Exploring the Nexus Between Sustainable Agricultural Practices and Blockchain Integration: Unraveling the Influencing Factors

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Abstract
Humanity is significantly affected by agriculture that provides crucial resources but also leads to environmental degradation, deforestation and loss of biodiversity. Sustainable Agricultural Practices (SAPs) came up in the 1980s through conservation agriculture, organic farming and sustainable intensification to address these issues. Nevertheless, the adoption of SAPs has its hurdles derived from personal traits, farm attributes, psychosocial factors and external forces. Notwithstanding its limitations, the Theory of Planned Behavior (TPB) is frequently used for understanding adoption intentions and integrating with other theories. It can be argued that Blockchain technology can transform agricultural supply chains by improving transparency, traceability and efficiency. Its use helps ensure compliance with sustainability standards, better data management as well as automating transactions using smart contracts thus reducing costs that encourage SAP adoption. In future research should focus on closing the intention-behavior gap in SAP adoption in developing countries particularly and how blockchain can further improve the effectiveness and uptake of these practices towards fostering resilient and sustainable agricultural systems worldwide.

Keywords: Agriculture, Environmental Impact, Sustainable Agricultural Practices (SAPs), Theory of Planned Behavior (TPB), Blockchain Technology, Transparency, Traceability, Supply Chain Efficiency, Intention-Behavior Gap, Resilient Agricultural Systems
Jell classification: Q01 Q16 Q57 O33 M15 L14

Introduction

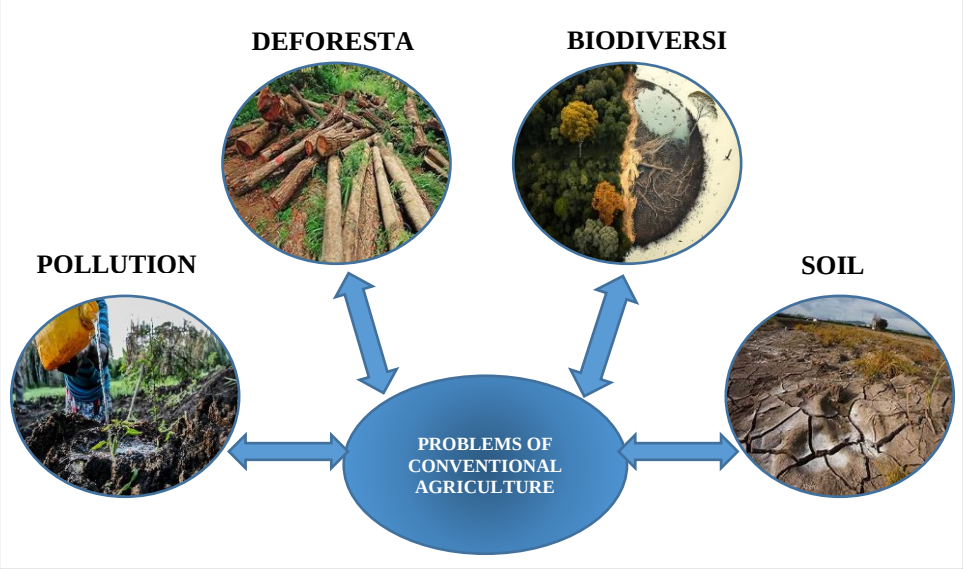
Agriculture impacts all mankind for better or worse. From 1950 to 1980 There was an increase in land conversion farmland in order to feed the increasing Inhabitants [1]. However, this intensification of agriculture has brought about severe environmental problems.

Between 1990 and 2015, the surface area covered by forests decreased by 3% from 4,128 million hectares to 3,999 million hectares which means that agriculture is the major cause of deforestation worldwide [2]. More than half of newly cultivated lands in tropical zones between 1980 and 2000 came at the expense of primary forests, according to a study conducted [3], while another research reveals that this expansion destroyed over one quarter of secondary forests in the region. Deforestation like this results in loss of biodiversity, approximately one million species could be extinct within decades or centuries [4]. Biodiversity refers generally to all variety among living organisms on earth at any level including diversity within species as well as ecosystems themselves, it encompasses different genes among individuals within populations, also various forms of environment where life exists together with their interrelationships such as competition for resources between different kinds of plants and animals etc. When there are fewer types of animals or plants present in an ecosystem then what happens next can't work properly anymore because some parts may stop functioning due its decline. This will affect not only economic systems but also civilizations themselves. Many human societies rely heavily on diverse plant, animal and microbial species which serve both as sources of sustenance food items necessary for survival materials used during construction activities or any other form relating human life with natural surroundings [5].

