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# BLOCK-CHAIN-ENABLED TRACEABILITY AND INTELLIGENT SYSTEMS INTEGRATION FOR SUSTAINABLE AGRICULTURAL SUPPLY CHAINS

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**ABSTRACT**------------------------------------------------------------------------------------------------------
*This study has examined the revolutionary capacity of block chain technology in promoting agricultural supply chain changes, increased risk management and sustainable development. Block chain product authenticity, improves consumer confidence and food security, which provides temper-proof traceability and origin. The inclusion of smart contract enables innovative financial structure, including clear loan projects and automatic insurance for climate risk, especially to help small farmers. In addition, block chain cooperation with new technologies such as Io T and AI in e-agricultural systems increases assets allocation, reduce fraud and facilitate advanced smart agricultural techniques such as vision-based disease identification. This research emphasizes the essential role of block chain in promoting more effective, powerful and fair agricultural systems while addressing current infrastructure problems.*

**KEYWORDS:** *Block chain, Agricultural Supply Chain, Traceability, Smart Contract, Risk Management, Durable Agriculture*------------------------------------------------------------------------------------------------------------

## INTRODUCTION

Dc Agricultural industry is at an important stage, fighting the growing challenge of nutrition to rapidly growing global population in the face of increasing environmental pressure and limited resources (UN Food and Agricultural Organization, 2020)**[1,2]**. Common Agricultural methods often face inefficiency of supply chain management, sensitivity to climate-related threats and problems of transparency and traceability, which affect both producers and consumers (Camillaris ET Al., 2019)**[3,4]**. As a result, adopting advanced digital technology in agricultural ecosystems is becoming a key technique to improve productivity, durability and elasticity**[5,6]**. Among these breakthrough technologies, block chain received considerable attention to the ability to convert agricultural supply chain by providing temper-resistant traceability and origin (Sal ah ET AL., 2019)**[7,8]**. Its decentralized and cartographic features allow the establishment of irreversible records, promoting transparency and confidence in all parties from production to cost. This feature addresses important issues related to the authenticity, protection and origin verification of food, which increases consumer confidence and reduces fraud-related risk (Tian, 2016)**[9,10]**. Also, the use of block chain includes new financial solutions for farmers ahead of traceability. Block-chain-enabled smart contracts can automate insurance payment based on environmental conditions, providing rapid financial support in the push of climate change (World Bank, 2020). In addition, credit systems powered by block chain are facilitating loan delivery processes, especially for small and marginal farmers, improving financial inclusion and protection in the agricultural sector (Agarwal and other, 2021)**[11,12]**.The collaborative combination of Internet of Things (IOT), artificial intelligence (AI) and other developing technologies, including Big Data Analytic s, further enhances its impact on agriculture. IOT sensor collects real-time data on environmental factors and crop health, where AI algorithms can evaluate this data to improve resource management and predict potential risks**[13,14]**. Block chain provides a reliable and clear platform for overseeing and distributing this data, encouraging better-knowing and more efficient decision making across the agricultural

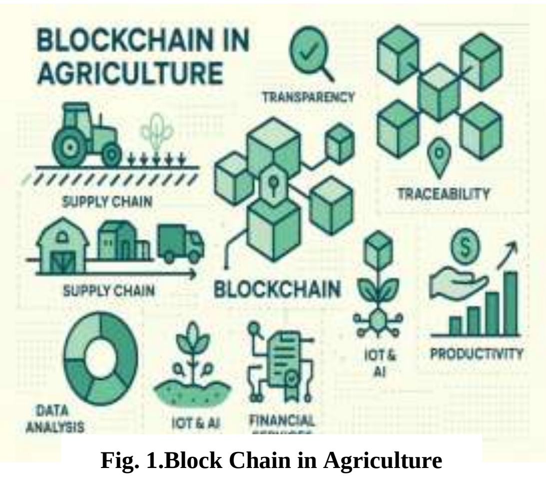

**Fig. 1.Block Chain in Agriculture**

price chain (Vardow and others, 2016). This research paper explores a variety of block chain technologies in contemporary agriculture, checks how it improves traceability and origin verification, supports innovative risk management methods and encourages sustainable growth**[15,16]**. We also explore block chain combination with other innovative technologies to develop intelligent and efficient e-agricultural distribution systems and smart agricultural methods, which include sophisticated techniques for crop disease detection. This work tries to address upcoming food protection problems and synthesize recent studies and provide a thorough insight on how block chain technology is improving agriculture to create more elastic and transparent food systems**[17,18]**.

**Block Chain-Enabled Traceability and Provenance in Agricultural Supply Chains**

Traceability refers to the ability to track the life cycle, movement and location of a product within the supply chain. When combined with block chain technology, traceability is increased using Temper-proof timestamp and cryptography digital signature. Each product is given a distinct digital identifier and is logged into block chain with all transactions or transfer timestamps and digital signatures in the supply chain. It creates an irreversible record that enables real-time monitoring and verification of product authenticity and location. Block-chain tracking also supports the origin, allowing the product source and its way to verify the different stages of supply chain.These systems are relevant in different fields such as food, wine, industry and ancient accessories. By verifying the product's authenticity and source, companies can improve the quality of the product, increase consumer confidence and reduce the risk associated with fraud and fraud.In case of food supply chain, traceability using block chain technology provides a clear, safe and effective way to track food products from production to use. It improves food safety, ensures product quality and helps in regulatory compliance. Also, the use of block chain in agriculture is expanding to include new financial models, such as loans for small farmers based on smart contracts. These measures want to facilitate access to debt, reduce transaction costs and increase the integrity and transparency of information. Despite the obstacle to the inclusion of block chain in the agricultural supply chain, inclusion of block chain in order to effective implement, improve functional efficiency, increase sustainability and facilitate information-based decision making**[19-21]**.

**Block chain Applications in Agricultural Risk Management and Sustainable Development**

The insurance solution designed for farmers, especially structural in cooperatives, has enough potential in improving block chain technology. Using smart contracts and decentralized information, block chain can help create automatic and transparent insurance systems that protect farmers from unexpected climate events, such as drought, floods or other natural disasters. These insurance models can be made to activate payment according to specific weather criteria, which provides immediate financial support without the need for the comprehensive demand process**[22,23]**. In addition to financial services, block chain is being investigated for greater use in the agricultural industry. The efforts are ongoing to empower small farmers, encourage sustainable agricultural techniques and improve local agricultural cooperatives. In various cases, experimental initiatives have shown how block chain can increase transparency, best en resources delivery and help in community-driven agricultural growth, leading to stronger and more inclusive food systems**[24,25]**.

