Technology for Social Good Foundations: A Perspective From the Smallholder Farmer in Sustainable Supply Chains

Matthew Quayson, Chunguang Bai, and Joseph Sarkis

***Abstract*—The livelihood of smallholder farmers in emerging economies' cocoa supply chain is substandard because of fraud, exploitation, corruption, deceit, child labor, and financial exclusion, usually perpetrated by influential actors. This situation creates a social sustainability problem which needs urgent attention. Digital technologies such as sensors, drones, satellites, and blockchain show promise toward fostering social sustainability deep into the supply chain. This innovation is consistent with the United Nations 2030 sustainable development goals of transforming world economies toward a more sustainable future vision by reducing poverty and inequality. As our contribution, we adopt a traditional approach in our perspective article to initiate a scholarly curiosity to discuss and develop research needs on how to use technology to address this current and critical sustainability and supply chain concern. Blockchain can solve the inefficiencies, complexities, and other social issues of smallholder farmers in the supply chain. This article identifies some blockchain technologies in emerging economies, such as Hara Technology in Indonesia and Cellulant Agrikore Blockchain Solution in Nigeria. Again, we observed that the promise of using technology to improve smallholders' vulnerability in the cocoa supply chain remains underexploited in Africa and other emerging economies. Therefore, rigorous research on smallholders' social sustainability is needed to make sound policy recommendations. This short perspective article describes issues facing these smallholder farmers and how technology can play a role for them and their supply chains to alleviate various social and environmental concerns. Accordingly, we propose some research questions for technology, innovation, and engineering management researchers.**

***Index Terms*—Supply chain management, sustainable development, technology.**

I. Introduction and Background

THE United Nations 2030 sustainable development goals seek to transform world economies toward a more sustainable future. These sustainability goals mean addressing environmental concerns, reducing inequality, and addressing poverty, especially for the most vulnerable and disadvantaged in society in this current economic paradigm.

Modern industrial supply chains contribute to inequalities and environmental burdens. These supply chains may also hold promise for addressing social and ecological ills. Inequities and poorly environmentally sensitive portions of the supply chain appear in the deepest upstream parts of the supply chain [4]. As an example, the Africa agriculture commodity supply chain—beginning with its smallholder farmers—are at the mercy of various influential actors from established global supply chains. In this perspective article, we describe issues facing these smallholder farmers and how technology can play a role for them and their supply chains to alleviate various social and environmental ills. A couple of salient examples provide practical insights. This discussion sets the foundation of important research questions for technology, innovation, and engineering management researchers, focusing on technology for social good.

II. Smallholder Farmer in the Modern Supply Chain

Smallholder farmers are typically marginal and submarginal farm households that own and cultivate less than ten hectares of land—and constitute the vast majority of farmers in developing countries. Over 80% of farmland in sub-Saharan Africa (SSA) and Asia—the Global South—is managed by smallholders; with 80% of holdings smaller than two hectares [16]. Many of these farmers in sub-Saharan Africa make about 200 USD a year. They form the first link in the complex commodity agriculture supply chain, which has many actors.

Notable actors in these supply chains include transporters and distributors, agricultural extension officers, financial institutions, wholesalers, retailers and consumers, local manufacturers, and international manufacturers. These actors play a significant role in how smallholder farmers are treated and how they react.

Several activities and concerns face these smallholder farmers. They prepare the land and grow the crops—essential commodity crops such as cocoa, sugar, tea, rice, and maize. For example, after harvest, cocoa produce passes through many intermediaries in the agriculture commodity chain before it gets to the final consumer. In one country—Ghana—the cocoa supply chain eventually lead to export to developed countries, including The Netherlands, the USA, Belgium, and other developed nations. The cocoa is then made into chocolate by manufacturers

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and then, sent to retailers and consumers within the developed country supply chain for consumption.

Along this complex supply chain, smallholder farmers face fraud, exploitation, corruption, deceit, and child and slave labor [4], [7], [8], [15], [19], 22]. They also face or contribute to numerous environmental issues, such as environmentally unsustainable farming practices, theft, low commodity prices, poor information flow, and financial exclusion perpetrated by intermediaries and other significant players in the supply chain.

