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Making Smallholder Value Chain Partnerships Inclusive: Exploring Digital Farm Monitoring through Farmer Friendly Smartphone Platforms

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Abstract: Value chain partnerships face difficulties achieving inclusive relations, often leading to unsustainable collaboration. Improving information flow between actors has been argued to contribute positively to a sense of inclusion in such partnership arrangements. Smallholders however usually lack the capability to use advanced communication technologies such as smartphones which offer a means for elaborate forms of information exchange. This study explores to what extent co-designing smartphone platforms with smallholders for farm monitoring contributes to smallholder ability to communicate, and how this influences smallholder sense of inclusion. The study uses an Action Design Research approach in engaging smallholders in Ghana, through multi-stakeholder and focus group discussions, in a reflexive co-design process. The research finds that co-designing a platform interface was significant in improving farmer ability to comprehend and use smartphone based platforms for communicating farm conditions and their needs with value chain partners. Farmers were however skeptical of making demands based on the platform due to their lack of power and mistrust of other actors. This highlights a need for adjusting the social and political dimensions of partnership interactions, in tandem with the advancement of digital tools, in order to effectively facilitate a sense of inclusiveness in partnerships.

Keywords: collaboration; partnerships; value chains; smallholders; inclusiveness; digital agriculture

1. Introduction

Smallholder farmers in developing countries generally lack access to advanced agricultural supplies, timely market information, and a full range of financial services [1]. Stimulating partnerships, which include mutual benefits for smallholder groups and value chain actors, is increasingly seen as a means to improve smallholder access to these crucial services [2]. These multi-actor partnerships leverage collaboration to create services to smallholders [3] and therewith reduce the transaction costs [4]. Research however notes that such multi-actor partnerships are often driven by power dynamics and stakeholder interests [5,6]. Hence, deliberate actions are needed to safeguard inclusiveness for weaker groups like smallholders [7]. Without such measures, partnerships may reproduce extant forms of marginalization for smallholder farmers [8].

For smallholder value chains, making partnerships inclusive for farmers presents a unique challenge. In partnerships, smallholders tend to be engaged as a collective, receiving general support

measures such as improved seeds and credit [9]. This structure is pragmatic but poses some challenges as farmers are heterogeneous in nature and face diverse socio-ecological challenges which necessitate more personalized support than offered [10]. At the same time, smallholder farm settings are highly variable making it essential for farmer conditions to be frequently communicated, understood, and responded to if their needs would be appropriately met by the support mechanisms offered by partnerships. Resource limitations and communication difficulties that characterize smallholder institutional contexts however limit the ability of individual farmers to communicate and influence partnership decisions to align with their needs [11]. As such Bitzer and Glasbergen argue that smallholder organizations often lack genuine representation in partnership arrangements [12].

Tackling these communication constraints is crucial in making partnerships more inclusive for smallholder farmers. Several studies have highlighted the potential and actual contributions of mobile technology in enabling this in smallholder value chains [13,14]. Smartphones, with features like cameras, internet, and access to global positioning systems (GPS) offer further opportunities in this domain [15]. Leveraging these advanced mobile features, smartphone devices could contribute to more detailed forms of farm monitoring and communication that enhance information flow, mutual understanding, responsiveness, and accountability between smallholders and partners. This digital approach to farm monitoring and communication by smallholders, offers a new means of capturing and communicating locally specific farm information [16,17]. In this way, smartphone devices could contribute to building more inclusive value chain partnerships.

Although smartphones have become more accessible in recent years due to rapidly declining costs, a persisting constraint to their adoption is that most smallholders lack the capacity to navigate their interface or use their advanced features. Caine et al. reason that to overcome this capacity gap, attention should be paid to designing digital tools to meet the information needs and technological abilities of smallholder farmers [18]. Such an approach should seek to reflect the local context, user capacities and the cultural background in smartphone applications, and therewith make digital tools more user friendly to farmers [19–21]. These arguments suggest that a participatory design approach, adapting digital tools to smallholder needs and capacities, is essential for smallholders to harness these communicative benefits of smartphones. There is however a knowledge gap on the efficacy of such an approach in enabling farmer use of smartphones for monitoring purposes. More specific, not much is understood about how smallholder farm monitoring and communication through smartphones could influence smallholder inclusiveness in value chain partnerships. This study therefore seeks to answer two research questions: (i) In what way does co-designing farm monitoring platforms with smallholders influence farmer capability to monitor and collect farm information via smartphones, and related to that (ii) how does this influence farmer sense of inclusiveness in value chain partnerships?

We study these questions by focusing on the case of smallholder maize farmers in the Techiman locality (Ghana). In this case, we reflect on the participation of farmers in a co-designing process for farm monitoring through online platforms. To this end, we present the theoretical framework for the study in the next section, followed by our methods and results. In the final section of this paper, we discuss and conclude on both the reflection on the co-design process and the influence of this process on the inclusiveness of value chain partnerships.

2. Theoretical Framework

2.1. Value Chain Partnerships and Inclusiveness

Partnerships are defined as collaborative institutional arrangements between actors from various sectors of society [22]. In the context of smallholder agriculture, Bitzer et al. theorize that value chain partnerships are about the construction of institutions that enable smallholders to participate in value chains [9]. By engaging different actors, partnerships have the ambition to leverage divergent expertise and specialized roles that can complement each other and address the constraints faced by smallholders.