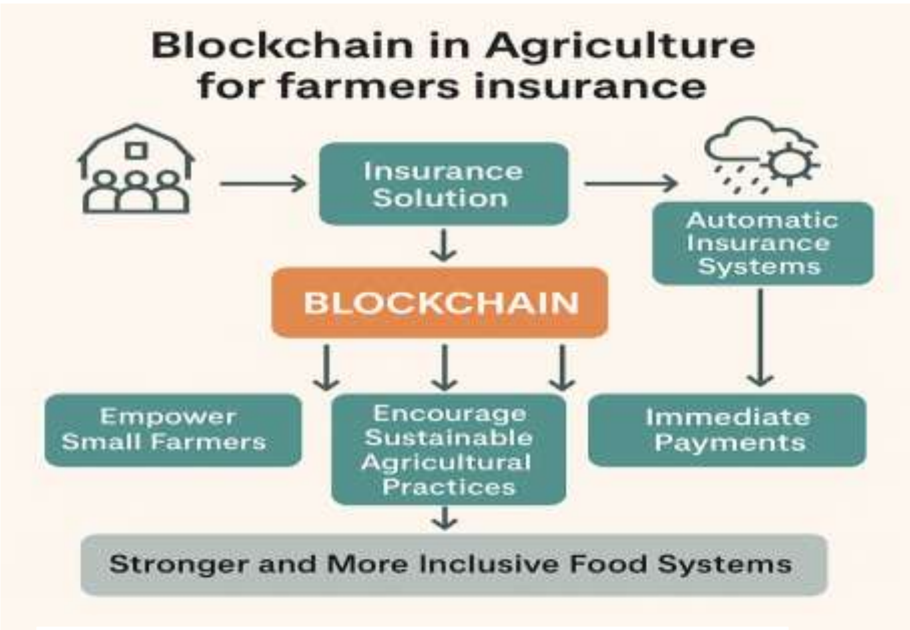


**Fig. 2.Block Chain in Agriculture for Farmers Insurance**

**Advancing Agricultural Supply Chains Through Block-chain-Enabled Credit and Traceability Systems**
A loan programme operated by block chain technology launched in India is aimed at improving the financial benefits of small and marginal farmers. The aim of this fancy initiative is to facilitate loans allocation, guarantee quick financial support to individuals at the community level and provide fair financial support. Includes block chain technology,The project increases transparency and security in loan transactions and also helps in increasing the overall efficiency of agricultural supply chain. The use of block chain in the management of agricultural-food supply chain (SCM) is a developing field, which has attracted attention to both academics and industries in recent years. Research in this field emphasizes the trans-formative capacity of digital and distributed laser technology in developing more transparent, efficient and safe food supply chain. The main benefits include better traceability, reducing transaction costs and improved data integrity – components that are important to build sustainable agricultural methods and ensure accountability in supply chain**[26-28]**.

**Integrating Block chain and Emerging Technologies in E-Agriculture Provisioning Systems**
In many developing countries, agricultural supply systems have not yet fully developed, which is creating obstacles in effective resources distribution and information organization. In the electronic agricultural supply system (EAPS) block chain technology inclusion presents a promising method to improve the efficiency, safety and durability of agricultural activities. Block chain can reduce corruption and fraud activity by providing a transparent and safe system for monitoring transactions and resources**[29,30]**. The integration of block chain with the Internet of Things (Io T) increases the effectiveness of the agricultural system. It increases transparency, traceability and operational functionality in food supply chain. Despite that, certain technical and infrastructure problems need to be solved to achieve its full potential. Moreover, the use of decentralized data structure such as indicated acyclic graph enables safe and transparent monitoring of resources, data and financial transactions. Intelligent agreements have the ability to automate and apply contracts between parties, improve processes and reduce manual involvement. Sophisticated systems like smart agricultural technology integrated with IOT, block chain and Edge computing provide advanced functionality for managing environmental and agricultural information. These systems provide immediate supervision and delivery information management facilities, promoting more powerful, flexible and smart agricultural methods**[31,32]**.

**Smart Farming and Vision-Based Disease Detection in Agriculture**
Common methods of detection of crop disease usually depend on visual tests and skills of farmers and agricultural experts. Although effective in certain situations, these methods require considerable time and labor, which makes them unrealistic for extensive agricultural enterprises. To overcome these limitations, smart agricultural technology has been created, using automation to improve disease detection efficiency and accuracy.Intelligent Agriculture brings together the Internet of Things (IoT) sensors, cloud computing and artificial intelligence (AI) to immediately collect and test agricultural information. It allows for improved supervision and decision making based on information. In different methods, vision-based techniques are extremely important for detection of crop disease. These techniques use drones, satellites and ground cameras to get pictures evaluated for the initial indicators of the disease.Image analysis includes the use of image processing (IP), machine learning (ML) and Deep learning (DL) techniques. In recent decades, image processing has become important to test complex agricultural images by providing complex methods such as improvement, recovery, contraction and division. These methods improve the quality of the photo and enable precise drainage of important features, even from the solid visible background, resulting in the detection of disease more accurate and effective**[33-35]**.

**Systematic Literature Review on AI-Based Plant Disease Detection**
A thorough literature was reviewed using the PRISMA (for preference report items and methodological reviews and meta-analysis) structure to discover relevant research on plant disease identification with artificial intelligence. The review process began with identification of nearly 900 research articles obtained from credible academic databases such as Google Scholar,IEEE Explore, Science Direct, Sc-opus and ACM Digital Library. Inquiries a wide range of keywords were used including agriculture, artificial intelligence, plant disease identification, image processing, deep education, machine learning, Io T, fusion, self-supervised education, few shot learning, attention process, generative adversarial network and data growth. To improve the reliability and accuracy of information, find the similarities of & note reference management software were excluded duplicate entries using functions**[36-38]**. Other studies carried out three-stage boycott process. Among the criteria were: (i) excluding work that is not related to artificial intelligence, (ii) excluding study without relevant significance of plant disease identification, and (iii) excluding articles that lack adequate or complete information. This strict filtering method has excluded 360, 157 and 216 articles at each stage. In the end, a total of 112 research articles were selected for deep testing in the study**[39,40]**.