Climate change is another threat to agriculture. Also, it can be said that agriculture causes climate change as well as being affected by it. In fact, agriculture accounts for approximately 17% of all greenhouse gas emissions that contribute towards global warming [6]. Biochemical reactions release methane (CH_4), soil management leads to the emission nitrous oxide (N_2O), fossil fuel combustion produces carbon dioxide (CO_2) while changing land usage are some of the major contributors to this group of gases known as GHGs greenhouse gases [7]. Additionally, this industry is very sensitive to variations in weather patterns. For example, higher temperatures decrease yields of useful crops while short term modifications in precipitation increase chances for failure and long term reduction in productivity [6]. Pests and plant diseases are also more likely to occur under such conditions. Most pest species establish themselves and spread easily when there is an increase in both temperature and moisture content because these provide them with warmth, humidity and water necessary for their growth stages. Moreover, pesticides used against pests can poison water bodies such as lakes rivers or even seas besides contaminating air or soil with other farm chemicals like fertilizers which are toxic too if not properly handled since they could kill marine life forms through eutrophication process caused by excess nutrients entering water bodies from land activities mainly agriculture [8].

Soil has suffered greatly due to increased agricultural production. However, this has not been without consequences on the ground itself either indeed quite literally so! The shift from natural vegetation cover to farming practices has greatly reduced soils' self-sustaining ability thereby leading among others things soil erosion

compaction loss of structure degradation nutrients salinity etcetera which may ultimately result into desertification if corrective measures are not taken urgently enough especially given that there is no substitute for fertile topsoil [9]. Trees are cut down leaving bare ground exposed to rain impact such that a layer of soil forms as if it were a roof over another one thereby creating what is commonly known as hardpan or plow pan which acts like an impermeable barrier against further infiltration by water hence less rainwater seeps into the subsoil than falls from above as rainfall [10]. Flooding becomes more frequent and widespread with rivers



becoming sediment-laden while dams get filled up with silt thus reducing their capacity for hydroelectric power generation besides blocking navigation channels due to increased deposition of sand bars along river courses thereby greatly impairing water quality through increased pollution caused mainly by agricultural chemicals washed off fields [11].

Fig 1: Some environmental problems in conventional agriculture

With the environment continuing to deteriorate and fears of global food shortages increasing, it is clear that changes in agriculture are necessary. There are many ways to farm, and with all of these considerations in mind, different actions have been taken since the early 1980s to reduce negative environmental impacts caused by farming, this is what we call sustainable agriculture. The definition of Sustainable Agriculture varies depending on what issues people are concerned about [12]. For [13], it's seen as an ideology, whereas according to [14], sustainable agriculture could be considered as a selection of strategies: "a management strategy which helps the producers to choose hybrids and varieties, a soil fertility package, a pest management approach, a tillage system, and a crop rotation to reduce costs of purchased inputs, minimize the impact of the system on the immediate and the off-farm environment, and provide a sustained level of production and profit from farming". [15]) defines sustainable agriculture as an ability to fulfil certain goals: "agriculture that can evolve indefinitely toward greater human utility, greater efficiency resource use, balance with environment that is favorable both humans other species". According to [2], It sees sustainable agriculture not only as meeting needs but also conserving resources. "The

management conservation natural base, technological institutional change should be oriented towards satisfying current generation's requirements without compromising ability meet same for future generations". The only consensus among these wide range definitions or nearly so is that all these aspects must be addressed if we want our farms feed us tomorrow too.

The aim of this research is to review the numerous factors that impact on the acceptance of sustainable agricultural practices (SAPs) and the incorporation of blockchain technology into agriculture. It seeks to discover how personal farmer traits, systems' aspects, and outside forces affect movement from conventional agriculture to sustainable farming techniques. Furthermore, it wants to investigate if blockchain technology can improve visibility, traceability, and speed in agri-food supply chains therefore leading to sustainable actions and filling up the intention-action void especially in developing countries.

The paper is structured as follows. The next section provides the background on the sustainable agricultural practices including the role of blockchain technology in enhancing these practices. The third section reviews empirical studies that explores the multifaceted factors influencing the adoption of sustainable agricultural practices and the integration of blockchain technology in agriculture. The final section concludes the study, summarizing the key findings and suggesting directions for future research.