In pooling actors, value chain partnerships bring together actors with different interests as well as ways of reasoning and knowing. For instance, value chain partnerships may involve smallholders collaborating with bankers, insurers, and/or agribusinesses, who tend to be business-oriented in their thinking and have formalized rules and relationships whereas smallholders are relation-oriented and rely more on interpersonal relationships. As partners seek to conduct activities according to their ways of knowing and reasoning, there is an on-going tussle to meet different actor interests [6]. These differences mean that although partnerships may be formed with the intention to improve smallholder circumstances, they may not necessarily be inclusive [12], nor do they always result in beneficial outcomes [23], especially for those less empowered or able to speak up. Value chain partnerships aiming for inclusion, thus, not seldomly result in the opposite, calling for a re-examination of the inclusiveness of such arrangements.

To do so, Vermeulen and Cotula offer four criteria for determining the inclusiveness of value chain collaborative arrangements for smallholder farmers [2]. These consist of the level of ownership, voice, risk, and reward that farmers have in the collaboration. Ownership relates to how much of the key project assets are owned by smallholders. Voice represents the extent to which farmers can communicate with partners and influence the decisions and actions taken in the value chain set up. The level of Risk borne by smallholders and the commensurate Reward in the given arrangement are also argued to be critical measures of how inclusive a value chain collaboration is. These four criteria are argued to be interconnected as changes in one can lead to alterations in the others, and consequently the overall level of inclusiveness in the value chain arrangement [2]. Enabling inclusiveness in partnerships thus goes beyond linking farmers to key value chain actors, to enhancing farmer ability to make these linkages work for their benefit [24] by ensuring that partnerships function in ways which improve smallholder ownership, voice, risk, and rewards [2].

2.2. Smartphone Platforms for Inclusive Partnerships

Vermeulen and Cotula aver that enhanced communication mechanisms help to give voice to actors, which could make value chain collaborations more inclusive [2]. For instance, since smallholders are heterogeneous and have diverse needs [10], allowing farmers in collectives to communicate their farm-specific conditions would improve partners' awareness and understanding of farmers' contexts, and help farmers to attain more farm specific and timely support services [25]. Thus by providing credible information, smallholders could counter ignorance, distrust, and self-protective behavior of powerful value chain partners. Transparency creates a public space in which value chain partners are called upon to reconsider their decision-making. Reducing information asymmetry may enable farmers and partners to mitigate conflicts by building transparency, accountability, and trust in the partnership [12]. To attain more inclusive partnerships, smallholders need to be able to communicate their farming activities, conditions and needs in ways that partners can comprehend, trust, and respond to [26]. On the other hand, heightened monitoring for information symmetry could contribute to counter inclusive outcomes through farmer experiences of surveillance and being controlled [27]. However, by making smartphone platforms more user friendly for smallholders, through an inclusive co-design process that involves them, farmers could take the lead in farm monitoring and communication that might enable an accretion of their agency in partnerships. In other words, inclusive partnerships could be facilitated through smartphones by empowering smallholders with a voice and systematically increasing their capability to influence change in their context [28,29].

Using these theoretical concepts, we explore how farmer oriented smartphone platforms for farm monitoring in a specific smallholder context influences partnership inclusiveness. We do this by developing and reflecting on a co-design process (see methods section for a further elaboration on the co-design method). In this process, we focus our analysis on farmer views of:

(i) the extent to which the co-design process enhanced farmer perception of their ability to use smartphones for farm monitoring and communication in partnership arrangements;

(ii) the extent to which this increased farmers' perception of inclusion in terms of ownership, voice, risk, and reward.

3. Materials and Methods

3.1. Study Context

The study was conducted in the Techiman municipal district in Ghana's Bono East region (see Figure 1). About 46.2% of the households in the municipality are engaged in agriculture; of these 95.4% are crop farmers. In the rural localities, 75.8% of the households are engaged in agriculture whereas in urban localities the figure falls to 33%. Maize is a major food crop produced in the area with the district's center having one of the biggest market centers for maize trade both within and across Ghana's borders [30]. Smallholder maize farming in the Techiman area, like most parts of Ghana, is characterized by rain-fed production, limited storage facilities, poor information flow, powerful traders, and weak farmer groups. These have historically translated into many experiences of uncertainties, unfair farmer treatment, strategic defaults, conflicts, and mistrust when value chain actors partner for collaboration. Farmers generally have limited options for financial and material support from formal sources, resulting in significant reliance on value chain actors for such needs and a precarious position in partnerships [31]. The study area was chosen as it resembles a prime example of a context in which multiple actors interact in varying maize value chain partnerships. In addition, several projects have been implemented in the area to help facilitate value chain development and collaboration enhancement. These characteristics provided the appropriate conditions for this study.