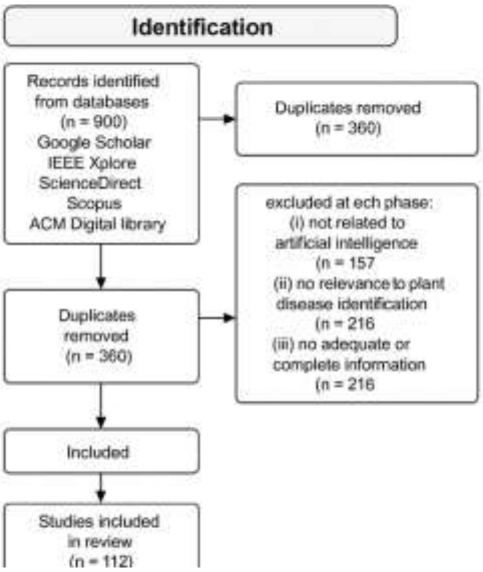


**Fig. 3.AI-Based plant Disease Detection**

### Integration of Advanced Technologies for Sustainable Agricultural Practices

Implementation of artificial intelligence and automatic technology in agriculture is transforming conventional methods into a more durable and efficient system. The irrigation system powered by AI, drought-resistant plant and soil preservation method is essential for maximizing water efficiency and preserving soil health. Implementation of artificial intelligence and automatic technology in agriculture is transforming conventional methods into a more durable and efficient system.The irrigation system powered by AI, drought-resistant plant and soil preservation method is essential for maximizing water efficiency and preserving soil health. Agricultural Robotics: Contemporary Agricultural Robot, known as Agricultural Bot, is designed to operate various kinds of agricultural activities independently or with little human support. These robots can plant the right seeds, ensure the right interval and depth for the growth of crops. Sophisticated sensor, they evaluate the status of the soil and apply the fertilizer specifically in the case of the necessary, resulting in reducing waste and environmental damage**[41-43]**. Also, these robots collect real-time information about soil humidity, nutrient levels and other things, which facilitate information-based preferences for irrigation and nutrition management. Customizing robotic functions to meet the needs of specific crops improves their efficiency and effectiveness in different agricultural environments. Grain and soil surveillance: Running monitoring of grain and soil is essential to make informed decision making and maximize yield. Technology such as high-resolution imaging and sensor-censored satellite and drone provide deep information about the health, growth trends and soil conditions of crops. Internet of Things (Io T) is very important for tracking soil humidity in different depths, which allows for proper irrigation management. Sensors are able to detect crop pressure, illness and nutrient deficiency by checking chlorophyll density and leaf temperature. Moreover, soil nutrition sensor helps optimize fertilizer application techniques for growth of nutrients of plants.Implementation of artificial intelligence and automatic technology in agriculture is transforming conventional methods into a more durable and efficient system**[44-46**].

### Smart Horticulture and Block-chain-Driven Agricultural Supply Chains

Parking has remained one of the most important agricultural areas worldwide, with increasing attention being given to incorporating advanced technology to improve production and delivery methods. Intelligent Garden involves a mixture of technology, equipment, communication standards and computational systems designed to improve various kinds of agricultural activities. Technologies, including block chain, Big Data Analytic s, Artificial Intelligence, Cloud Computing and Edge Computing, provide important functions for storing, management and analysis of large amounts of data produced in the parking system.An important use of these technologies is in the agricultural supply chain, which tracks the route of product from farmers to buyers. The supply chains powered by block chain provide a decentralized and transparent system that connects between different participants of the agricultural ecosystem. This method eliminates the requirements of centralized entity, intermediary and conventional record-keeping procedure. By improving the integrity, accountability and security of information, block chain builds a reliable and powerful agricultural supply chain, thereby increasing the operational efficiency and increasing the trust of consumers**[47-49]**.

**The Role of Smart Farming in Addressing Future Food Security Challenges**

By 2050, the global population has been predicted to be around 10 billion, so sustainable and innovative agricultural methods are very important to meet the growing food demand. The current trend of agricultural production is insufficient to hold this expected growth, which highlights important requirements for changing food production methods. Like the Agricultural Revolution that happened in the 1970s, new emergence of technical innovation is essential to ensure global food security, encouraging sustainable use and improve public health and wellness**[50,51]**. New technology is increasingly essential for sustainable agriculture to reduce dependence on natural resources such as water, fertilizer and agriculture chemicals.Equally important is the environmentally friendly system that prevents the invasion of crop waste and insects, resulting in losses after harvesting and prolongs the lifespan of the food. Together, these progresses come under the smart firming department. Intelligent uses sophisticated technology to improve the agri-farm method. The most important progress include the use of low-height aerial hypercritical imaging for crop health evaluation to track environmental and soil conditions. Agricultural-food technology companies are actively developing and implementing these technologies, as well as automation and data-driven solutions, indicating a significant change towards a more efficient and elastic food system**[52-54]**.

**Empowering Agriculture Through Technological Integration**

The impact of technology in different industries is inevitable, and agriculture is associated with this change. The integration of new technologies has led to significant changes in agriculture over the years. Among these, block chain technology has become a key component of agriculture transformation and improvement by providing new structures for connectivity, transparency and efficiency. Block Chain facilitates the complete conversion of agricultural process, increasing data management, traceability and trust in the supply chain.The current challenge is to ensure that these technologies are available and used properly by farmers. In everyday agriculture, incorporating sophisticated technologies such as artificial intelligence, machine learning, neural networks and deep education is becoming increasingly practical, resulting in user-friendly user interface being created like mobile applications. Unlike previous restrictions, farmers are now increasingly interested and interested in searching and implementing digital solutions. This change is inspired by the ability to greatly increase the productivity and functionality of these technologies. Democracy in agriculture is not only stopping the division between innovation and practical application but also enabling farmers to be more involved in a data-centrist, elastic agricultural system**[55-57].**

**Advancements and Applications of Block chain Technology in Supply Chain Management**

Block chain technology has stimulated global interest due to its essential functionality in cryptocurrency networks and its wide use in multiple cases. Initially launched as a digital record for cryptocurrency, it includes various technologies including unlimited encryption, distributed network, peer-to-peer communication, smart contracts and consensus protocols. These elements guarantee safe, irreversible, verifiable and timestamped transaction records together, creating decentralized beliefs without relying on intermediaries. In addition to its financial root, block chain is being investigated in various fields, such as supply chain administration, healthcare, energy and development of smart cities. Its basic features – decentralization, transparency, stability, ignorance and audibility – put it as a best solution for high level demanding settings of confidence and traceability**[58,59]**. In supply chain management, block chain offers a communal digital laser that is consistently kept current and updated by a decentralized network of nodes. Each transaction needs to be confirmed by the network before permanently recorded in the laser. This method allows real-time monitoring and transferring property ownership within a safe, transparent and temper-resistant structure. Implementation of block chain in supply chain increases the operation efficiency, increase the product traceability and reduces dependence on centralized authorities or intermediaries. This research attempts to evaluate existing environment, potential application and future pathways of block chain adoption in supply chain system**[60,61]**.

**Integrating Artificial Intelligence and Block chain for Decentralized Data Sharing**

The proposed structure provides a integrated method that combines artificial intelligence (AI) with block chain technology to improve decentralized data management and distribution. In this structure, block chain acts as a public register that document each transaction and activity within a network node. Each transaction recorded by any node can be viewed and confirmed by all other nodes, which promote significant transparency and belief. An essential element of the structure is the idea of using shared education, where knowledge a This is possible due to the decentralized laser of the block chain, which allows each node to learn group learning without going through separate training activities. The decentralized and protected features of the block chain ensure that each verified update or transaction is synchronized quickly within all the involved nodes, preserving data compatibility and integrity. A trained entity – such as a vehicle – the data required by – spread across the entire network. This is possible due to decentralized laser of block chain, which allows each node to learn group learning without going through separate training activities. The decentralized and protected features of the block chain ensure that each verified update or transaction is synchronized quickly within all the involved nodes, preserving data compatibility and integrity. This system acts as an integrated digital record, where each node contains a uniform version of the laser. Any messages or transactions that started by a node are quickly displayed across the network, which includes nodes that directly participate in interaction. This wide visibility guarantees smooth data sharing, which is very important for the purpose of collaborative intelligence and effective learning structure across the entire system. In short, the block chain's irreversible record-maintenance combined with AI's flexible learning capacity creates a strong foundation for safe, clear and smart data management in decentralized settings**[62,63]**.

