The Role of Blockchain in Documenting Land Users' Rights: The Canonical Case of Farmers in the Vernacular Land Market

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In this article, we discuss the potential of blockchain technology in addressing the documentation of users' land rights in the informal land rental market. Blockchain technology is a peer-to-peer protocol that can be leveraged to keep track of transactions over the internet. Publicized for its use in the bitcoin revolution, the technology provides transparency and traceability that can be used in the management of land rights. When it comes to the formalization of land rights, blockchain technology promises to authenticate owners and other users of land, and provides a fixed ledger of land use rights transactions. At present, blockchain technology is being explored as a proof of concept in several countries to track land titles (state to individual). We extend the idea to capture the granting of land use rights (individual to individual) making use of the decentralization, peer-to-peer nature of blockchain technology. While the technology is not a panacea to all land administration challenges, it can offer an effective means to manage land transactions, provide digital documentation to actors in the informal land rental market and reduce inefficiency in land systems. However, the uptake of the technology in land administration is limited by human related factors. These limitations include, but are not limited to, the accuracy of data being entered into the system, the ability of the system to facilitate data preservation, pre-existing institutional and legal pillars, and the digital divide across communities. Part of overcoming these barriers requires the political will of governments to invest in digital technologies and develop institutional capacities to overcome current limitations to bring land management into the industry 4.0 era.

Keywords: blockchain, informal land market, land tenure, agriculture, vernacular land market

1. INTRODUCTION

In this article, we explore the feasibility of blockchain technology in the documentation of land tenure to enable the empowerment of agricultural land users who participate in vernacular (informal) land markets. Currently, the idea of blockchain technology for land administration is being actualized within land registry projects globally to further the efficiency of land registries. Blockchain is a data structure that rests on distributed ledger technology, which is concerned with capturing and transferring value (Janowicz et al., 2018). The Distributed Ledger Technology used in blockchain applications can be described as a "collaboratively managed database of shared, synchronized, and replicated records that typically does not rely on central governance" (Janowicz et al., 2018, p. 545).

The emergence of blockchain as a disruptive technology has been argued to have potential tremendous impact in land administration and management (Anand et al., 2016; Reese, 2017; Shin, 2017; Swan, 2017), which can facilitate the functioning of land markets in developing countries as well as diminish the threat of losing land rights for vulnerable communities and women. Ongoing projects in Ghana, Georgia, and India are real-time proof that governments have bought into the idea of blockchain to help in the efficacy of land governance, the protection of people's land rights, reduce land conflicts, and address corruption and land fraud (Reese, 2017; Shin, 2017; Swan, 2017; Oprunenco and Akmeemana, 2018). Especially for developing countries, the idea of going from paper to digital based management is even more important in this emerging global digital economy, whereby the Information and Communication Technology (ICT) transformation of government services (via e-services) is a mechanism for reaching targets of the Sustainable Development Goals (WBG, 2016).

Whilst blockchain land administration projects focus on the state to individual relationship to land through the preservation of titles, there is little discussion or evidence of the application of blockchain in addressing individual to individual relationships to land (transferring of rights). The question arises as to how this nascent technology can be applied to the manifold verbal land agreements/handshake deals to protect livelihoods, while maintaining transparency, openness, confidentiality, and protection of both land users and landowners.

While it is understood that plurality and diversity of rights and tenure systems exist, in this paper we consider the canonical example of small-scale farmers who gain access to lands through vernacular land markets. We draw from case studies of small-scale farmers, in particular the case of Trinidad and Tobago wherein informal tenure excludes some farmers from accessing state incentives for their livelihoods and inhibits livelihood resilience (Daniel et al., 2019). Through these examples, we will illustrate how the properties of blockchain apply to the vernacular land market. Moreover, we highlight how the challenges of informal access and tenure documentation can benefit from the transparent nature of blockchain while at the same time protecting people's land data in an immutable manner, within the scope of fit for purpose land administration systems. The article concludes with a look at the current limitations in the application of the technology.