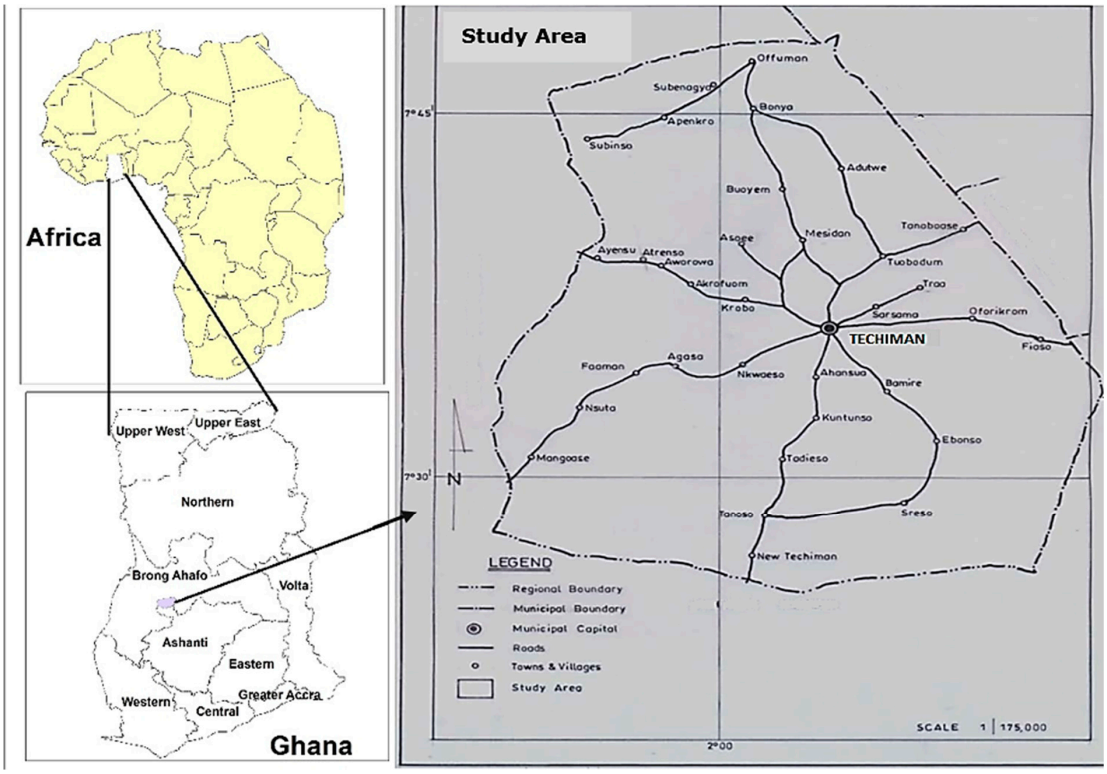

Figure 1. Location of study site.

3.2. Scope

The study involved farmers who had been a part of a partnership arrangement facilitated by the Ghana Agricultural Development and Value Chain Enhancement (ADVANCE) II project. The project aimed to support smallholder farmer groups by linking them to markets, finance, inputs, and information through larger farmers and traders. For the study, we purposively selected 6 villages

in the Techiman municipality in which farmer groups and collaborative arrangements with value chain actors had been established under the ADVANCE project. One farmer group was randomly selected from each village. Five members were then nominated from each farmer group to participate in co-designing a farmer friendly farm monitoring platform. Each farmer group was provided with a smartphone on which the finalized platform would be installed for farm monitoring purposes. In total, 30 fields were to be monitored by the farmers via the platform.

3.3. Co-Design Approach

Since the study aims to facilitate the design of a digital platform and understand the influence of the process and output, we adopted the Action Design Research (ADR) method. The ADR as a research method looks to utilize a building and evaluation process for garnering relevant knowledge for effective design in a given organizational context [32]. This approach is undergirded by the principle that information technologies are shaped through actor interactions in relation to their specific context. In this way, building, implementing, and evaluation are not seen to be iterative processes but an intertwined process of inquiry in the development of information technologies that both represent the intentions of researchers as well as the influence of users. The method enables co-design through three main phases: (i) problem formulation; (ii) building, intervention, and evaluation; (iii) reflection and learning. Reflection and evaluation however happened though all three phases especially on anticipated social/technical risks in implementing agreed design decisions and suggested responses for improvement. Since the co-design process involved diverse groups, different communication strategies were used and reflected on, including narratives, storytelling, interactive games, images, and prototypes. These strategies were chosen to bridge communication gaps between the researchers and other stakeholders, and played an integral role in the co-design process [33]. Table 1 below presents our data gathering methods for each of the phases. All interviews and discussions were tape-recorded, transcribed, and translated where necessary. Translation was conducted with key focus on maintaining content and semantic equivalence in English as possible [34]. Afterwards and following our theoretical exploration, the data were analyzed in terms of ownership, voice, risk, and reward.

Table 1. Data gathering methods for each phase.

Phase	Data Gathering Methods	Stakeholders	Purpose
Phase 1	Preliminary semi-structured interviews Multi-stakeholder discussions	Farmer leaders (6), Traders (3), Agribusiness representatives (2), Extension agents (2)	Joint problem definition, information needs assessment, mobile phone perceptions, and experiences
Phase 2	Observation Focus group discussion Semi-structured interviews	Farmers (5 per village) Farmer leaders (6)	Developing context relevant platform for farm monitoring
Phase 3	Focus group discussion Semi-structured interviews	Farmers (5 per village) Farmer leaders (6) Traders (3) Extension agents (2)	Refection on co-design process and platform in relation to learning and inclusiveness

To facilitate the design of the mobile farm monitoring platform on smartphones, we adopted the Sapelli mobile application. Sapelli is an open-source application which uses highly configurable icon-driven user interface to overcome literacy and/or language barriers in data collection. The application allows for configuring icons in a manner which reflects local perspectives and needs in order to enhance user friendliness [35]. Records of data are generated and stored automatically on the application and presented in an XML or CSV file format. These records can either be downloaded or sent via sms to another actor. Sapelli was thus appropriate in exploring digital farm monitoring in the African smallholder context.

4. Results

The results section describes the outcomes from the co-design process following the ADR method which was undertaken in three iterative phases: (i) Multi-stakeholder discussion; (ii) building, implementing, and evaluating the mobile platform; (iii) actor reflections on the co-design process and output (the platform). As this results section reflects the different roles and characteristics of these phases in the co-design process, each section of the results hold a slightly different style.