These smallholders—economically—are at the mercy of powerful multinational actors in the global supply chain [6], especially in the food industry, dominated by four multinationals called the ABCD (ADM, Bunge, Cargill, and Louis-Dreyfus) firms [17], [21].

How can these concerns be mitigated? Can technology support more sustainable supply chains in these early stages, especially smallholder farmers, to establish a more equitable relationship?

There have been many studies of technology innovations to improve the social conditions of less privileged in many sectors. In the energy sector, IEEE Smart Village uses a broader range of technological innovations to drive efficient power, education, and the entrepreneurial endeavors needed to empower a village, usually occupied by smallholders (IEEE Smart Village, 2019). Similarly, studies have found the adoption of off-grid or decentralized renewable energy technologies (RTech), such as solar photovoltaics (PV), biogas digesters, and improved cookstoves (ICS), as a solution to reducing the effects of poverty and improving the living standards, especially in rural communities in SSA [5]. However, RTech compatibility changes with adopter socioeconomic status, especially when benefits such as lighting are highly valued [1].

While many organizations proclaim technologies in the field of agriculture and sustainable development for smallholder farmers, few studies have been completed on the use of these technologies to improve the ecological and social sustainability of smallholder farmers in emerging economies [14], [20]. Queiroz *et al.* [20], for example, observed that the majority of smallholders in emerging economies do not understand blockchain, and hence, find it challenging to use for supply chain social sustainability. Therefore, it is still unclear how the blockchain technology influences sustainability and inclusiveness of smallholders in the emerging economies. Also, age, levels of education, poverty, and underlying technology skills affect technology usage [26]. These characteristics provide some particular sociocultural dynamics for the technology used by smallholders in emerging economies as compared to smallholders in developed countries, such as the United States, who mostly have more mature levels of education and necessary technological skills [11]. It is, therefore, essential to understand these dynamics in the context of emerging economies to achieve social sustainability among smallholders in the cocoa supply chain.

In effect, this perspective article seeks to initiate discussion, discourse, and the development of research needed to address this current and critical sustainability and supply chain concern in the emerging economy context which has not been extensively explored in previous studies. Although other perspectives are included, we primarily focus on digital ways of connecting buyers directly to suppliers preventing smallholders from exploitation and other social concerns from intermediaries and influential actors.

III. Technology to Foster Sustainability Deep Into the Supply Chain

Technological solutions have great potential in resolving sustainability issues in the agriculture commodity supply chain in Africa and other developing countries [2]. Technologies such as the drone, the Internet of Things (IoT), global positioning systems, and blockchain technology can each provide potential solutions. Examples of sustainable supply chain and technology solutions exist in Kenya, Nigeria, Tanzania, Malawi, Liberia, and Indonesia.

Broader needs exist for improving supply chain transparency, traceability, security, and information exchange among stakeholders to promote sustainability and to build greater trust [9]. Blockchain and other technologies can address the inefficiencies, complexities, and conditions in the supply chain to achieve sustainability [3], [13]. Blockchain technology integrated with IoT and big data analytics can automate data collection and recording updates and build tamper-proof record blocks. This integration prevents data manipulation and enhances traceability to achieve supply chain social sustainability [23].

Two practical examples provide some initial insights into technology, especially blockchain technology, to address sustainable supply chain concerns facing vulnerable smallholder farmers. These short cases exemplify complexities, benefits, opportunities, and risks.

IV. Practical Technological and Socioecological Solutions

A. Ease the Process of Accessing Loans From Financial Institutions.

Smallholder farmers are willing to transact with various intermediaries despite additional costs since intermediaries may supply much-needed capital for farming and offseason needs. Smallholder loans from "loan merchants" typically may have upwards of 100% interest [18]. The absence of access to formal financial institutions is a severe limitation on their well-being. This lack of financial institution access is due to lack of identification—identity, credit history, ownership, and other formal documentation required by financial institutions to prove their creditworthiness [4]. For instance, banks in Ghana need electricity or water bill receipts, and any national identification card to open an account. Most smallholder farmers live in villages with no electricity and water.