2. VERNACULAR LAND MARKETS CREATE INFORMAL ACCESS

Vernacular Land Markets (VLM) are informal markets through which land is allocated outside of statutory regulations, rendering their access informal (Chimhowu and Woodhouse, 2006; McCarthy et al., 2012). Access to land, which falls outside of Western land administration conventions, are deemed as informal regardless of the resilient communal land systems that uphold cultural identities of communities over generations. There are many communal tenure regimes in effect throughout the world under various names such as *family land* in the

Caribbean, *customary tenure* in Africa and *indigenous lands* in Latin America and Asia. In sub-Saharan Africa, approximately 90% of lands are held under customary tenure (Deininger, 2003).

Studies on the vernacular markets and informal access highlight the diversity, complexity, and social embeddedness of land rights negotiations within communal systems (Delville, 2002; Mathieu et al., 2002; Chimhowu and Woodhouse, 2006; Choplin and Dessie, 2017; Chimhowu, 2019). However, when it comes to livelihoods, studies predominantly focused on ascertaining whether there are direct relationships between formalization of land rights (titling), livelihood investments and wellbeing (Bromley, 2008). Although these studies provide mixed evidence, they mostly focus on traditional communal situations or squatters, where people occupy the land and legitimately derive ownership from their socio-cultural ties to the land and long-term land improvements (Chimhowu and Woodhouse, 2006; Chimhowu, 2019). Other studies on land rental markets center on the role of tenure security to a functioning rental market, with emphasis on the leasor's participation in rental markets, tenure security and productivity (e.g., Holden et al., 2009, 2011; Deininger et al., 2011; Lowery et al., 2018) and not necessarily shedding light on the demand side of the market and its effect on the leasee's livelihood.

The VLM is nuanced and there is increasing evidence of its monetization across the global south, wherein money is exchanged for use through verbal permissions either on communal lands (Delville, 2002; Mathieu et al., 2002; Chimhowu and Woodhouse, 2006), private lands (Stanfield and Singer, 1993), or state lands (Stanfield and Singer, 1993; Choplin and Dessie, 2017; Daniel et al., 2019), moving away from traditional reciprocal land relationships. Transactions usually occur without formal documentation of use rights. Land scarcity and competition drive demand for land through informal markets and are mediated through the social-ecological contexts of societies (Chimhowu and Woodhouse, 2006).

As VLMs continue to evolve to meet the needs of the land poor, informal access will continue to shape how livelihoods and social powers unfold over the land. Yet, forging legitimate and secure rights to land through the VLM is a persistent demand-side challenge especially in cases where money is transacted for sale or rental. In relation to VLMs in rural West Africa, Delville (2002, p. 92) stated that "insecurity in relation to farmland hinges to a significant degree on the issue of transactions." The issue of land transactions brings into focus the contested nature of access and legitimation.

When it comes to land, legitimate access determines who has the rightful power to benefit and make exclusive claims to the land (Ribot and Peluso, 2003). For example, in agricultural livelihoods in Trinidad and Tobago, Daniel et al. (2019) showed how the relationship between legitimation and access can mediate livelihood resilience. The ability of a farmer to access state entitlements hinges on the type of farmers identification card in their possession, which is based on tenure documentation. The type of card determines what farmers can legitimately claim from the state in terms of livelihood support. Only farmers with the relevant cards can access state incentives (e.g., for land preparation, irrigation, chemicals etc.) as well as lines of

credit from the agricultural bank. These entitlements strengthen farmers' overall buffer capacity[1] and positively shape their livelihood resilience. Exclusion from incentives, remove state buffers for livelihoods, which can then lower farmers' buffer capacity. Farmers in the study area who are renting through the VLM generally tend to feel less secure in their livelihoods compared to farmers who access a friend or family member's land through the VLM (Daniel et al., 2019).