4.1. Phase 1: Multi-Stakeholder Discussion

For purposes of establishing the contextual frame within which farmers operated, and in particular the problems impeding collaboration, we deemed it necessary to engage with wider actors within the value chain as a starting point of the co-design process. To do this, phase 1 centers around a multi-stakeholder discussion as kick-off between traders, farmer leaders, and government extension agents who were partners under the ADVANCE program. The actors explained that their partnership worked as an out-grower scheme with an agribusiness, called 'Agricare', serving as a creditor. Agricare provides inputs to a farmer group and receives predetermined quantities of maize from each farmer as repayment. This repayment was done through the traders who served as middlemen between the farmer group and the agribusiness, and signed contracts with the agribusiness to guarantee the supply of a given number of bags from the farmers in repayment of the credited inputs. Agricare expected the traders to work with the farmer leaders to monitor production and ensure that the contract terms were met. This was because Agricare deemed the traders and leaders to be better placed to ensure that farmers provided the required maize since they had better relations and more frequent interactions with the farmers than the agribusiness. The farmer group members agreed to share joint liability in the event of defaults.

During the meeting, we sought for a joint identification of the main problems impeding the partnership. Most of the collaboration challenges raised by the actors were related to crop yields and production output. Since the partnership revolved around a reciprocal relationship of inputs for crops issues regarding crop failures, that is, the emergence of diseases and pests, failure of seeds to germinate, fertilizer application, or the onset of drought/overly wet periods, were highlighted as sources of tension in the partnership. One trader expressed a perspective that was felt among traders, that crop failure was used as a major excuse by farmers to free ride and avoid repaying partners who support them: "For some farmers, all they want is a little excuse so they can blame their defaulting on crop failure, so we need to monitor various things" (trader). This assertion was consented to by the other traders as well as the Agricare representative. The farmers did not dispute this claim but argued against the generalization of this perspective. Farmers argued that only a few recalcitrant farmers seek to default, however for the majority, crop failure was a genuine problem which occurs due to farmers lacking support for appropriate and timely response to farming challenges. This was countered by Agricare who intimated that most of the farmers are experienced farmers and if they undertake the right farming practices, barring unknowns like drought and novel diseases/pests, they should be able to respond adequately to farm challenges. Information asymmetry in relation to crop yield and production was as such a source of conflicting viewpoints and contention in the partnership. Following an inquiry whether improved information flow regarding these issues would be relevant for addressing the conflicts in the partnership, Agricare affirmed this position, arguing that this could help farmers gain some reasonable support for timely resolution of problems when necessary or at least let partners gain awareness of developments. Farmers and traders also agreed with this claim. On the issue of what to monitor, the traders and Agricare indicated that key observations that were necessary for conflict reduction included regular descriptions of the state of farms in relation to agricultural practice, pest, diseases, and the weather. One trader suggested monitoring of harvesting, de-shelling and storage as also important for tracking maize produce to prevent losses from improper handling or side selling activities. Based on this, we highlighted these issues as key information needs with choice and decision-making implications in the partnership in the following steps of the co-design process.

Following this, we sought to understand actor perceptions on mobile devices and whether/how they had been used previously in attempts to address such information related conflicts. In general, the actors had a highly positive perception about mobile technology and its role in facilitating their collaboration. One trader mentioned that he and a farmer had tried to use a camera phone to help them work together: "There was one farmer I worked with who had a smartphone, so sometimes he will take pictures of the crops and show it to you so that you will see what is going on". Mobile devices were deemed to be very important by the traders but mainly used for interpersonal verbal communication with farmers but not explored for farm monitoring purposes at group level. This was due to the fact that most of the farmers did not have such smartphones and were unfamiliar with using the devices. Farmers also shared this concern: "We farmers we don't have those kinds of phones. Also those phones; most of us cannot use it, so you have to teach us" [leader]. "We know there's so much you can do with phones but with farmers it will be difficult for them to use" [trader]. There was therefore consensus on the potential utility of smartphones for collaboration purposes but challenges of access and capability were seen as major barriers to adoption.

To further open up the discussion on the possibility for using mobile devices, we asked the actors to imagine that farmers had been given smartphones that they could easily operate to share images of their farming situations with the other actors and what concerns they would have if this were possible. This framing of the issue allowed actors' discourse to move away from perceived barriers to smartphone use. From this angle, the conversation very quickly centered on the authenticity of information provided such as images. Interestingly, the first actor to raise this concern was a farmer and not the traders as we expected. This farmer was the only farmer who indicated owning a smartphone and as such his experience may have contributed to his insights: "But what if a farmer is taking pictures of someone else's farm because I can go anywhere and take pictures". Thus, we noted that for information to be effective in improving collaboration, its trustworthiness was crucial. To enhance perceptions of trustworthiness, a trader suggested that if farmers were to undertake monitoring through user friendly platforms, it would be best to begin with farmer leaders as monitoring actors, instead of perhaps a rotation of a smartphone among farmers. This was because the leaders were already trusted by traders and farmers alike to monitor and keep farmers in check.

Based on these responses, stakeholders were asked to reflect on the possible approach of farmer leaders monitoring farms with smartphones and anticipate potential issues/risks which could emerge from such an approach. Through this anticipation process there were some concerns about the use of farmer leaders for this detailed monitoring. A leader raised the issue of superstition and suspicion in relation to their presence on the farms of other group members. A key concern was that some farmers may associate certain negative developments on their farms as emanating from their farm visits: "Some farmers believe that some people can do something in the farm which will affect their farm's productivity. As for me the leader, now they trust me but people are people so we have to be careful". This concern was backed by another leader who highlighted that this could be an issue particularly when a farmer was not on very good terms with the leader. From this perspective, leaders noted that such circumstances could generate some conflict between leaders and certain group members. To address this issue, leaders suggested that farm visits should involve farm owners as often as was possible. In addition, one leader suggested that to introduce such an approach, initial farm visits should include the researchers, together with the farm owner, to get farmers used to the idea of these farm visits by the leaders. This extra level of transparency was to serve as means of maintaining social relations while altering the configuration of interactions, and added in phase 2. Table 2 presents a summary of key findings from this phase of co-design.

