the fully commercial Arbolmarket platform and the Qoldau and Beacon platforms, which are developed with the involvement and support of the public sector. The development of this type of platforms could contribute to lowering the costs of agricultural insurance and, consequently, translate into an increase in the scope of insurance cover in agriculture. In this context, digital parametric insurance, which meets the need to increase protection of farms against weather and climate risks, has a high development potential. Another significant benefit is related to the possibility of integrating smart contracts with applications that enable the monitoring of risks and threats in the agricultural sector. Therefore, it can be expected that the popularization of platforms for digital agricultural insurance, including smart insurance contracts, could significantly strengthen the risk management system in agriculture.

There are also specific risks and threats associated with Blockchain technology. Some of the solutions proposed on blockchain platforms are radical innovations for which the agricultural sector may not be prepared. Legal regulations that would protect enterprises and consumers against certain risks related to the use of smart contracts (e.g. contracts involving payments in cryptocurrencies) are also not ready. The wider use of Blockchain also threatens existing business models and may arouse resistance from traditional participants in the insurance value chain. Despite the indicated limitations, it should be expected that the importance of digital technologies in the agricultural insurance system, including Blockchain technology, will increase. The factors that will encourage enterprises to increase investments in digital solutions will be the increasing costs of traditional instruments for insuring risks occurring in agricultural activity. Digitization in the area of business insurance, including agricultural insurance, will also be supported by the involvement of the public sector. In the recent period, the number of regulatory actions has clearly increased in order to ensure appropriate conditions for the use of digital technologies in the economy. Regulations concerning strictly crypto assets and technologies based on

distributed ledgers are being prepared in the EU. At the same time, the value of public investments supporting digitization and the use of new technologies in agriculture is growing, also with a view to increasing the efficiency of the subsidized agricultural insurance system. In addition, international organizations, states and public sector institutions increasingly and to an increasing extent provide business with public data on the Earth, climate, environment and other domains with a view to building a socio-economic system that is more intelligent, sustainable and risk-resistant.

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