Other studies illustrate the similar interplay of legitimation and access and the ways people try to establish legitimation and tenure security through the VLM. For example, Delville (2002) highlighted that in francophone West Africa, farmers used various forms of documentation such as "little papers" that record rent payments, written contracts with or without customary approval, and certificates from extension officers. Mathieu et al. (2002) also described such a practice in Burkina Faso identifying five forms of land transaction validations through inscription. These entail: (i) visible customary acts of gratitude e.g., gift exchanges; (ii) the presence of a witness during the transaction; (iii) little papers; (iv) a grant certificate—a semi-formal document that contains the land agreement and the verified signatures of both buyer and seller; and (v) a record of palaver—a legal document about the terms of the land transaction, which bears the signatures of the administrative and customary authorities related to the land transaction (Mathieu et al., 2002). The record of palaver is lodged at the administrative offices and is the initial step toward gaining a land title (Mathieu et al., 2002). The various practices of documenting aspects of land transactions were used as a basis to draw a sense of legitimization and tenure security through transactions (Delville, 2002; Mathieu et al., 2002).

Choplin and Dessie (2017) described that in Mauritania, access to state lands through the informal channels called tieb tieb is usually authorized in front of a Muslim judge. Given the strength of tieb tieb practices, people who gained land access in this way generally have a stronger sense of tenure security compared to access through formal state means since the latter is lengthy and acquiring titles are expensive (Choplin and Dessie, 2017). These examples of recordation or witnessing are what Chimhowu and Woodhouse (2006) described as a "recourse to documentation" and a familiar trait of VLMs. Looking at such actors in the VLM, shifts the focus from the "owners" to the land users and the inherent need for legitimizing their access to land through the informal market. In this regard, how can blockchain assist in the documentation and legitimization of land users' rights for their livelihood security and resilience?

3. BLOCKCHAIN TECHNOLOGY AND HOW IT WORKS IN THE LAND ADMINISTRATION CONTEXT

Blockchain technology is a peer-to-peer protocol that can be leveraged to keep track of transactions over the internet (Swan,

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[1]Buffer capacity refers to "the capacity to cushion change, and possibly to use the emerging opportunities to achieve better livelihood outcomes" (Ifejika Speranza, 2013, p. 523).

2017). Publicized for its application in the cryptocurrency revolution, the technology provides transparency, traceability, and built-in trust that can be used in the management of land rights. The purpose of the system is to disintermediate resource transactions over the internet (Andoni et al., 2019). Built on the distributed ledger technology, the key tenets of this system are (Anand et al., 2016; Swan, 2017; Vos et al., 2017; Nasarre-Aznar, 2018):