The Practices in Sustainable Agriculture

There are a lot of sustainable farming practices being advocated for worldwide. These are collections of indicators for various sustainable farming practices that incorporate Sustainable Agricultural Practices (SAPs). Most methods can be grouped into five categories of farming [16]. The first category is pest control methods, which are designed to avoid the use of pesticide and herbicidal agents in order to conserve biodiversity, soil resilience and the natural environment [17]. Agriculture mechanization comes second. It has techniques like substituting ploughing the soil with minimum tillage or no tillage at all for conserving original soil quality [18]. When crops are grown and harvested with minimal disturbance to soil, maintaining natural cover on its surface, being able to manage crop rotations so as to maximize yields from them. This is the third set of techniques that directly relates integrated nutrient management where nitrogen levels in soil can be adjusted without any other external input except fixing by legumes like clover or alfalfa alone from air through only but also includes manures, as organic sources [19].

One point to note is that category four deals with blending trees and plants in the same area i.e., agroforestry thus improving on the already present artificial nutrient transfer systems, energy flow systems, and carbon footprint [20]. The second aspect covers soil-water conservation practices built around a succession series where water harvesting is allowed while still controlling wind/water erosion [21].

Different concepts about sustainable agriculture have emerged due to adaptation SAPs promotion based on nations or areas specific needs [22] some of which include:

Conservation Agriculture
- Minimal soil disturbance
- Diversified crop rotations
- Organic soil cover
- No-till planting
- Crop rotation
- Conservation buffers

Good Agricultural practices
- Ensures safe, healthy food
- Prevents problems proactively
- Quality of produce
- Market advantages
- Resource use improvement

Organic farming
- Sustains soil, ecosystem, health
- Ecological processes and biodiversity
- No synthetic materials
- High-quality food
- Environmental benefits
- Fair relationships

Sustainable intensification
- Increases resource efficiency
- More food, same land
- Reduces environmental impact

Fig 2: The practices in sustainable agriculture.

Conservation Agriculture: This refers to a system of cultivation that emphasizes "minimum soil disturbance, diversified crop rotations, maintenance of organic soil cover" [23]. Conservation Agriculture (CA) is among the Best Management Practices (BMPs) approaches used in ecosystem restoration through crop management based on three principles which include planting without tillage or

direct planting, keeping residues or cover crops permanently on soils and rotating crops [24]. BMPs are methods for conserving water and soil, other techniques for managing land as well as social interventions developed at local level as practical solutions for environmental protection. In many cases it is not one practice /action that will solve the problem but multiple measures taken together. Some examples of BMPs include changing farming practices such as conservation tillage and crop rotation; nutrient management for crops; pest control; conservation buffers; irrigation control grazing animal feeding operations erosion sediment control simple actions like not applying manure before forecasted rainfall etc.

Good Agricultural Practices: According to the Food and Agriculture Organization (FAO), Good Agricultural Practices (GAP) are "a set of principles for on-farm production and post-production processes, resulting in safe and healthy food and non-food agricultural products, while ensuring economic viability, social acceptability and environmental sustainability" [25]. One of its main aspects is "prevention before rather than after". It has three major goals: (1) ensuring safety and quality of produce in the food chain, (2) capturing new market opportunities through modifying supply chain governance, and (3) improving natural resources utilization efficiency as well as workers' health conditions. "Prevention before rather than after" is one key element among many other elements that make up GAP.

Organic farming: Referring to the words of [26] "organic farming is a production system that sustains the health of soils, ecosystems and people by relying on ecological processes, biodiversity and cycles adapted to local conditions rather than input with adverse effects, it combines tradition with innovation and science for the benefit of our shared environment while also promoting fair relationships between different actors involved". To provide high-quality food organic agriculture needs certification which means issuing a declaration by a third party where possible agronomic biological mechanical methods should be used instead synthetic materials.

Sustainable Intensification (SI): Sustainable intensification came up because extensive farming was becoming too much to handle. The objective was to improve efficiency in utilization agricultural resources so that more food can be produced from same land area while minimizing negative environmental social costs associated with such intensification efforts [27]. For instance, stone bunds along contours can be implemented or shallow bowls filled with organic matter among others which are aimed at achieving SI objectives according to encouragements given by [28].

Permaculture: According to [29], permaculture is defined as "the awareness that we can create ecosystems which are both as productive as they are natural." For instance, it's possible to regenerate landfills into wetlands and repair dirt while reusing waste streams during permaculture. What this implies basically is coming up with a system where plants functions are designed in such a way that they assist one another through their various parts so elements within each plant help each other inspired by daily connections observed in nature.