Table 2. Summary of findings from multi-stakeholder discourse.

Farm Information Needs of VC Partners	Smartphone Perceptions	Anticipated Risks	Suggested Response
State of farm in relation to GAPs Pest/disease presence General weather condition Harvesting, shelling and storage	High utility potential Non-complex interface needed for farmers Needs verifiable outputs	False information provision Suspicion and conflict with farm monitors	Use of trusted actors (leaders) for information collection Transparent processes needed

4.2. Phase 2: Building, Implementing, and Evaluating the Farm Monitoring Platform

Building on phase 1, another meeting was organized to deliberate on the digital platform. This time only the 36 farmers and farm leaders were participants. This discussion was meant to transition interactions towards the designing of the platform. We began by revisiting the information issues which had been agreed upon at the multi-stakeholder meeting as relevant to monitor (Table 2). Based on smartphone perceptions that we found in the first phase, we concluded that a simple non-text platform with an image based interface would best suit the local context and foster inclusion. Therefore, our co-design process centered on using a participatory process for selecting images to use on the platform as representative icons for each of the information needs that needed to be monitored. Other design issues like layout and structure were constructed by the researchers. We had printed a collection of images, which we believed could provide good pictorial cues of the key issues which needed monitoring. The image that most farmers associated with an issue was to be adopted as that issue's icon on the platform. We presented this association activity to the farmers as a game to enable them participate in the abstract design process. We reframed the issues that had been identified as questions, for instance, 'are there any pests on the farm?'. While doing so we would raise an image, go through the questions and ask farmers to mention what issue/question they assumed fitted best with the raised image. We allowed open discussion about the image when farmers had different views to see if consensus would emerge. We played this 'game' for three rounds, dropping images that were difficult for most farmers to agree on. By the third round, there was at least one image that farmers generally agreed to associate with each issue/question.

Building upon this, we introduced the farmers to another aspect of the game. This time, farmers were to respond to the questions posed by the images with another set of printed images. These responses were to be provided using colors printed on A4 sheets. We adopted a color scheme which most of the farmers were familiar with: the traffic lights. We explained that based on the traffic light color scheme, red represented danger, amber showed emerging/developing danger, and green was an all-clear. Farmers were to use these colors in response to the questions/issues they had associated with images earlier. Farmers were taken to random farm plots in the community where they were asked to give their individual assessment of the farm plots using these colors. The process was non-verbal. At each point, researchers simply raised an image corresponding to an issue and based on this, farmers assessed the farm and responded using their colors. After farmers responded, we inquired of the reasoning behind their responses to determine their comprehension of the associated question and the evaluation task. Farmers were generally successful with this task and in this way the game was effective in creating an abstract representation for monitoring real life situations.

Following these activities, we uploaded the selected images unto the Sapelli interface as icons. The platform interface was a simple linear process where a user selects a farmer profile from the home page and proceeds to monitor each of the issues as prompted by their associated images being displayed. To simplify the interface, we focused on only monitoring issues related to on-farm activities, excluding post-harvest treatment and storage. To provide an assessment of each issue, a user selects from the red, yellow and green colors. Each assessment is followed automatically by a camera screen

for farmers to capture evidence of their assessment. These pictures are automatically geo-tagged and stored. Figure 2 presents the Sapelli interface adapted to the farming context. Screens A, B, C, D, and E represent the farmer profile, farm state, weather state, pest state and disease state respectively. These are evaluated using the color scheme and photographed where applicable.