1. The decentralized peer to peer nature of the database: This means that there is no central storage of data as each node that forms part of the distributed system keeps a copy of the data. In land registry projects, the peer to peer database can involve several computers within the national land registry office or across land agencies at the national and municipal levels, thereby enforcing a type of private blockchain. Nodes across the system perform various functions such as wallet services, mining, routing, and storing (Reyna et al., 2018).
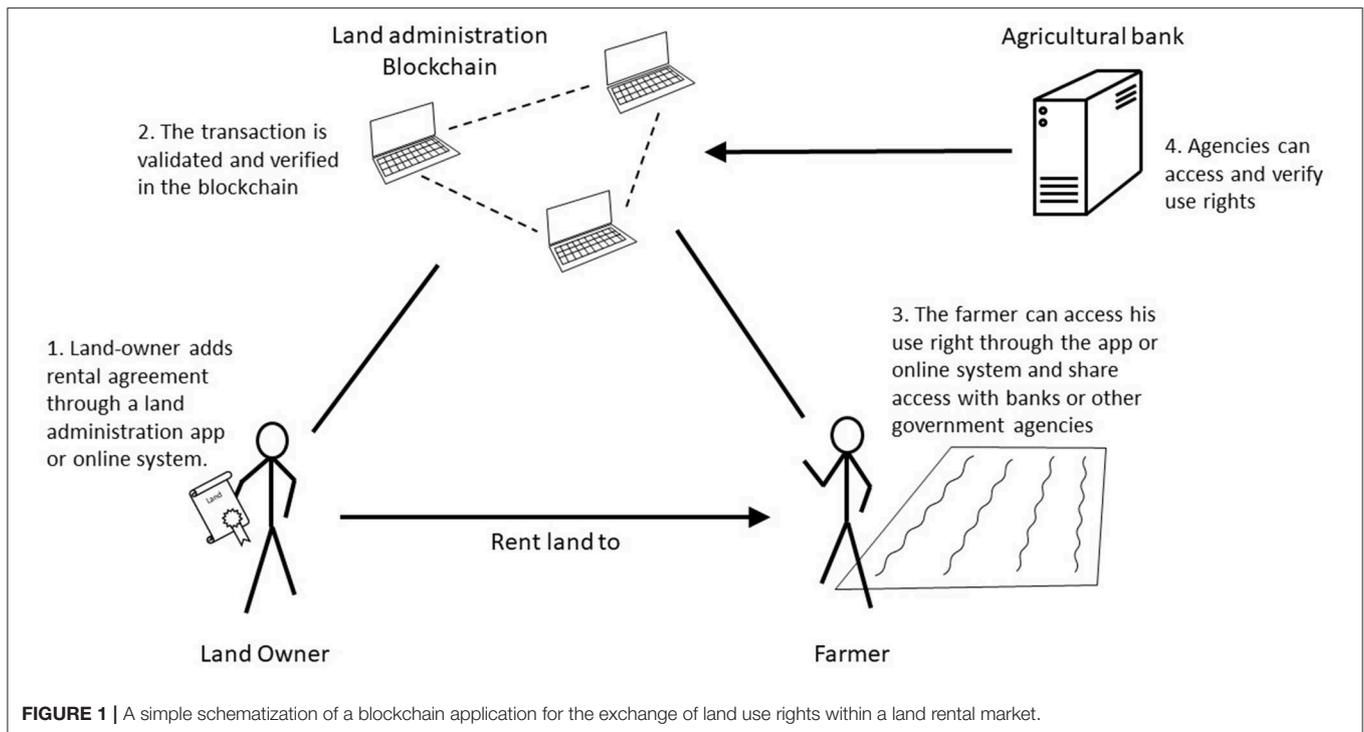
   In a land registry blockchain system, wallet services by nodes store public and private keys (Anand et al., 2016). These keys are needed to create a unique signature or multiple signatures to initiate a transaction in the system, which are part of the cryptographic technology of the system (Anand et al., 2016). Depending on the type of in-built consensus mechanism [rules for validating transactions (requests) into the system], all or some nodes (proof of work vs. proof of stake consensus) can be network validators that verify each transaction (e.g., to change the landowner's name for plot A) before they become part of the ledger (Vos et al., 2017; Reyna et al., 2018). Nodes also act as routers sending information of transactions to other nodes in the system (Reyna et al., 2018).

2. The removal of a third-party verification entity in validating transactions into the ledger (e.g., conveyancer): Disintermediation is one of the key purposes of blockchain applications (Ryan, 2017). In a land registry application, this would mean that there is a reduced need for officers in land agencies to do title or deed searches or land registrars or conveyancers to verify document contents and update a registry.

3. Cryptographic and chronological linkages of transactions: Embedded in this distributed system are cryptographic protocols that secure the network and transactions to ensure data privacy. Transactions containing data are linked in sequence into a block. A history of all transactions in a block is stored across all nodes. Once a transaction is added to the ledger no one can alter it. Additionally, any data stored in that chain cannot be modified or removed. The decentralized network, embedded consensus mechanisms and cryptographic encryptions allow for a tamper-proof database.

   Transactions executed in the system are done via smart contracts. Smart contracts are "programmable applications that manage exchanges conducted online" (Ryan, 2017). They can be used to encode legal contracts, terms of conditions or the steps of a financial transaction, which can run automatically within a blockchain (Walport, 2016; Ryan, 2017). In so doing, transferring an easement right to another party can be automatically executed via a smart contract

FIGURE 1 | A simple schematization of a blockchain application for the exchange of land use rights within a land rental market.

without the need for someone to physically verify, approve and record the right in the registry (Nasarre-Aznar, 2018). Smart contracts promote the disintermediation of resource exchange, with the added benefit of reducing costs associated with third party actors (Ryan, 2017).