Factors Impacting Upon the Adoption of Sustainable Agricultural Practices

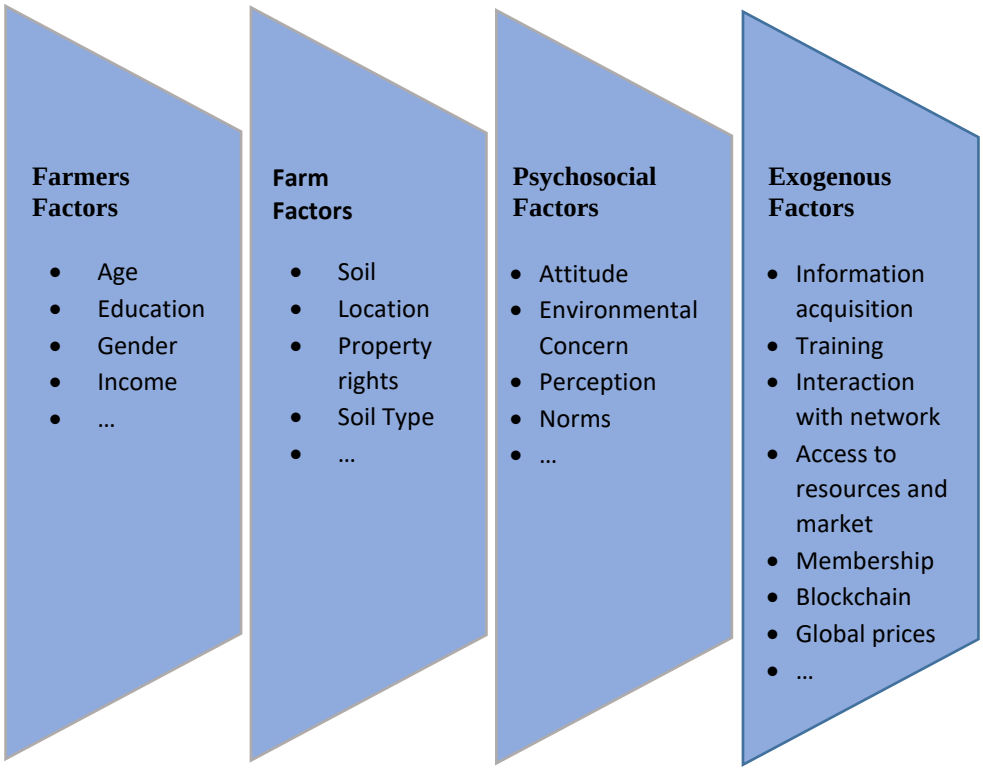


Fig 3. Overview of factors affecting the adoption of sustainable agriculture practices.

As per some researchers, adopting sustainable agricultural practices can capable of improving people's resilience to climate change, reducing soil degradation, and enhancing agricultural output in terms of its profitability, cost-effectiveness, and productivity [30-32]. Since the 1950s there has been scientific interest in farmer uptake of new farming methods [28]. The decision making process for selecting which SAP to adopt is multifactorial due to its interdependence [33]. Many studies have tried to explain what affected farmers' adoption of SAPs at large scale level. There are a lot of publications that are repeated, experiments that show consistency at times and conflict at other times. Factors among farmers are

Farmer Factor

Age is one farmers' characteristic that has been most studied with regard to its effects on adopting SAPs but findings are not consistent. Older farmers may have more knowledge and resources which can enable them have wide range of options for trying out new technologies while young ones might be more adaptive because they have higher level of education than their counterparts who belong to other age groups [34]. Some scholars argue that the older farmer a person becomes the less likely he/ she will embrace any new technology [35, 36]. Another factor which is inconsistent with respect to this issue is education level attained by farmers

themselves vis-à-vis their adoption behavior as found out by [37], who revealed negative relationship between these two variables, other studies showed positive correlation whereby better educated individuals readily accepted technological advances in agriculture [36, 38], while [39] did not find any significant impact of education on the adoption. In terms of Gender there was evidence that the female farmers found to be more likely than males to adopt sustainable farming practices in all results that were obtained [40-42]. In some studies, income was hypothesized to have a correlation with adoption of new agricultural technologies, for example [43] discovered an association between Brazilian farmer's income and their uptake level for SAPs whereas [44] reported negative effect of farmer's income on Canadian farmers' adoption while [45] observed similar trend among Spanish ones. According to [46, 47], the adoption of SAPs by farmers was significantly influenced by farm experience.