**Human Cyber Physical Systems (H-CPS): A Synergistic Integration of Human Intelligence and Technology**

Human-Cuba-Physical System (H-CPS) is composed of three-level architecture, including human, network and physical system components. This model highlights the collaborative interaction between people and machines, whose aim is to improve the working efficiency while saving human skills. Instead of working autonomously, each level of the system plays a distinct role in increasing overall performance: physical systems work and collect data; network systems manage data analysis and counting; and human contributors provide decision-making skills and special knowledge. First, H-CPS architectures facilitate smooth machine integration and automatic activities using industrial Io T devices and cloud platform, where human efficiency acts as a key component of system. With the advances of time, technology innovations such as block chain and artificial intelligence have been integrated into H-CPS. Block chain improves system-level solidarity and precision, where AI brings self-education features, which gives sophisticated analysis and cognitive abilities. As a result, the basis of contemporary H-CPS knowledge is influenced by human contributions and intelligent systems that can learn and adapt, even integrating underlying or silent knowledge that can be difficult to express. In this advanced structure, people take the role of creators, caregivers and operators, their skills are increased by the technical structure of the system – thereby increasing productivity and making decisions are more efficient**[64-66]**.

**Towards Agriculture 4.0: Advancing Industrial Agriculture through Technological Integration**

Although significant improvements have been, industrial agriculture is still facing ongoing problems, such as environmental damage, slow digital adoption, food safety concerns and inefficiency in agriculture-food supply chain. The current fourth industrial revolution, called Industry 4.0, brings a mixture of landmark technologies such as the Internet of Things (Io T), robotics, Big Data Analytics, Artificial Intelligence (AI) and block chain. These progresses are pushing industrial systems towards greater autonomy and intelligence. Incorporation of the concept of Industry 4.0 in agriculture – known as Agriculture 4.0 – provides a revolutionary opportunity to address the current challenge in industrial agriculture. Using these technologies, Agriculture 4.0 facilitates the spatial-time data collection, processing and testing of high-resolution spatial-related data at each stage of agricultural price chain, including production, processing, distribution and consumer interaction. This progress promotes a durable, information-based ecosystem that is characterized by real-time farm administration, wide automation and smart decision making. These progresses will greatly increase productivity, increase agricultural-food supply chain efficiency, strengthen food protection systems and maximize the use of natural resources, leading to more elastic and future-based agricultural industries**[67,68]**.

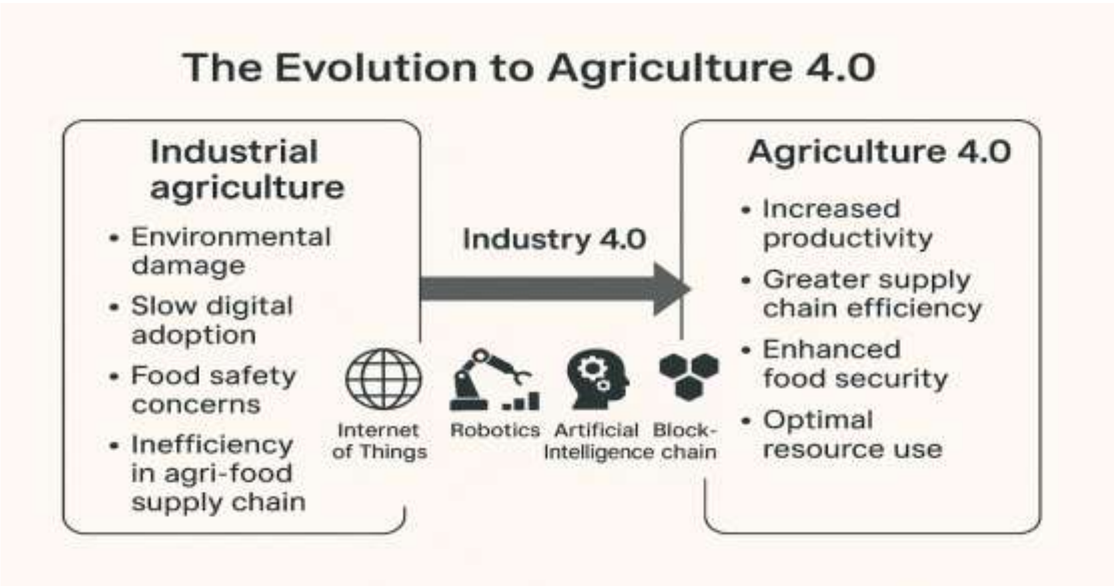


**Fig. 4.The Evolution to Agriculture 4.0**

**Sustainable Energy Solutions for Agricultural IoT Systems**

Effective short-energy sensation is essential in agriculture, where sensors are often placed in difficult situations such as underground, submerged, plants, or planted with animals. These situations make regular battery replacement impossible. Wireless Power Transfer (WPT) has been seen as an optimal solution, allowing sensor battery recharge through electromagnetic wave. Nevertheless, numerous agricultural conditions require long-distance WPT and are continuing to create a major research barrier to efficient energy transfer in harsh environments. Recent progress has led to the introduction of Photovoltaic Agricultural Io T system, which combines agricultural production with local energy production. In this kind of system, wireless charging units distribute power to sensors, but the schedule of energy allocation remains complicated due to the variation of sensor type and usage types in agriculture. Moreover, ambient energy collection has been investigated as an effective durable alternative. Testing configurations showed that sensor nodes can use energy from environmental sources such as river currents, liquid speed, vehicle activity and surface vibration. Despite that, existing limitations of energy conversion skills limit the practical use of these techniques, which highlight the need for additional research to improve electricity production and reliability to implement the Agricultural Internet of Things (Io T)**[69,70]**.

**Applications of Block chain Technology in Sustainable Systems**

Block chain technology acts as a distributed network that uses encryption to manage, hold and share information safely without relying on any central authority. By spreading data across the network of nodes, block chain improves transparency and reduces the chances of data tempering or manipulation greatly. The immutability of the system ensures that once the data is logged, it cannot be changed without the agreement of the entire network. In addition to its essential functionality in secure digital transactions, block chain facilitates automation of processes through smart contracts performed on peer-to-peer (P2P) networks. These self-enforcement agreements facilitate reliable, trust-free exchange among participants, making block chain extremely relevant for multiple industries. In supply chain management, block chain products cover their entire life cycle – from source to end consumer – allow real-time monitoring – guarantees authenticity, ethical sources and traceability.Opening this level enables customers to get a wide range of details of products, help informed preferences and encourage responsible use. In the case of waste management, block chain technology can increase traceability by documenting waste transportation and tracking, promoting accurate extraction and recyclable enterprises and reducing illegal dumping activity. It helps protect the environment and promotes the rules to comply. The power industry significantly benefits from the progress of block chain technology. Block chain enables decentralized energy transactions, which allows individuals and communities to transact extra renewable energy. These platforms increase fuel freedom, improve grid reliability and help in greater implementation of clean energy technology. Block chain facilitates the establishment of decentralized fuel market, gives customers the opportunity to profit from surplus fuel, encourages more durable and incorporated fuel ecosystems**[71-73]**.