4. DISCUSSION: MATCHING THE DIMENSIONS OF THE VERBAL LAND MARKET WITH THE CAPABILITIES OF THE BLOCKCHAIN

Part of development agencies' pro-poor agendas underscore the importance of formalization of land rights as a vehicle toward economic empowerment for the poor and marginalized. As such, organizations like the World Bank and the United Nations' International Fund for Agriculture and Development (IFAD) invest in programmes to help vulnerable, indigenous and marginalized communities to provide formal or quasi documentation to land rights. For example, the IFAD alone has invested approximately US$177 million on tenure security related projects between 2012 and 2016 in 56 developing countries (IFAD, 2018).

In the individual to individual relationship to land, land administration systems should assist in the protection of farmers' use rights through the VLM, the legitimization of farmers, and foster trust in the rental system by protecting both landowners and land-users in an incorruptible manner. While technology has bridged the gaps in capturing different types of informal tenure, in this new digitalization era two core concerns remain: data protection and the timely verification of documented rights obtained through grassroots programmes (Lengoiboni et al., 2019).

Blockchain technology can work alongside low-cost digital approaches such as the UN-Habitat Social Tenure Domain Model (STDM) Tool and the FAO's[2] OpenTenure software for capturing land rights information on the ground. Once, the use rights of the parties involved in the rental market are collected, this information can be piped along a blockchain driven land administration system for timely, secure, and cost-effective verification and recordation.

The peer-to-peer value exchanges within the VLM make blockchain apt for tracking these transactions. Access rights can be tokenized in the system and the rights transferred from one party to another through smart contracts, with the digital footprint of this transaction transparent in the system, but secured across all nodes (Anand et al., 2016; Nasarre-Aznar, 2018). The updating of the rights exchange over a plot of land can be validated through smart contracts, which can ensure that the authorization comes from the owner of the plot and that the transaction meets the standard criteria (Anand et al., 2016).

Taking the case study of small-scale farmers in Trinidad and Tobago into consideration (Daniel et al., 2019), farmers in the VLM can draw on the digital documentation of their use right (e.g., via an app) for legitimacy as a farmer and land user, and use this record to request farmers identification cards and state incentives. **Figure 1** demonstrates how such an application can work. What is envisioned is a private land administration blockchain with nodes held at the regional County Agricultural Offices, the Ministry of Agriculture as well as the Agricultural Development Bank.

The landowner interacts with the blockchain system through a land rights interface such as the STDM tool on their mobile

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[2]FAO: Food and Agriculture Organization of the United Nations.

devices or computers at home or at the County Offices to record when a new use right is granted to a farmer and the rental conditions of their agreement (name of tenant, name of landowner, rental cost, duration, title/lease registration number, size of plot to be rented etc.). An identification check is performed via the blockchain system to ascertain whether the landowner is indeed the owner of the plot that is to be rented. Once the ownership is established by the system, the farmer receives a notification via text messaging and/or email to log into the system to provide consent to the rental contract. Changes in ownership and rental agreements (e.g., as instructed by legal rulings) are not specific to the blockchain and take place outside of the technology. Authorized land administrators can enter the changes as new data into the system.

The rental transaction is then completed via a series of smart contracts, which validates the terms of the rental contract, creates, and records an access right for the land user as well as a farmer identification credential for the land user. Upon completion, the farmer will be notified (via text messaging or app) to login to the system and view the recorded contract. He or she can then download a certificate of the contract and farmers ID. If the farmer wants to get a loan from the Agricultural Development Bank to start land preparation, this request can be facilitated through the blockchain since the bank is a nodal point of the land administration system. Each step of the loan process from the initial request by the farmer, to documentation checks, approval, consent, and payment can be automated across the distributed system through a series of smart contracts. As a node, the bank can easily verify a farmer's tenure. Once the loan transaction is validated, it can be appended to the farmer's tenure data on the chain and monies directly paid to his/her account. Such an approach to regulating the verbal market is a mechanism for securing people on the property ladder but also for transforming agriculture and placing and securing agricultural stakeholders on the digital agriculture ladder.