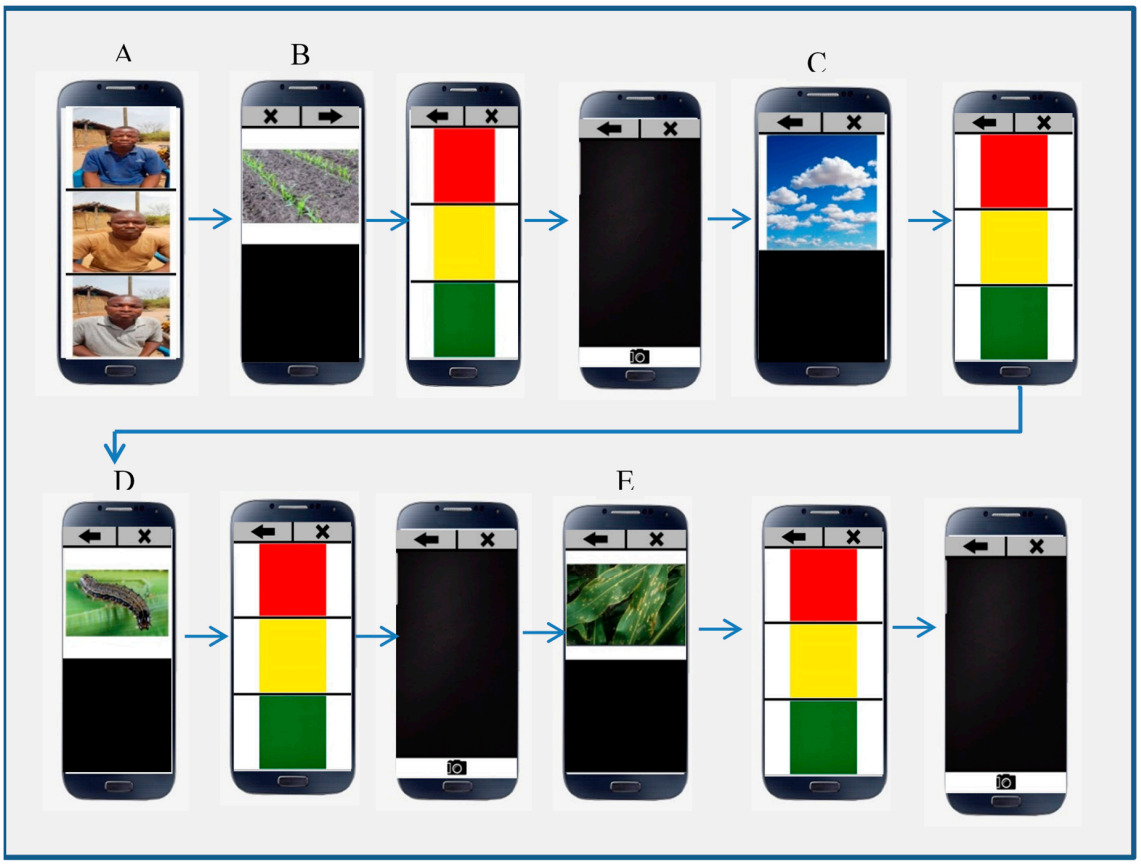

Figure 2. Co-designed platform interface.

After developing the platform, farmers were taken through training over a period of two weeks on how to use the co-designed platform. We found that some people developed proficiency with the software very quickly, as early as on their first try whereas others required more familiarization. Most had however gained significant mastery over the application within half an hour of use. By practicing the use of images as metaphors for inquiry and the use of colors for response, the farmers were ready to transfer the concepts to the smartphone application, facilitating speedy comprehension: "Because from the beginning we went through some question and answering where we used some pictures to represent the problems we talked about before. So since they were the same pictures it was easy to remember".

From this perspective, the use of games and images in the co-design process was significant for farmer learning how to use the digital platform. This also meant that processes which could not be practiced through the co-design process but remained an abstract concept on the platform posed some difficulty for some. For instance, a challenge for some farmers was in comprehending the concept of going back in the application using the back arrow. Most were more comfortable with the step by step process and not when one needed to navigate backwards and forward in the app. This aspect of the interface took more time to grasp for some farmers. On the other hand, most of the group leaders more easily remembered abstract icons such as crosses and ticks. There appeared to be some familiarity with these common symbolic conventions on smartphones. We attribute this to the fact that most farmer leaders had some form of basic education which meant that they could appreciate concepts

such as a tick implying correct and a cross indicating wrong. Age of the farmers was no impediment to comprehension as most of the farmers were above 45 years and still were able to grab the concept of the application fairly quickly. During practice, some farmers had their children present who were more conversant with smartphones to serve as a helpful assistant when they forget the required action on the platform.

Following the training, it was agreed that farmer leaders would monitor the farms every 2 weeks. This time period was deemed as optimal for monitoring changes in the farms and also to allow leaders collect data without much stress. In the first month, leaders were phoned to remind them when monitoring was due. Farmer leaders were observed and assisted by researchers as they monitored the farms during this period. A few challenges were observed at this stage regarding leaders' handling of the smartphone device. The first issue was that some pictures were a bit blurry due to the leader's hands being a bit shaky while capturing images. This was due to nervousness in handling the devices and reduced after a few farm visits. Again, during use of the platforms, some leaders inadvertently pressed the side buttons on their phones. When the power button was pushed, resulting in the screen going off, leaders became confused as they thought something was wrong. In addition, when selecting icons on the platform, the touch screen presented some frustration to farmers as selected options were not always effected on the first attempt due to callouses on their fingers. Finally, on occasions when the GPS locator delayed for a while in establishing the geo-location of the image, leaders were uncertain on what to do next or how long to wait. These experiences needed further discussion to better guide use of the digital platform.

After the first month, leaders were allowed to follow the protocols without researchers being present for the next two months. All the leaders were consistent with their farm visits even when the reminders ceased. After the two months, farmer leaders had successfully captured farm photographs for the period via the platform. Farmers were asked at key points during this period to recount the processes involved in using the platform as well as the meaning associated with its images. Most of the farmers were able to provide satisfactory explanations and descriptions over the period. This demonstrated general comprehension of the platform throughout the season: "as for now no fear, now we can do it on our own...it's not difficult". Assessment of the images generated showed that farmers faced a few challenges in the process. The first difficulty farmers faced was in reporting on the general condition of the farm. Farmer leaders faced difficulty remembering how to get a good wide view photo of the farms. Some often took portrait shots when landscape images would have been a better option. Furthermore, as the maize crops grew, finding a good position to stand to capture wide view of a farm became more difficult in some farms where farmers had only narrow paths to stand on between fields. This gave limited space to move back for wider pictures. In terms of picture quality, the images were generally in focus. The main challenge faced here was with the timing of the photographs. Some leaders monitored farms around dusk when there was limited lighting. This led to some pictures being unclear. It was necessary to have some further discussion on best times for capturing farm images.

After using the device over the period some leaders identified an issue which needed to be anticipated and addressed regarding the protocols of the digital approach of data collection. The agreed protocols for farm data collection was that each of the 5 farms would be visited every two weeks. However, during implementation, leaders had questions about how to effectively collect data should the group numbers be increased. For instance, if the group size were to increase to 10, leaders would have to do twice as much work which would claim more time. Leaders noted that even though they were motivated to help with monitoring, the approach would need to find ways of addressing such challenges. A key suggestion which some leaders had explored was engaging local motorcycle users in the community during their monitoring activities. This enabled monitoring to be undertaken rapidly and also provided the opportunity for covering more farmers. This could have cost implications. If this option is not available in a given community's context, farmers suggested that other group members could be trained and recruited to assist leaders. It was noted however that this would result in some

degree of trade off with the trust which the leaders offered. Table 3 presents a summary of key findings from this phase of co-design.

Table 3. Findings from building, implementing, and evaluating the platform.