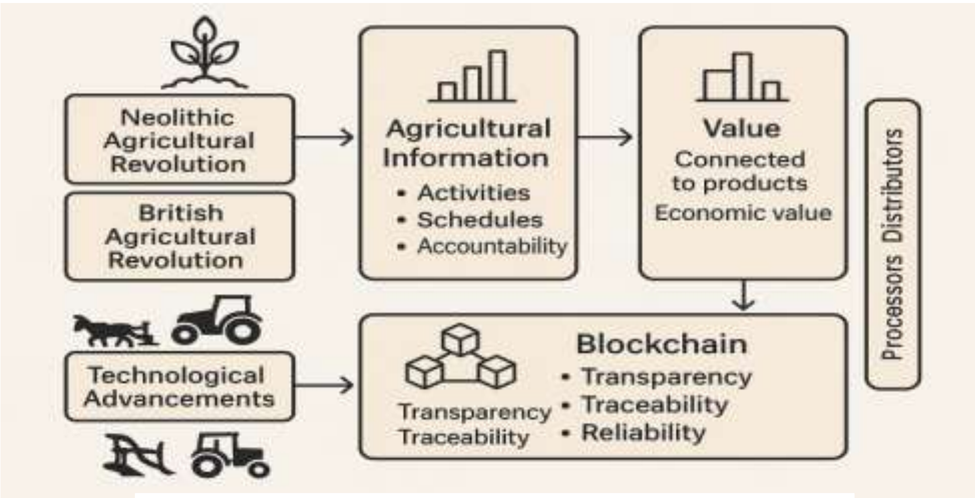


**Fig.5.Block Chain Technology in Sustainable Farming**

**The Evolution and Technological Advancement of Agriculture**

Agriculture is one of the oldest landmark technologies of mankind. The New caste Agricultural Revolution began the rise of the permanent community, where the British Agricultural Revolution of the 18th century created the stage of the Industrial Revolution (Russel, 1966). As a practice and technology, agriculture continues to advance through practical search about which crops and animal husbandry are rich in special environmental and management situations. Contemporary agricultural practices in countries such as Australia depend heavily on nonnative species, which highlights the adaptive features of the agricultural system. Technical progress has continuously improved agricultural production. From primitive machinery such as seed drill and steel plow, to advanced agricultural methods such as steel harvesting machinery, and grain rotation and organized animal husbandry management, technological progress has become very important (Grilliches, 1957; ET Al., 2010; Pots and Castle, 2017). These advances have increased the opportunity to convert the necessary agricultural materials into valuable products such as grain, cotton and fur, including seeds, animals and capital. Currently, the concept of agricultural productivity has only gone out of real products. Farms create extensive calculation of agricultural activities, schedules and accountable individuals – information – which contains economic value when connected to the products that come out of the farm. This information supply chain is essential for partners in chain, such as processors, distributors and consumers. To retain the price of this information, it must be not only present but also credible. Innovative technology such as block chain provides a new way to improve the transparency, traceability and reliability of agricultural information, thus reducing the cost of transaction related to information sharing and strengthening the connection between farms and larger markets**[74-76]**.

### Understanding Distributed Ledger Technology and Block chain: A Decentralized Framework for Trust and Transactions

Distributed Laser Technology (DLT) acts as a digital system for documenting, sharing and refreshing a laser documenting, sharing, and refreshing at multiple places at the same time. This distributed structure enables data duplication and synchronization between different nodes in a peer-to-peer (P2P) network controlled by open-source protocol. Unlike the centralized system supervised by a single entity that operates the laser, DLT is autonomously verified through consensus methods such as voting algorithms. This method ensures that each involved node supports a uniform and valid copy of the laser. Block chain is an independent application of DLT that defines a data structure connected through cryptography. Initially imagined by Nakamoto (2008), it works using processes like work proof and includes digital currencies such as bitcoin. The essential components of block chain technology include public key cryptography, peer-to-peer networking, distributed database, game theory and consensus algorithms. Combined, these components create a strong structure for safe and decentralized data management. The importance of DLT is found in the power of supporting a current, synchronized, protected and reliable laser independent from a central authority. Unlike the conventional system depending on 'trusted intermediary' to verify and document transactions, block chain systems remove this dependence, which makes direct peer-to-peer price transfer possible.This is why block chain is often referred to as "unbelievable technology" – not because of the absence of trust, but because of the reorganization of faith. The belief is made through technical protocols and consensus process instead of institutional intermediaries. As proposed by Berg ET Al (2019) and Warbach (2018), the block chain presents a new structure of belief. It enables strangers to conduct safe transactions without reliance on mutual trust or third party entities such as banks, brokers or government institutions. This change has significant impact on how society operates and legalizes social and economic transactions**[77,78]**.

### Block chain Applications in Agriculture: Transforming Trust, Transparency, and Supply Chain Integrity

The use of distributed laser technology (DLT) in agriculture indicates a new type of automation and industrialization, which is different from conventional mechanization. What's being automated here is not manual labor, but also create and verifying confidence on social information. DLT, especially using block chain technology, is creating a new trust framework – which verifies data, maintains analytical integrity and presents data usage processes (Werbach, 2018; Van Rizmenam and Ryan, 2019). Block chain technologies do not provide legal ownership but create rights like property on data, facilitating safe, traceable and verifiable transactions. This change raises important ethical problems related to data privacy, digital equity and moral use of data. Nevertheless, these problems are not exclusive for block chain and reflect the difficulties already encountered in terms of tracking, compliance confirmation and monitoring of origin in the agricultural supply chain. One of the main expected benefits of block chain use is its ability to reduce fraud in agriculture-food systems. It can help tackle fake labels and fraudulent claims related to features such as durability, fair trade certification, or origin. Through improved traceability, block chain can greatly reduce threats to food security violations and public health. Companies like IBM, through their food-trust platform and agricultural business like Car-Gill, which has launched block-chain-based turkey traceability initiative, depicting this technical transformation. These systems enable accurate and quick product withdrawal when pollution occurs, resulting in massive disruption and delay prevention. The introduction of block chain and DLT can not be expected to cause physical or environmental damage directly in rural areas. Nevertheless, these technologies are made to convert business models through intermediate isolation, meaning eliminating conventional intermediaries. Although automating certain terms can temporarily affect jobs, the overall effect is reduced in relation to creating confidence, which result in improving economic efficiency and stability across the agricultural price chain. Economically modelling these structural changes can help them predict their range and results. Customers are ready to benefit greatly from this digital transformation – not only reduces trust spending resulting in product prices but also through increased access to trusted product information. Block chain technology increases the transparency and credibility of agricultural information, allowing customers to make knowledgeable decisions through tools such as applications or digital assistants that authenticate block chain entries. It increases the freedom of customers by reducing dependence on corporate promotion or government messages, thereby making access to accurate product information democratic**[79,80]**.