Blockchain technology has the potential to digitally transform legacy systems in land and agricultural administration in developing countries. At its core, blockchain reflects the theory of documentality in which social objects (agreements, permissions, rights, payments, registration of marriage etc.) of the world are recorded and these records create new kinds of social relations and powers (Ferrari, 2012; Smith, 2012, 2014; Ferraris and Torrengo, 2014). In this regard, the verbal rental agreement and permission of use rights are given a materiality as artifacts in the distributed system that endure through time. These digital artifacts are the "content produced in the social act [rental agreement] and then recorded somewhere that establishes the nature of the actual constraints, and guarantees the endurance of the social object [use right]" (Ferraris and Torrengo, 2014, p. 16). They transfer performative action and deontic powers to actors (e.g., both landowner and farmer) tied to these artifacts (Ferraris, 2012; Smith, 2012), which both actors can use to strategize their livelihoods. For the VLM, blockchain provides the architecture to record and track land rights transactions, through which farmers gain the power to use this record to access other resources (e.g., loans, state incentives) for their livelihoods. In so doing, the technology helps in addressing the documentation issue that

prevents farmers who access land from the VLM from further developing and securing their livelihood due to a lack of tenure documents to prove their legitimate use right.

We see at least the following properties of the verbal land market that correspond to properties of blockchain technology. An explanation is provided below on how these properties of the VLM and blockchain are related and can be generally leveraged for the documentation of use rights for farmers in the vernacular land market.

1. Peer-to-Peer Relationships: The VLMs are characterized by handshake deals and oral agreements. The very nature of the vernacular land market is to offer access to lands (albeit informal) so that actors (both owners and users) can derive mutual benefit. These transactions in the market between farmer and landowner are in nature peer to peer, similar to transactions within a blockchain database. However, in the VLM, the transaction is inscribed in the memories of the parties involved, witnesses, and through payment receipts for the land on which people draw legitimization in their transaction (Delville, 2002; Mathieu et al., 2002; Chimhowu and Woodhouse, 2006; Choplin and Dessie, 2017). Yet, payment receipts are not a placeholder for tenure documents and tenure security cannot be pegged on such receipts. In a blockchain, the transcription of the transaction is durable, which can be verified at any time and used in other digital transactions for a farmer's livelihood that require a documented proof of use right. In so doing, the blockchain provides a digital footprint of a farmer's land transaction, which he/she can use to access other livelihood resources.

2. Legitimization: Vernacular land markets can either enable or disable the legitimization of farmers through informal access to lands. For example, in Trinidad and Tobago, informal access prevented farmers from legitimizing their role, which prevented some farmers from accessing state incentives (Daniel et al., 2019). In other examples, a "recourse to documentation" is taken by individuals as a means to bring legitimacy to land transactions and forge a sense of tenure security (Delville, 2002; Mathieu et al., 2002; Chimhowu and Woodhouse, 2006). General livelihood resilience is dependent on documented tenure for access to resources (Daniel et al., 2019).

   However, a consequence of low cost technological means of capturing rights is the slow pace of verification as "it is the question of how, when and by whom both the analog documents as well as the digital data are considered legitimate and for what purposes they can be legitimately used" (Lengoiboni et al., 2019, p. 27). A blockchain approach provides the added value of having to not depend solely on human intervention for verifying and approving land data thereby making the process quick and cost-effective. The digital footprint of the transaction and artifact of land rights within the land administration system can be used to draw legitimacy in land usage or ownership by actors. In the case of the VLM, a series of smart contracts can be executed within the system, for example, to legally verify the landowner and his/her capacity to enter into a rental contract, terms of the rental agreement, leasees consent to the terms that are needed

to fulfill the contractual engagement and confer the use right to the farmer.