Observations During Information Collection Via The Platform		Anticipated Risks	Suggested Responses
Positives	**Challenges**		
Farmers demonstrated recall of icon/issue association Farmers were able to follow protocols without assistance	Abstract concepts Calloused fingers Understanding of basic photography dynamics	Time costs of monitoring Differing picture standards	Use of locally available motorcycles More training and familiarity with phone photography

4.3. Phase 3: Reflecting on the co-design Process and the Farm Monitoring Platform

At the end of the season, the farmers were brought together again to reflect with the researchers on their experience in using the digital platform and their perceptions on the co-design approach. The reflexive process aimed to review farmer perceptions and experience vis-a-vis our assumptions and observations on (i) the linkages between the co-design process and farmer capability to use smartphones for farm monitoring and (ii) the link between enhanced communication and a sense of inclusiveness, described here as a sense of being able to influence change in ownership, voice, risks, and reward. In the discussions, the following subjects were brought up:

On the first issue, farmers discussed what factors they thought contributed to their ability to follow the protocols in the use of the platform. The simplicity of the platform was identified as an important reason for this. By providing a simple and intuitive platform based on issues they could identify with as well as icons they had participated in selecting, farmers felt they were able to quickly feel a sense of competency without much supervision or facilitator present: "It is not complicated so we just follow one step after the other and you are done. And it is also our issues that we talked about so it is straight forward" [leader]. The ease of use offered by the interface meant that farmers felt ownership over the platform and confidence to use the smartphone application was high after trying the platform a couple of times. Leaders indicated and demonstrated that they were confident they could use the platform on their own effectively. By this, farmers confirmed that co-designing and using the platform for monitoring their farms had positively influenced their perceptions on their capacity to use smartphones for farm monitoring.

On the second issue, whether enhanced communication via the smartphones could affect farmer sense of being able to influence change, the farmers had two positions. First, farmers highlighted that the use of pictures could help them alleviate the challenge of describing conditions they encounter on their farms. This took away earlier feeling of risk that was associated with sharing information as misunderstandings were less likely to occur and that it was easier to voice up their point of view to traders. An extension agent confirmed this with an example: "there was this farmer, she spent so much money on different chemicals, more than 1500 cedis ($300) dealing with the fall army worm, so later I went to look at what chemicals she had been applying and she was using fungicides! She says that's what the chemical shop gave her after she described her problem" [extension agent]. By capturing and viewing images from each other's farms, farmers indicated that they felt ownership over the platform and better positioned to interact with traders and other farmers on farm issues, increasing their position to voice their perspectives and interests. In addition, one trader stated in an interview that with the farm images he would be better placed to help the farmer make decisions on what measures to take given the specific conditions identified: "If I am just explaining to him is different. But if I can add picture then that one it will be clear". Additionally, the trader indicated he could contribute to bridging the extension agent–farmer gap by sharing the farm images with extension officers within his network. It was indicated by an extension agent that some extension agents already use WhatsApp groups to interact and seek information from each other concerning field conditions. Thus, some of the farm pictures could be shared on these platforms by partnering with extension agents who were already present on these WhatsApp platforms. Based on the outputs from the digital platform, traders,

extension agents, and the farmers perceived opportunities for better extension support and tailored advice through digital communication.

The farmers however had a less certain position on their ability to influence responsiveness from partners when the response would involve material support from value chain partners in general. This was due to certain experiences with partners in the past. For instance, some farmers indicated that in a previous season, they discovered during de-husking that the fall army worm had decimated the maize cobs. They attempted using photographs of the harvest to convince the agribusiness to delay their debt repayment due to this unforeseen predicament. These photographs were however ignored along with their request. Farmers therefore distrusted partners and had concerns on their being inflexible with the contract agreements that guide their collaboration. In this way farmers were pointing to the overarching socio-political frame within which their contractual agreements were implemented, which is characterized by mistrust and a sense of lack of power to push for responsiveness from more powerful actors in the partnership. Farmers agreed that if farm monitoring via the platform was to be accepted by partners as a mutually agreed process for responding to farmer needs, and integrated into their contract agreements, they would feel more confident of using the platform to influence material support. In present contexts, where there is mistrust and power inequalities between collaborators from different backgrounds, improving communication appears but a first step to building and reconfiguring relationships towards more inclusive partnerships.

5. Discussion

Our results show that the participatory process for co-designing a farm monitoring platform was effective in enabling the successful development of a farmer friendly smartphone platform which facilitated rapid farmer learning and capacity to use. The success of the process was significantly influenced by the use of story narration, images, games, and prototypes. These activities and artefacts served as effective bridging mechanisms for linking actors from different social worlds, e.g., farmers and researchers; traders and credit institutions, in the co-design process [33]. By this we contribute to a growing literature on co-designing digital platforms through such bridging mechanisms by showing further evidence of the efficacy of the design approach [36,37]. In addition, our findings show that aligning digital platform design with the capabilities of farmers as well as focusing directly on their key needs enabled farmer comprehension, ownership, and ease of adoption of the platform. This finding is in line with theory on information technology acceptance [38–40] as it demonstrates how perceived usability and usefulness of farmer oriented platforms motivated and influenced speedy farmer understanding and engagement with the platforms.