**Integrating Block chain, Smart Contracts, and Io T in Smart Agriculture: Enhancing Transparency, Efficiency, and Trust**

The integration of block chain technology in smart agriculture carries revolutionary commitments for the industry, which provides a decentralized and safe system for farming information and transactions supervision. Block chain facilitates clear and secure monitoring of food supply chain, increasing confidence between producers, consumers and different partners. The necessary agricultural information such as soil health, climate situation and yield results permanently documenting block chain decisions and functionality as a reliable resource to improve effectiveness. The use of smart contracts based on block chain automatically automatically transactions and improves agricultural activities by reducing dependency on intermediaries. These agreements enable fast and safe payment, reduce the possibility of fraud and simplify disposal processes, resulting in a more equitable price determination system for farmers and increase consumers' confidence about product quality and origin. Despite the progress of agricultural machinery, the industry is relatively slow in adopting new digital technology, especially after harvesting time and harvesting. This delay has led to indefiniteness, including low payment to farmers, high price for consumers and insufficient search ability for food content. Smart contracts and Internet of Things (Io T) combine block chain with devices, it is possible to automate and oversee the entire process from agriculture growth to delivery, at the same time, to create verifiable confidence among all partners of the price chain. This study recommended structure is based on block chain technology, using IOT devices to collect real-time field-level data. Smart contracts are used to manage interaction between parties involved and automatically execute the contract. The study provides a wide example of setting up the system, integrating assessment of gas costs associated with block chain operation, increasing the understanding of economic potential. Through this integration, agricultural industry can benefit from improved data protection, operational transparency and irreversible record-keeping. The results of this study emphasize the significant potential of integrating block chains, smart contracts and IOT to further efficient development in this agriculture**[81,82]**.

**Block-chain-Enabled Cloud and Edge Infrastructure for Secure and Saleable Io T Networks**

The inclusion of block chain technology in the cloud and Edge computing structure has attracted significant attention as it is able to improve data protection, integrity and transparency. This method is particularly effective in case of distributed cloud storage, where information can be kept across numerous decentralized nodes worldwide. This kind of decentralization guarantees data redundancy and fault tolerance, and at the same time greatly improves the entire protection structure by removing dependence on centralized companies. In cloud settings powered by block chain, smart IOT devices can search for resources controlled and edited through smart contract algorithms.These intelligent contracts automatically facilitate service performance and transaction disposal, increase efficiency and reduce dependence on intermediaries.Users maintain full authority over their personal keys and data on each block chain block is securely encrypted, ensuring privacy and trust without third party intervention. Moreover, block chain enables immediate monitoring and verification of resources usage and service-level agreement (SLA) between clients and service providers. This accountability system improves the quality of service with the guarantee of consistent performance of contractual responsibilities. In order to successfully establish a safe and saleable Internet of Things (Io T) structure, especially one that uses Edge Computing, should comply with various architectural guidelines. This includes: high-efficiency Edge computing: the system should be able to quickly process and analyze data on the network edge to reduce the latency and increase performance. Scalability: Infrastructure must be formed to manage the growing amount of Io T devices by maintaining performance and security.Security-centrist techniques: strong encryption, authentication and access control protocols should be integrated with the system to keep data secure and ensure the integrity of the device. Service-based Architecture (SOA): Implementing SOA allows for creating and manage modular, adaptive and protected services designed for various Io T applications. Interactivity: To ensure overall efficiency and protection, smooth communication and data exchange between different devices and services must facilitate. Remote sensing technology is essential in this structure, which facilitates the running and precise monitoring of environmental and system variables. Together, these elements encourage to create a powerful infrastructure capable of meeting the changing challenges and requirements of contemporary IOT ecosystem**[83,84]**.

**Applications and Techniques of Image Processing in Smart Agriculture**

Image processing includes computer-based changes in digital image to collect significant data or create improved visible results. This field includes a wide application in medical diagnosis, geological research and growing intelligent agriculture. In agriculture, image processing methods are used to identify parts of damaged plants such as leaves, tuberculosis and fruits and evaluate diseases spread in the field or to estimate the weight of fruit. The basic process of image processing begins by converting an image into a numerical matrix, where each pixel is depicted by a specific value. Various algorithms are systematically applied based on desired results in these matrices. One processes are performed in each pixel to change desired image or achieve data recovery one after another. Numerous basic methods of image processing apply especially in agriculture: Image enhancement: This method increases visible transparency of the image by modifying general distortions such as Gaussian words, contrasting discrimination or blurring. Advanced techniques may include sound reduction, sharpness, change of brightness and contrasting growth so that more suitable images can be created for human understanding or automatic evaluation. Picture Recovery: Recovery methods try to recover pictures that have been degraded or contaminated due to problems such as camera settings, external hassle or change over time. The goal of these techniques is to make pictures possible to recover the quality created for their original purpose, to use additional processing or evaluation. Picture Compression: In order to increase storage efficiency and reduce the duration of transmission, picture shrinkage is used to reduce the size of file during storage quality saving. It is especially important for sending agricultural images through remote sensing system or online platform where bandwidth and storage limitations exist. Together, these methods facilitate proper tracking, diagnosis and decision making in agriculture, which helps in evolution of information-based agricultural practice**[85,86]**.

**Security Challenges and Threats in Smart Farming Systems**

The addition of sophisticated technologies such as Internet of Things (Io T), Cloud Computing and Networking in smart agriculture creates numerous security vulnerabilities underlying these technologies. As a result, intelligent agricultural systems are becoming more risky for numerous cyber and physical hazards. A major problem is node capture, where harmful individuals can physically interfere with Io T devices or replace, which endangers the integrity of the system. Also, attacks such as service denial (Dos) and sleep deprivation can quickly eliminate the battery of Io T devices, which disrupt the ongoing transmission of data and interrupts real-time decision making activities.Due to technical limitations, Io T sensors in agriculture can often not be placed in protective coating, which has the risk of environmental impact and interference.Moreover, these systems typically require specialized installation and supervision, which creates concerns about practicality and technical challenges associated with wide implementation. Interconnection of smart devices creates substantial threats to data privacy and system protection. A single device violated can act as access points for hackers, which highlights the importance of strong cybersecurity systems.Energy efficiency is still an important thing, because most sensors run in batteries that cannot be replaced. Therefore, it is essential to optimize energy use in implementing smart agriculture and to take sustainable extraction or recycling methods. Considering the wide nature of rural agriculture regions, providing complete physical security is challenging in both logistic and financial aspects. Although security cameras can oversee important fields, it is not possible to keep the entire farm secure. Integration of advanced technologies such as Internet of Things (Io T), Cloud Computing and Networking in smart agriculture introduces various security vulnerabilities associated with this technology. As a result, smart agricultural systems are becoming increasingly sensitive to various cyber and physical threats. A significant concern is node capture, where harmful individuals can physically heater or replace Io T devices, which threaten the integrity of the system. Moreover, attacks such as service denial (Dos) and sleep deprivation can quickly end the battery of Io T devices, disrupt current data transmission and disrupt real-time decision making processes. Due to their technical limitations, Io T sensors used in agriculture can often not be placed in protective enclosure, resulting in environmental exposure and disruption risk. In addition, these systems typically require specialist installation and management, leading to concerns about potential and technical difficulties associated with large range of deployment. Smart device’s network data also creates significant risks for privacy and system protection. A single compromised device can act as an entrance point for attackers, which emphasizes the need for powerful cybersecurity protocols. Most sensors remain as an important concern for energy efficiency because they work on non-replaceable batteries. Therefore, it is important to maximize energy efficiency and adopt sustainable waste extraction or recycling method to implement smart agriculture. Due to the huge expansion of rural agriculture, ensuring massive physical safety is difficult in both logistic and financial aspects. Although security cameras can monitor important places, it is unreal to keep the whole farm secure**[87,88]**.