3. Confidentiality and Trust: Vernacular land markets are characterized by confidentiality and trust. In some cases, it is the fear of losing the land that prevents landowners from documenting rental agreements with farmers or even entering a rental agreement in the first place. For example, in Brazil, small-scale farmers who are landowners shy away from renting lands to large-scale farmers and corporations for fear of being dispossessed in the process (Arsenault, 2016). Lack of trust and insecurity therefore outweighs potential economic benefits and contribute to an under-performing agricultural rental land market (under 4% of lands) in the country (Arsenault, 2016).

Trust plays a role in whether farmers receive some type of legal or quasi legal documentation for usage. In a national land tenure study in Trinidad and Tobago, Lemel (1993) stated that private landowners in Trinidad and Tobago largely avoided providing rental contracts or some form of tenure documentation to agricultural users for fear of adverse possession by renters (approximately 44% of landowners did not provide any form of documentation while 10% provided lease documents). In the present case of the VLM for agricultural lands in Trinidad and Tobago, the lack of tenure documentation still exists (Daniel et al., 2019). It can also be assumed that the lack of tenure documentation to support agricultural rentals in Trinidad and Tobago is still a cautionary measure taken by landowners.

Where there is a need to establish trust in transactions, as is in the case of the VLM for agriculture, blockchain provides a good opportunity to facilitate rights (value) exchange between parties in the land market. The very nature of the blockchain is its built-in trust as the system is based on the principle of disintermediation of data exchange in a secure and incorruptible manner (Swan, 2017). The landowner and farmer do not need to establish trust between each other to document their transaction. Rather trust transcends the parties involved and is placed in "the computational smart network system" of blockchain (Swan, 2017). Through the system, confidence in land market transactions can be harnessed knowing that rights exchanges and recordation only occur when the requests are authenticated and confirmed based on specified system rules. Data across the system are timestamped and stored cryptographically thus ensuring that landowners and land users' data are confidential, but at the same time if a landowner and farmer wants to view the information about their land transaction he/she can access this securely. Once the transactions are recorded on the chain, it will make it easier to track land usage and prevent adverse possession.

5. CONCLUSION

This article put forward arguments for the potential use of a blockchain application in managing and legitimizing land transactions through the Vernacular Land Market. Discussion

papers on blockchain for land administration primarily focus on the state to individual relationship to land i.e., representing and storing titles through this technology. The objective of this article was to highlight the strong commonalities between the VLM and blockchain and how these commonalities can be leveraged for deriving legitimization for land users such as small-scale farmers and their livelihoods. As most food production in the global south occur on informal tenure mediated through the VLM, the VLM presents a ripe use case for where blockchain applications targeted for land administration can be most beneficial. Furthermore, it has the potential to transform legacy systems used in overall agriculture administration, for example, to provide digital identification of farmers, subsidy pay-outs in the form of digital payments to farmers, as well as monitor agricultural usage and production levels on farms through the tracking of land rights stored within the system.

In this article, the primary focus was on the application of blockchain to establish legitimacy in land transactions through the VLM. Emphasis was placed on the digital documentation of use rights, which can be called upon by land users to prove their tenure, establish a sense of security and access other livelihood resources. In the process, both landowners and land users' rights can be verified and protected in land dealings and in so doing quell fears of land dispossession between entities. With the distributed ledger technology in place keeping track of land use rights, land officials can have a better oversight of lands through rental markets, their land management and can use the records to monitor and sanction unsustainable use.

While the potential for blockchain in this special case is evident, we also need to be realistic and critical about the limitations of blockchain for land administration. Firstly, blockchain cannot magically fix pre-existing contestations over lands and the bringing of communal tenure under statutory regulations (Anand et al., 2016; Vos et al., 2017). Such issues are related to the institutional and legal pillars of land administration, which have to determine how best to bring diverse tenure regimes under statutory oversight (Lengoiboni et al., 2019). Thus, a blockchain application to land administration will likely work best in cases where there are no land ownership issues to facilitate land transactions (rental or sale) involving titled or state leased lands (Vos et al., 2017). However, blockchain technology can be used to prevent titled lands in communities transitioning to informal tenure due to changes in ownership that have not been updated in land registries.