Reflecting with farmers on whether the co-designed farmer-oriented platform could make partnerships more farmer inclusive, we found that farmers had positive perceptions about the platform as a communicative tool that could bridge the communication gap between them and other actors. In particular, the platform was perceived as an effective mechanism for breaching the information and knowledge differences in smallholder partnerships. Farmers felt empowered to influence change in two main ways. The first was in their ability to share farm information with partners for specific extension advice either from extension agents or traders. Secondly, farmers felt empowered to demonstrate transparency in transactions as a means to enhance trust with partners. In line with Vermeulen and Cotula's criteria for inclusiveness in value chain collaborations [2], we argue that through these communicative roles, farmer-oriented platforms contribute to inclusiveness by enhancing farmer voice and ability to influence partner decisions and actions that relate to extension support and accountability. By so doing, the platform further contributes to smallholder risk reduction as it helped mitigate farming risks which emanate from lack of extension access. Moreover, actors also indicated that the co-design process resulted in a stronger feeling of ownership and fit of the platform to the local context. In this way, farmer-oriented platforms enable a more inclusive partnership arrangement for farmers by improving conditions of farmer voice and risks.

On the other hand, farmers were less certain about using the platform to get other partners to support farmer needs that require further commitment of resources or flexibility with terms of agreement. This is because in this scenario, partners would take on more risks by their additional investments or flexibility. The predominance of mistrust between actors due to past negative experiences makes them cautious about taking on further costs and risks [41]. Since other actors tend to be more powerful than the farmers, the farmers were less confident about using the platform to influence partner response in such scenarios. This situation shows that even though farmer oriented platforms help to level the communication field between farmers and other actors, the power relations between them generally remained the same, affecting farmer perception of ability to influence change via the platform when conflicting interests arise. In essence, negative past experiences and power differences contributed to path dependence and perceived resistance to the institutional changes being introduced by the digital platform [42].

From the perspective of Vermeulen and Cotula's criteria for inclusiveness [2], we interpret this development to mean that farmer voice in negotiating risks and costs with partners through the digital platform was limited by the existing power inequality and mistrust. This was possible because although the platform contributed to one aspect of the voice criteria of inclusiveness, which is the provision of a means to reduce information asymmetry, other aspects of the criteria such as improving farmer weight in decision making or a clear process of review and grievance addressing against more powerful actors were not contributed to. Prowse argues that asymmetrical power relations between commercial actors and smallholder farmers skews negotiation power significantly away from farmers [43]. Even though farmers perceived the platform as an effective means for communication with partners, farmers sensed little empowerment to enforce their communicated needs when there was conflicting interest with more powerful actors. This situation suggests that effectiveness of digital platforms for inclusiveness in partnerships may be constrained in such instances by power differences.

Thus, there is a crucial role for governing the development and implementation of smartphone platforms for farm monitoring, especially in negotiating trust, interests and power dynamics. There is a need to focus efforts on developing platforms to empower farmers and farmer groups not just from a communicative perspective, that is, through user friendly platforms, but to look critically and more broadly at how the platform's functioning is influenced by its contexts and potentially influences its context, including existing structures and relations. To begin to facilitate this, attention needs to be turned to partnership agreements and contracts, which usually serve as mechanisms for governing interactions between farmers and partners [9]. For partners to be more responsive to farmers through the use of the platform, our results suggest that contractual agreements need to acknowledge and indicate the role of intended farm information that would be provided via the platform. This implies that in order to empower farmers, digital platforms must work together with contract agreements. For instance, clear guidelines and criteria for conducting digital monitoring as well as the protocols for response by partners must be negotiated and integrated in contractual arrangements in partnerships with farmers.

From this perspective, there is the need for more in-depth reorganization and transformation of partnership processes and practices, through the establishment of new practices in which contract agreements capture and integrate the role of information output from farmer led platforms, so as to empower farmers and make partnerships more inclusive. This re-echoes arguments on the need to combine technological innovation together with institutional innovation particularly when power inequities and diverging political agendas are present [44,45]. In making partnerships more inclusive for smallholders, then, there is a necessity for critical political considerations of stakeholder practices and interests in smallholder partnerships, and the processes by which these may be re-negotiated and re-organized in relation to technological innovations such as farmer oriented platforms. Further research is therefore needed to address this knowledge gap.

6. Conclusions

In conclusion, our study sought to understand the extent to which smallholder value chain partnerships could be made more inclusive for smallholders through enhanced communication between farmers and other stakeholders in the value chain. In this, we focused specifically on farmers' perceptions on inclusion in the process of design and usage. Our findings show that a participatory process of co-designing a simple platform interface was significant in improving farmer ability to comprehend and use smartphone based digital platforms for monitoring and communicating farm conditions with value chain partners. Through the use of context relevant stories, game activities, and field testing, an image based and non-textual interface was developed, which enabled smallholder use of smartphones for digital monitoring. Concerning the extent to which the farmer oriented platform enabled inclusiveness of farmers in value chain partnerships, we found that farmers were empowered through the use of the platform to bring attention to their farm conditions. This was particularly deemed helpful in enabling them gain access to specific extension advice as well as demonstrating individual accountability to partners as a trust building mechanism.

On the other hand, farmers did not feel empowered to use the platforms to push for material support or flexibility from partners in response to emerging farm conditions such as pest and disease outbreaks, particularly since this would involve further costs and risk to the more powerful partners. As such farmers saw the platforms as a means to appeal to the benevolence of partners by building trust through transparency, without a sense of empowerment to engage further with these partners. Even though the digital platform improved farmer ability to communicate with partners to an extent, we found that on matters where conflicts of interests were expected to arise, unequal power relations reduced expectations of the platform's effectiveness at enabling inclusiveness. This highlights a need for critical consideration and adjustment of the social and political dimensions of partnership interactions, in tandem with the advancement of digital innovations, in order to effectively facilitate inclusiveness and equality in partnerships. Such consideration might include advancing the power position of smallholder farmers in specific contexts in order to move away from existing power inequalities that show a strong path dependency. As the growth of digital innovations rapidly accelerate in smallholder contexts, it is necessary to commensurately rethink, renegotiate, and reorganize the structure of value chain partnerships in order to progressively make actor interactions more inclusive through digital tools.

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