Farm Factors

On the farm side several physical attributes have been identified from previous work as being important determinants for success or failure in adopting new agricultural practices. One such attribute is size which has been supported by many earlier studies as significant predictor variable where larger farms were assumed to be more likely investing into technological advancement [46-49], although its influence on adoption is not uniform across contexts and regions such that [50] found it to have adverse effect while [51, 52] also recorded same results in different contexts but within same country Namely China India respectively it was associated with lower levels of adoption among smallholders rather than large scale commercial farmers who were thought able to absorb costs associated with this innovation due perceived profitability advantage related with economies of scale. Agricultural community may consider farm size as indication of healthiness or social honorability.

Hence, according to [34], farmers with larger plots of land may adopt organic farming on some parts of their farms if they can afford to. The rights to own a piece of land by the farmer were also considered because it increases the chances of adopting new ways of farming [53]. Similarly, during the adoption process, certain conditions were identified as vital such as temperatures, soil type, location in relation to the equator, rainfall and distance from research institutions, markets and specific districts [28].

Psychosocial Factors

The third category is psychosocial factors which provide a description of how a particular action affects people [54]. Cognitive evaluation is the method by which farmers weigh the advantages and disadvantages of SAP offers in relation to their existing farming techniques [54]. Consequently, when environmental impacts were seen as better than other aspects like yield response or simplicity of use then they became more willing to use it even so far cost benefit analysis were done in terms of economic advantage etcetera. For this reason, most SAP are widely appreciated for its positive impact of ecological benefactions on environment since healthy environment should lead to higher yields thus more income. Furthermore, cognitive thinking encompasses another aspect deals with risk management pertaining implementation stage for different types or versions but still under same broad umbrella referred simply as Saps package covered by [34]. Following theories [55] argue that there are several attitudes which affect sustainable farming adoption

likelihoods one being "An environmental attitude is a psychological inclination expressed by evaluating beliefs or perceptions about conservational issues of the environment that includes awareness on what affects its quality and the extent to which it is good or bad" [56]. This was supported by [34] as well as [55] who demonstrated in their systematic reviews almost all studies reported positive correlation between adopting environment friendly practices and attitudes. Perception also plays a crucial role in identifying irrespective of people will adopt sustainable behaviors such as farming practices. Positive relationships have been found with perceived behavioral control over adoption decision-making process [57, 58], risk perceptions associated with new adoption strategies [59] and perceived benefit from adopting SAPs [60].

Exogenous Factors

These refer to externalities that influence smallholders' ability to adopt sustainable practices. As a matter of fact, it could be any service related to agricultural development as acquiring information, accessing markets, contacting extension agents, becoming a member of an association, or even taking part in trainings. Several research findings have shown knowledge is one of the key drivers behind the uptake of new farming methods because it allows farmers know about technology availability and how they can use it practically thus increasing its chances of being adopted. You can only adopt what you know [61]. The use of mass media and educational books falls into the same category as the numbers of Agricultural information sources [62].

In emerging economies, extension services are important for increasing agricultural growth particularly in resource-constrained countries [34]. These are experts and information providers that help farmers utilize new technology and innovation better by giving them advice on how to do so. Various studies have found out that farmers were more likely to adopt sustainable farming practices when they were in contact with extension agents[63-65]. Another crucial element is, membership in a farmer group which has been shown regularly to positively affect adoption of SAPs [28]. For instance, [53] among Mexican farmers, [60] among Nepalese farmers or among Thai farmers identified positive relationship between membership in farmer organizations and adoption of SAPs [35].

Training programs teach farmers about good practices as well as proper procedures leading to sustainable production while informing them about what they stand gaining should they change their traditional methods of doing things [34]. Better trained tea growers from Nepal were more likely to adopt organic cultivation techniques according to study concluded [66]. Many other researchers have also shown that training positively affects adoption process towards sustainability [30, 45, 60, 67]. Access to credit is one of the major factor that determines individual's ability get resources needed for any given activity like farming or any other business. [68] work with maize farming households showed financial constraints relief through risk taking capacity building at household level due credit availability which in turn led to increased technology adoption rates among farmers in Malawi (2006). Additionally, [69] study on rice farmers' decision to adopt sustainable agricultural practices revealed positive relationship between access to water sources in Thailand and such decisions being made by these farmers (2011).