But some technological advancements may provide this accessibility. Companies such as Hara in Indonesia use blockchain technologies along with IoT—mobile phone technology—to connect smallholder farmers with financial institutions, NGOs, suppliers, and buyers through the exchange of valuable data (Hara, 2018). These data include farmer profile, land ownership, and cultivation data. They accomplish this feat using

field agents—local people to collect the data and earn payment through cyber currency. Farmers get incentives for sharing data and also share in revenue sold to financial services that have access to verified farmer customers. The company uses technology to empower farmers and field agents to work better through incentives.

Hara uses a point system and provides tokens to farmers as data are shared. The points may be used to redeem agricultural inputs and even groceries at designated shops. Useful information serves as the basis for good credit and goodwill. The company works with over 20 000 rice farmers. The result shows that farmers get microloans with a high repayment rate. In 2018, Hara used its blockchain technology to assist smallholders in Situbondo, East Java, to access microloans to the tune of IDR 332 million from Bank Negara Indonesia (BNI) with a 100% repayment rate (Hara, 2019). Notwithstanding the positives of this technology, there are some compelling issues of ensuring data accuracy, trust and privacy, regulations, sustainability, accessibility, and adoption [12]. It can provide openness and at the same time, security of information storage.

B. Reducing Excessive Intermediation—Middlemen

The complex cocoa supply chain in Africa involves many activities and actors. Activities include purchasing, warehousing, transportation, manufacturing, customer service, and demand and supply planning. The key actors in the cocoa supply chain include farmers, material suppliers, licensed buying companies, shipping companies, distributors, cocoa marketing companies, local processing companies, retailers, wholesalers, and government regulatory bodies such as COCOBOD in Ghana.

The smallholder farmer encounters many intermediaries before the cocoa beans are processed locally or exported. The licensed buying companies have agents in the districts called purchasing clerks (PCs). These PCs work on commission and operate within communities and deal directly with farmers. Some of these PCs even have local buying assistants who also buy directly from smallholder farmers. They purchase and deliver cocoa to the district officer (DO) at the district depots. The DO prepares it for grading, sealing, and delivery to the port for Cocoa Marketing Company Ltd. to takeover. A substantial amount of real money flows through intermediaries to buy the cocoa. There is room for corruption and theft as sometimes the money is diverted, and smallholder farmers do not receive compensation after they have transferred their farm produce to local buying assistants or PCs [25]. Blockchain technology plays a significant role in reducing the many middlemen by connecting smallholder farmers directly to buyers and end-users [14]. It also reduces direct cash transactions and protects smallholder farmers from being shortchanged**.**

To address these social concerns, Cellulant Agrikore provides a blockchain solution which connects smallholder farmers directly to buyers, suppliers, financial institutions, insurance companies, and other development partners in a trusted ecosystem in Nigeria and other parts of Africa (Cellulant Agrikore, 2019). The technology provides access to direct markets and financial services to improve their livelihoods. The commodity buyer or agent through the blockchain issues digital money (called MULAB) into the farmer's wallet after receipt and checking of the produce. The smallholder farmer can then exchange the MULABS for MULA—also known as Tingg cashable payments. The smallholder farmer need not travel long distances to look for buyers and has direct secure access to various partners in the supply chain. The smallholder farmer is assured of payment as they automatically receive the digital money in the wallet, which they can easily convert into cash.

Other practical examples exist and include integrating global positioning systems with blockchain and IoT application technology to define and confirm land ownership for smallholders. This type of technology is useful for verifying or evaluating the diversity of farmland, protected lands, and flora or fauna in the region. Drone technology is also helpful in viewing various difficult-to-view areas to help in the certification of practices, diversity, and farmland infringement on protected areas.