**Applications of Machine Learning and Artificial Intelligence in Smart Agriculture**

Artificial Intelligence (AI) equipment to address various problems in the agricultural industry, such as machine learning (ML), specialist systems and image processing, being used gradually. These methods help create intelligent systems that can improve agricultural production, efficiency and decision-making process. AI’s

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effectiveness has been shown in the application for smart farming in recent studies. For example, Shakil and other [183] have launched a deep teaching model aimed at classifying cattle behavior, improving animal husbandry monitoring. In the same vein, duwara and others. [184] Using random forest classification and deep learning methods mixture for crop classification, gaining extraordinary accuracy of 95.45%. In a different study, Rahman and others have used the decision tree, K-nearest neighbor (KNN) and random forest algorithms to classify mushroom species, which achieved the accuracy of 100% of the classification. The quoted research table outlines the complementary AI methods and their performance indicators in 6 and 8. Interestingly, junior and others [185] have demonstrated better results in spectrum, classified and DBSCAN clustering functions with decision trees and KNN algorithms, which exceeded other models in terms of classification accuracy. Sharma and others. A deep analysis has been provided with emphasis on the important impact of machine learning on accurate agriculture. Their results show that data-driven methods greatly improve both the quality and quantity of agricultural outcomes. In case of forecasting the growth of crops, techniques such as KNN, logistic regression and ensemble classifier showed encouraging results. Linear regression is usually used to predict agricultural results based on climate related issues such as precipitation, temperature and humidity. Deep teaching models have demonstrated extraordinary performance in agricultural datasets for work such as weed detection, image classification, division and object tracking. Moreover, the classification of insects and neural networks, KNN and Naive Bayes are being successfully used in classification, experimental results often show accuracy rate above 90%. These developments highlight the important importance of AI in the continuous progress of smart agricultural systems, which provide saleable and accurate solutions for sustainable agricultural methods**[89,90]**.

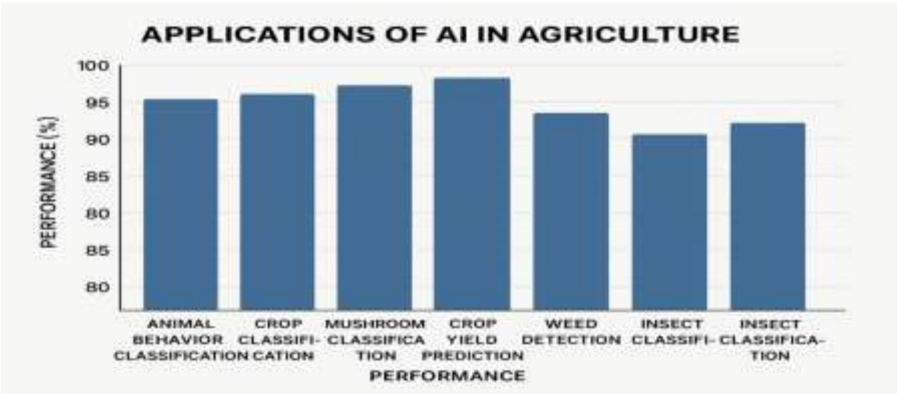


**Fig. 6.AI in Smartagriculture**

**Descriptive Statistical Analysis and Text Mining for Block chain and Artificial Intelligence Research in Agriculture**

Description statistical techniques were used to display the space of research related to block chain and artificial intelligence (AI). Results obtained from literature collected to improve the analysis method were depicted using images and graphs. At this point, text mining methods were used to provide a comprehensive summary of research on block chain and AI in agriculture. NVivo 12 software was used in the text mining method, which focused on journal articles in line with the research subject. The results of this analysis showed sound clouds and bunch trees that apparently depicted keyword frequency and subject-based format in literature. These visual aids have facilitated more detailed integration of the research environment. The synthesis stages included deep analysis of the role of each article in agriculture, as well as difficulties facing this technology. Using the data obtained from descriptive and text mining analysis, research proposals were made to help in the progress and implementation of block chain and AI technology in the local agricultural industry**[91,92]**.

**Research Opportunities in the Integration of Block chain and Artificial Intelligence in Agriculture**

The combination of block chain and artificial intelligence (AI) demonstrates strong scientific justification and significant relevance in multiple industries such as agriculture. The integration of these two technologies still has huge research opportunities, especially in agriculture. A critical test shows the current state of research on block chain and AI in agriculture, where most block chain-related research emphasizes on agricultural supply chain management,

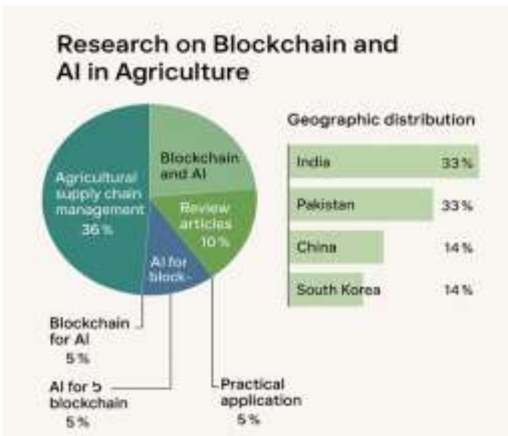


**Fig. 7.Block chain and AI in Agriculture**

representing 36% of literature. Focusing on the combination of block chain and AI in agriculture constitutes 20% of researchtested, equally divided between review articles (10%) and practical application (10%). In the application case, 5% of research investigate block chain use to improve data protection in intelligent system (block chain for AI), where another 5% focus on AI's use for block chain to increase block chain efficiency (block chain for AI). In this case, the spatial expansion of research activities shows the preference of information obtained from Asian countries, especially India (33%), Pakistan (33%), China (14%) and South Korea (14%). It highlights growing regional enthusiasm and knowledge in smart agricultural technology. There is a significant lack of research in the combined use of AI and block chain in agriculture. Different AI systems can be used to improve smart agricultural techniques, while block chain technology provides potential progress in data protection, especially in case of overcoming centralized AI system errors. Future research should emphasize the identification and implementation of technology that meets user requirements, to ensure that innovations provide real benefits for all agricultural participants**[93,94]**.