According to [70], internet of things can be used in creating supply chains for sustainable agriculture. Blockchain on the other hand, enables consumers and

businesses to verify where their products have come from by tracing them back right from the farm up until they reach our tables, it also gives details about when was this food harvested or produced as well as who produced it [71]. One reason why blockchain technology is important when it comes to agro-based firms lies in its provision for secure platforms through which goods can be tracked and traced. By incorporating blockchain into sustainable agricultural practices so many challenges facing the sector will be addressed thus making farming more resilient hence achieving sustainability at large. This part takes a look at how blockchain technology may enhance adoption as well effectiveness of sustainable agricultural practices thereby giving new dimension towards ongoing drive for agri-business alignment with global goals of sustainable development.

Block Chain

The blockchain technology, initially designed as a system for Bitcoin, is now proving to be a game changer in various sectors such as farming [72, 73]. It is a decentralized network of computers that keeps records of multiple transactions in a digital ledger and secures them against retroactive modification.[74]. This technology utilizes the concepts of cryptographic hashing, decentralization consensus and immutability which enhances its trustworthiness in keeping transparent and secure records [75, 76].

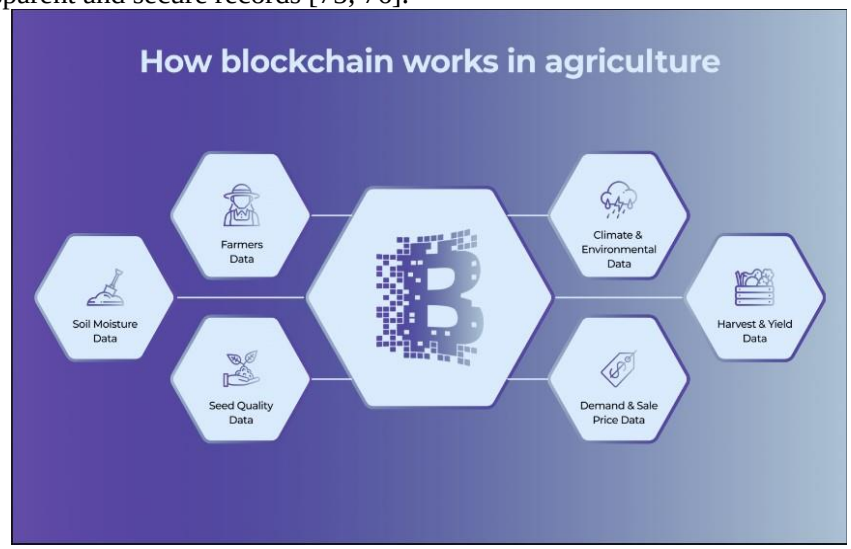


Fig 4. The way blockchain can help in agriculture

Employing block chain towards sustainable agriculture:

Agri-food organizations can use the blockchain technology to create an all-inclusive solution for addressing food safety challenges among others like food quality, food frauds, illicit trade, severe global climate impacts or animal wellbeing issues and inadequate governance [77, 78]. Coordination and collaboration within supply chain partners becomes easier with BCT because all product related information is on shared ledge [79]. Information validation along the entire supply chain improves traceability as well as process reliability [74]. Consumer purchase decisions are positively impacted by BCT through simplifying validation of product origins together with certification tags thus providing greater transparency and traceability system. With the help of smart contracts applications, the company can design the contract based on the company's requirements[80]. The Company can

make the contract based on company requirements using smart contracts application [81]. There are also some drivers of BCT in agri-food supply chain apart from benefits which include trade compliance [82], fraud detection, safe and quality food, government regulations, price of technology [83].

The use of blockchain technology in agriculture has great potential for promoting sustainable practices. [83, 84] argue that through enabling transparency and immutability of all transactions, blockchain can significantly improve traceability within the agricultural supply chain. This is important as it ensures that agricultural products are produced and processed according to sustainable methods thus gaining consumer trust as well meeting regulatory requirements [85].
In addition, blockchain have the ability to increase efficiency along supply chains by eliminating intermediaries and automating processes through smart contracts [86]. Smart contracts are self-executing contracts, containing the terms of the agreement directly in code, which can automate the execution of transactions without the involvement of third parties [87]. This will cut down costs, remove delays while ensuring farmers receive timely payments hence encouraging adoption of sustainable practices [88].
Furthermore, blockchain systems can provide secure platforms for recording sharing data on farming practices crop health environmental conditions which could be useful for better data management decision making in agriculture sector. Such information when used properly may lead to optimization of farming practices, improved crop yields as well reduction on environment impact caused by farming activities [89]. Farmers through leveraging on block chain can access real time information insights thereby making informed decisions that enhance sustainability [90].