Secondly, although blockchains are stated to be immutable, the system is not entirely immune to vulnerabilities. Nodes can be compromised through the hacking of cryptographic keys, which can allow an intruder control of the system to manipulate transactions (Saad et al., 2019) such as invalidating a rental agreement transaction. The manipulation of land transactions can also occur through the exploitation of possible loopholes in smart contract algorithms by savvy hackers (Lemieux, 2017). Furthermore, precautions must be taken to ensure that data entered into the system by human actors are correct as fake data will lead to the propagation of erroneous data across the system. Since "there is nothing inherent in the blockchain that fundamentally alters the accuracy of recording" the accuracy of

the data within the system is dependent on data entry practices of human actors outside of the system (Lemieux, 2017, p. 416).

Thirdly, questions arise regarding the ability of blockchain systems to facilitate the archival function of data preservation over time (Lemieux, 2017, 2019). For example, in blockchain land administration projects, original records are not stored on the system but hashes of the data (Lemieux, 2017). Any changes or loss in the original data and disruption to database servers undermine the veracity of the data stored in blockchain systems. Therefore, facilitating land transactions and data authentication for present and future needs are dependent on the integrity of the original data stored in central land databases so that hashes to the original and stored data in the blockchain always sync (Lemieux, 2017). Maintaining the original land data integrity over time is dependent on human, institutional, and technological capacities in overall data management (Lemieux, 2017).

Fourthly, there is a risk of excluding parties that are not digitally literate. What happens when a party is not computer-literate enough to initiate the transactions itself and needs an intermediary as is the case with many smallholder farmers? Considering that many farmers in rural areas of developing countries have low digital literacy (Trendov et al., 2019), the effectiveness of blockchain technology hinges on the integrity of the persons or organizations managing it by mediating between the blockchain and the farmer, as it will likely take some years for most of such farmers to engage directly with blockchain based land tenure verification. Yet the fast adoption of mobile phones in developing countries shows there is potential in exploring blockchain for improving land tenure and bridging the digital divide in agriculture. For example, evidence from mobile payments services show that Sub-Saharan Africa is the global frontrunner in the use of mobile money with one in 10 African adults using these services (Chironga et al., 2017).

The emergence of blockchain technology and the hype to utilize it for sustainable development can be used as an opportunity to springboard the digital economy in developing countries and attend to first mile issues (GEF, 2019). Addressing these first mile issues require investments by the public and private sectors into internet connectivity and access to internet and mobile phones especially in rural areas (WBG, 2016; UNCTAD, 2019). Despite mobile service uptake, Africa commands only 4% of internet access globally (Lavery et al., 2018). Additionally, improving digital literacy is essential so that people, especially women and the poor, can benefit from the digital economy and reduce the inequality gap within the digital divide (Townsend et al., 2019; UNCTAD, 2019). Therefore, for blockchain based land tenure verification to be effective, farmers will require access to: (i) internet networks and internet enabled devices, (ii) education on digital services within agriculture and how to use them to secure land access, and (iii) technical officers who can facilitate farmers in carrying out mobile land transactions. Putting these building blocks in place will help to close the digital divide and facilitate livelihood security via blockchain.

Lastly, the adoption of blockchain technology in property related matters require that certain institutional and legal arrangements for digitalization are in place, especially in developing countries. These include but are not limited to: the presence of digital infrastructure such as internet connectivity, digitized land information, data protection frameworks, the establishment of standards and legal conditions for smart contracts. Like any new technology, the uptake of blockchain to address informal land markets and overall land administration first require political will and buy in from state officials and key actors. Nevertheless, as the technology matures and institutions catch up to the new digital reality, the untapped potential of blockchain could eventually be realized.

AUTHOR CONTRIBUTIONS

DD conceptualized the idea of applying blockchain to informal tenure issues in agriculture in developing countries, wrote and edited the paper. CS provided expert feedback throughout the process, which made the article more balanced, contributed to writing as well as edited the article.

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