**Conceptualizing Agriculture 5.0: Personalized Digital Transformation in Farming**

Agriculture 5.0 indicates the upcoming progress of agriculture, which is characterized by customized application of digital technology fit with special circumstances in the field of individual, animals and agriculture. This developed model integrates flexible and made techniques, improves and exceeds traditional accurate agriculture by using artificial intelligence, Big Data Analysis and sophisticated technology such as automation. At its root, Agriculture 5.0 aims to include digital technologies with complex mobility of agriculture, so that resources can optimize, improve productivity, and encourage environmentally sustainable practices on small scale. It emphasizes the supply of smart, information-consumed equipment to meet the unique needs of their agricultural environment. In addition, agriculture 5.0 is not only technical progress but also involves a wide change that changes behavior among partners and adopts these technologies more. The change in this advanced agricultural model is composed of a combination of personal, technical, institutional and policy-related material. As a result, agriculture 5.0 not only includes the progress of digital technology, but also the sociolect-economic-technical transformation required to expose its potential to agriculture**[95,96]**.

**The Evolution of Agricultural Technologies: From Traditional to Smart Agriculture**

Over time, technical innovation has brought profound changes in agriculture, including the development of plow and the use of livestock, which has greatly improved the skills associated with handheld agriculture. However, the most important change occurred through the Green Revolution in the 1950s, when the inclusion of advanced mechanization technologies such as tractors and specific agricultural equipment, with significant growth in agricultural production, with the advancement of agricultural chemicals and crops and animal husbandry. This change indicates the transfer of agriculture from conventional agriculture, called Agriculture 1.0, to agriculture 2.0. Since the introduction of Agriculture 2.0, significant technical progress has had a huge impact on agriculture. The advent of satellite technology such as the Global Navigation Satellite System (GNSS) and Earth monitoring satellite, with the advances of computer science, initiated agriculture 3.0, also known as accurate agriculture. Agriculture 3.0 has emerged as a solution to environmental and health problems arising as a result of excessive use of agricultural materials. Agriculture 3.0 has significantly reduced the use of resources (such as pesticides, fertilizers, water, energy and labor), which has given resources more efficient and centralized application, at the same time preserving or even increasing agricultural production. Agriculture, known as digital or smart agriculture, has transformed industry into 4.0, integrating advanced technologies such as artificial intelligence (AI), Big Data, Internet of Things (Io T), Virtual and Augmented Reality (VR/AR), 3-D printing, quantum computing, block chain and robotics. These advances have opened the way for more sustainable agricultural methods. Despite this, global food safety (e.g., 60% growth requirements in food production by 2050), reducing the impact of climate change (e.g., reducing greenhouse gas emissions), protecting the environment (e.g., reducing soil and water pollution), and increasing public health (e.g., reducing pesticides application) is very important to include these technologies in effective, real-world agricultural systems**[97,98]**.

**Defining Agriculture 5.0: The Future of Sustainable and Smart Agricultural System**

By expanding on precise agriculture based on what, where and when, agriculture 5.0 can be identified as a sustainable agricultural system that is environmental, economic and socially responsible, using advanced technology, all things, everywhere and always work." "All the term refers to the broad interconnection implemented in Agriculture 5.0, where all physical and digital material, including sensors, robots, agricultural equipment and people, facilitates the transfer of smooth data of agricultural activities, creating insights and effective management." "Earth referred to the extensive use of agriculture 5.0, which is both internal and outdoor, and takes advantage of advanced technologies such as in various geographical regions, such as urban, rural and coastal regions, 6G and non-ground networks." "Always relates to the continuous and reliable functionality of Agriculture 5.0, which ensures stable connections and performance in all settings every day." As a result, agriculture 5.0 Industry 5.0 and society 5.0 were expanded on the technical progress of Agriculture 4.0. This integration will create more suitable and effective measures for agriculture and animal production. Agriculture 5.0 Society strives to improve efficiency, productivity and elasticity in agriculture, from agriculture to table, to agriculture, to digital technology, supported by the basic principles of 5.0[99,100].

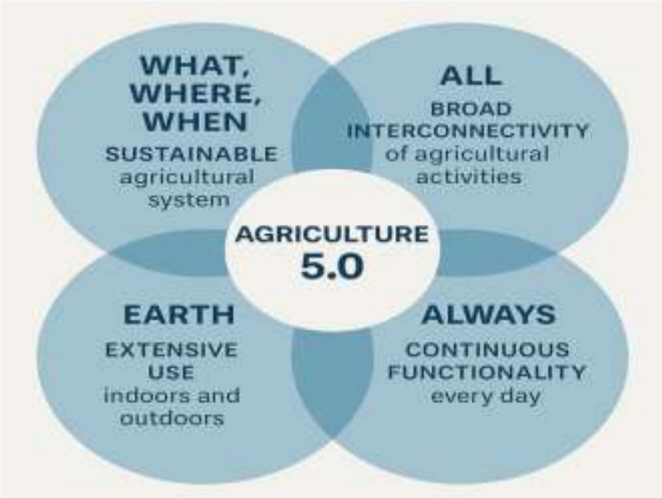


**Fig. 8.Agriculture 5.0**

## CONCLUSION

The search supply of block chain technology in the agricultural sector unveils its significant capacity to address important problems related to the traceability, risk management, durability and overall efficiency. By creating irreversible and clear records, block chain improves confidence and responsibility on agricultural ecosystems, helping producers, consumers and additional partners.Its inclusion with smart contract enables new financial systems, providing access to services such as improved security and insurance and loans, especially for risky small farmers. Moreover, block chain collaborative integration with other advanced technologies such as Io T, AI and large data analysis creates the opportunity to improve smart agricultural techniques and advanced resources management. These integrated systems provide advanced transparency, real-time tracking features and data-informed decisions, which lead to a more powerful and durable agricultural approach. The discussed case studies and theoretical models emphasize the ability of block chain to increase operational skills with increased equity and confidence promotion in the agricultural price chain. Although the use of block chain in agriculture is still in the early stages, impressive benefits shown in different applications indicate that a big change is coming. To achieve the full potential of this technology will be essential to deal with current infrastructure challenges and ensure wide accessibility and usability for each partner. Future studies should focus on dealing with these problems, checking scalability options and exploring deeply on sociolect-economic effects of block chain taking in different agriculture. Finally, the ongoing progress of block chain technology and strategic implementation is essential to create agricultural systems that are more transparent, efficient, durable and elastic, capable of meeting the global food demand of the 21st century.

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