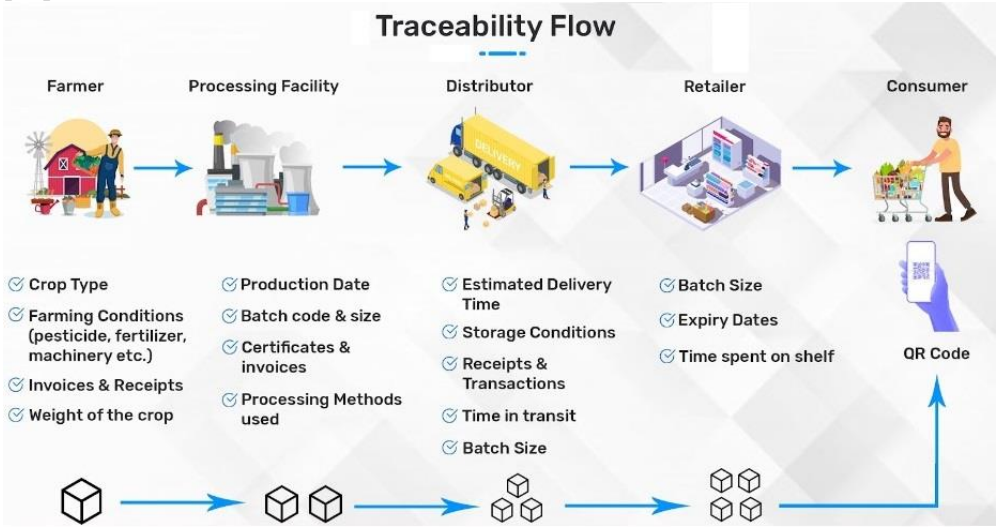


Fig5. Blockchain based traceability flow source [91]

Blockchain technology has a necessary part in sustainability standards and certification compliance, apart from these gains. For instance; it could make the verification of conformity easier for sustainable and organic products by giving a proof record through simplifying certification processes [92]. In addition to this

being able to prove their commitment towards such guidelines followed by them as farmers' it also can enhance marketability while building consumers' trust thereby driving demand for sustainable produced goods [93].

Debate and Gap in The Literature

A review of the literature has found that both exogenous and endogenous variables influence the adoption of sustainable agricultural practices (SAPs) and the integration of blockchain technology [94-97]. These studies have been conducted using different theoretical frameworks which offer diverse views on decision making. One such theory is The Theory of Planned Behavior (TPB) by Ajzen, which states that attitude towards a behavior, subjective norms surrounding it and perceived behavioral control over performing it determine intention to adopt it [94]. What this means is that before they act people think about what could come out as a result, what others expect them to do in that situation and what they feel might prevent them from doing so [98].

Though TPB has been widely used, criticisms have been made about its ability to completely explain behavior adoption. In response to this researcher have argued that attitude towards a behavior, subjective norms surrounding it and perceived behavioral control over performing it may not be enough predictors for intentions let alone subsequent behaviors [95, 96]. To improve predictive power of TPBs integrative models combined some other theories e.g. Technology acceptance model Norms activation theory Value belief norm theory diffusion innovation theory among others [95, 96, 99-101].

Mostly high income countries have been used as samples for researches into SAP adoption using extended TPB models according to [102]. This has left a gap in knowledge concerning the ways farmers in low income countries adopt sustainable practices and integrate them with their agricultural systems through block chain technology [31]. More so there is need for further studies to look into the attitude and intention of farmers in these areas and how they affect both SAPs adoption and use of blockchain [102].

TPB has been criticized for failing to account for the intention-behavior gap. [103] argued that although TPB explains intentions well it does not do so when it comes to behaviors themselves. The connection between intention and behavior is not always strong indicating that there are factors which determine whether or not people will translate their intentions into changes of conduct. Only few researchers have suggested mediators or moderators which can influence this relationship within SAP context [104-107].

In order to study mechanisms that drive Chinese farmers towards improving their agricultural systems [105] used eco-compensation as a moderating variable. This approach brings out the significance of external incentives when promoting sustainable practices [105]. Self-identity among other things has also been added by different scholars together with moral norms risk perception etcetera so as to better understand what goes on inside farmer's minds before they decide [104, 106, 107].

When it comes to incorporating blockchain technology into sustainable agricultural practices (SAPs), this requires an all-encompassing inquiry that closes the gap between intentions and actions. Such as current challenges in sustainable agriculture could be overcome through increased transparency, traceability, and efficiency which are among the potential benefits of blockchain technology [89].