However, there are issues. Blockchain technology can trace the delivery process for smallholder farmers. The lack of physical—regular fiat—cash also means a longer time for the farmer to process digital money to cash. Delays in the process may discourage smallholder farmers from adopting the technology and opt for intermediaries who usually settle them with money instantly. Other concerns include the question of who is responsible for validating the information, the loss of privacy and identity of more impoverished farmers, mistrust of outsiders, and various cultural barriers. In the case of child labor observation and recording, there may be dangers to children or other exposed employees (World Bank, 2019). Overcoming cultural concerns and barriers is also a significant concern for any technological solution. Substantial opportunities do exist for "leapfrog" technical solutions due to lack of technological legacy systems and infrastructure; planning, instilling, and managing these possibilities requires initiatives at multiple levels—national, supply chain, organizational, and social levels.

V. Research Directions and Needs

Given these background, issues, and potential solutions, our perspective article proposes the following research concerns. Answers may help advance understanding, investigation, and beneficial influences on supply chain sustainability—especially to the most vulnerable actors in modern global commodity supply chains.

1) How will these technologies diffuse through the supply chain to be able to reach the most vulnerable groups at the bottom of the pyramid?
2) Do such technologies result in improved sustainability-oriented conditions and performance measures? These measures and performance are not necessarily achieved simultaneously; in fact, paradoxical tradeoffs are likely to exist.
3) What cultural and socioeconomic barriers exist to the acceptance of these technologies? Do traditional acceptance theory frameworks and models apply to this supply chain environment?
4) Will privacy, identity, trust, social capital, and other relational factors and theories play a role in explaining,

understanding, and predicting technology effectiveness and use?

5) Are there specific philosophical and political theories that can be used to integrate technology adoption, sustainability standards, and social transformation? For example, postcolonial and neocolonial theory, ecological modernization theory, and neoliberal theory.
6) What new models, methodologies, and techniques can be used to capture, guide effectively, and predict technology selection? What characteristics of the technologies—such as transparency and security of blockchain technology—may be best integrated to model this environment?
7) Can technological forecasting and other innovation and technology modeling approaches effectively predict the evolution and development of technologies in a socioeconomically diverse supply and value chain? What happens at the intersection of technological innovation and social innovation?
8) What is the role and how to take advantage of existing platform technologies as they merge with emergent technologies? For example, existing African Mpesa and Icow electronic banking with emergent artificial intelligence, blockchain, global positioning, 5G, and cyber-physical systems?
9) What are the roles and effectiveness of various stakeholders and institutions in technology adoption? For example, private multinational firms, NGOs, governments, and local communities each play a role in introducing or managing technological innovations for sustainable supply chains.
10) Would supporting systems be helpful for smallholder farmers and their communities to succeed and improve their quality of life? For example, technological, financial, and sustainability literacy programs and education may be needed for the long-term success of such technologies and livelihoods.

VI. Caveats and Concerns

The research questions and potential technological solutions proposed here must be critically examined. We employed a very traditional approach to list and identify research questions. Whether this traditional approach is appropriate when wicked problems arise must be a concern for all players in the industry and researchers.

The research needs to be completed from a developing country perspective. How the impacts of the technological innovations reap a similar performance outcome, such as in developed world environments is another issue that has to be considered. If experiments are to be used, it needs to be remembered that ethical concerns will arise; careful monitoring of research practices is needed.

In some cases, technological solutions that eliminate intermediaries and loaners may jeopardize the livelihood for those that offer these services; significant unintended consequences may occur. This technology may shift benefit to those with power and resources, such as telecommunications companies and large financial institutions. Careful research, development, deployment, and examination of shifting resources need to be examined. The solutions should not be at the expense and exploitation of these vulnerable populations. There are ethical and moral research concerns when seeking to investigate technological solutions; we should be aware of and wary of these issues.

Finally, traditional reductionist research, evidenced in the IEEE Transactions on Engineering Management and other innovation and technology journals, may not provide effective solutions. Transdisciplinary, holistic solutions and investigations are necessary.

The smallholder farmer is one of the forgotten actors hidden deep in the supply chain, especially when it comes to business, technological, and economical solutions. Sustainable supply chains should not be blind to these members, especially those in emerging countries. These hidden actors can benefit most from accessibility, visibility, empowerment, and sustainability, benefits that can accrue with thoughtful technology and research. We encourage such research as we carefully call for an investigation on technology's role for social good. Global sustainable development goals with their complexities are likely to require some of these solutions.

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