However, the decision to use it depends on different factors whose understanding must be deepened for easy integration into farming systems [108-112].

The integration of BCT with IoT can allow sensors to collect data in real time for Agriculture Food Supply Chain AFSC towards Sustainable Agriculture Practices SAPs , solve information asymmetry problems between supply chain actors as well as ensure data reliability and integrity [113]. As BCT for traceability has developed, it has positively impacted AFSC's overall performance [114]. Collaborations are enhanced, information asymmetry is reduced, and stakeholder trust is increased when BCT is implemented [115]. Farm-to-fork traceability and transaction records are among the benefits of blockchain-based traceability, while at the same time leading to decentralization which eliminates bureaucracy in addition to enhancing safety reliability coordination reducing costs maximizing profits [116]. BCT solves several supply chain issues for SAPs ranging from large global platforms like IBM Food Trust [117] to companies such as Agri Chain ripe honeysuckle white.

Further studies should concentrate on investigating how effective adoption of SAPs can be fostered by blockchain particularly within developing nations. Among areas that need investigation include looking at how data management can be improved through blockchain in addition to enhancing supply chain efficiency as well as compliance with sustainability standards in this regard [118-122]. Furthermore, we need more research into those factors which either facilitate or hinder adoption of the technology by different players within agricultural sector thus providing useful information for policy makers researchers and practitioners who seek to promote sustainable technologically advanced farming practices [108, 109, 111, 112, 123] .

CONCLUSION

This paper has conducted a comprehensive analysis that highlights various determinants of adopting sustainable agriculture practices(SAPs) while also integrating blockchain technology. The move towards sustainable agriculture is necessary as it helps counteract adverse environmental effects caused by traditional farming methods such as deforestation, soil erosion, biodiversity loss and pollution [1, 2, 4]. Sustainable Agriculture refers to an approach aimed at ensuring the needs of the present generation are met without compromising the ability of future generations to meet their own needs through adoption environmentally sound socio economically viable farming systems [2, 12]. Nevertheless, there are many different factors affecting whether or not farmers adopt these practices ranging from individual characteristics among them up systemic level influences [124].

One of the main findings reported by studies is that farmers sometimes fail to put into practice their intention to adopt sustainable agricultural practices (SAPs) [54]. This is a serious obstacle which implies that there should be more sophisticated investigations into what links these two things together [103]. Although it has been widely used, the Theory of Planned Behavior (TPB) lacks predictive power hence requires some additional theoretical frameworks [94, 98]. For example, [95, 96, 99-101] recommend an integrative approach involving TPB along with such theories as the Theory of Reasoned Action, Diffusion of Innovation Theory, Value-Belief-Norms Theory, Technology Acceptance Theory and Norms Activation Theory.

Moreover, blockchain technology in agriculture can bring transformative changes through enhancing transparency, traceability and efficiency in agri-food supply chains. It is said that use of immutable records provided by blockchain could solve

sustainability problems like verifying compliance with standards for sustainable farming practices while improving data management as well as enabling faster operations within supply chains [108, 111, 125]. The reason why blockchain can track products from farms all way down to consumers' plates is because it establishes trust among them thereby ensuring adoption of sustainable production methods throughout this journey [80, 83].

Also blockchain has potential for streamlining activities through smart contracts which automate transactions without intermediaries [81, 82]. This will save money, cut delays and prompt payments to farmers for adopting eco-friendly methods [119, 123, 126]. Moreover, it can improve data management and decision-making in agriculture by providing secure platform where farming practices record keeping is done together with sharing same among relevant stakeholders [119-122, 127]. Use of such information may lead to better farming methods that increase crop yields while reducing environmental impact [78, 79, 128].

When considering integration of blockchain technology into SAPs it is important that more research be conducted so as to bridge intention-behavior gap. Further studies should therefore investigate the ways through which blockchain can help enhance adoption and effectiveness of SAPs especially within developing nations where contextual dynamics are significantly different from those found in high-middle income regions [102]. These gaps need filling if scholars are going to offer deeper insights on sustainable technologically advanced agricultural practices thus contributing towards resilience building worldwide.

In summary sustainable agricultural practices when integrated with blockchain have potential for addressing environmental efficiency challenges facing the sector. This study therefore advocates for joint efforts between researchers and policymakers aimed at closing down on intentions behaviors divide fostering wider spread use these innovations within a more sustainable equitable agri-food system.

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