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Impact Pathways of Weather Information for Smallholder Farmers: A Qualitative ex ante Analysis

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Abstract

This article explores ex ante the impact pathways of a hypothetical intervention which consists in providing smallholder farmers with weather-related information. It uses a qualitative approach based on focus group discussions in three villages with smallholder farmers and agricultural extension officers to build a theory of change. Results suggest that providing smallholder farmers with weather-related information has the potential to help them in taking informed production decisions. In doing so, smallholder farmers can better allocate their production resources and eventually record higher yield and income. The ultimate impact is that smallholder farmers will have better lives (i.e. livelihoods). There are several types of weather-related information that can be useful for farmers. There are also several dissemination channels. Some are based on local social networks and others on information and communication technologies. Each channel has strengths and weaknesses and the best or optimal dissemination approach would probably depend on the setting of the intervention area. A number of assumptions need to be in place for an impactful intervention. For instance, weather-related information needs to be accurate, available in a timely manner and easy to use. The described possible impact pathways need to be tested rigorously through policy-oriented research.

Keywords: theory of change, weather-related information, impact pathways, Benin.

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Résumé

Cet article explore de manière ex ante les éventuels mécanismes d'impact d'une intervention hypothétique qui consisterait à fournir des informations météorologiques aux producteurs agricoles. Une approche qualitative basée sur les informations recueillies lors des discussions de groupe dans trois villages avec les producteurs et les agents de vulgarisation agricole afin d'élaborer une théorie du changement a été utilisée. Les résultats suggèrent que fournir aux producteurs des informations sur les conditions météorologiques favoriserait une prise de décision plus appropriée dans l'allocation de leurs ressources de production. L'intervention contribuerait à l'obtention de rendements et de revenus plus élevés et par voie de conséquence, à offrir de meilleures conditions d'existence aux producteurs et à leur ménage. Divers types d'informations météorologiques sont potentiellement utiles pour les producteurs. Il existe aussi plusieurs options en termes de canaux de diffusion de l'information. Certains de ces canaux sont basés sur les réseaux sociaux locaux alors que d'autres s'appuient sur les technologies de l'information et de la communication. Chaque canal présente des atouts et des faiblesses et la meilleure approche dépendra probablement de l'environnement socio-économique de la zone d'intervention. Un certain nombre d'hypothèses et/ou de conditions doivent être en place pour une intervention efficace. Par exemple, les informations météorologiques doivent être précises, disponibles en temps utile et faciles à utiliser (lire et interpréter). De plus, les mécanismes d'impact possibles décrits doivent être testés de manière rigoureuse par la recherche.

Mots-clés : théorie du changement, informations météorologiques, mécanismes d'impact, Bénin.

Introduction

With the focus on weather-related information for smallholder farmers, we use a different perspective to approach climate change adaptation research. The core research hypothesis of our analysis suggests that smallholder farmers provided with weather forecasts can better allocate their production resources and therefore record higher agricultural outputs. Though the research does not extend up to the hypothesis testing stage, it represents an important contribution to our understanding of how a context-specific and low-cost intervention can be implemented and scaled-up to strengthen smallholder farmers' adaptive response to climate change. Thanks to the participatory and qualitative approach used, our results further highlight how and under which key conditions engaging smallholder farmers with weather-related information can be impactful.

It is now acknowledged that climate change and its related environmental stresses will lead to economic constraints that will in turn worsen social issues such as poverty and food insecurity. For farmers, the increasing burdens of poverty and food insecurity due to economic constraints will weaken their investments in agriculture, keeping them within a vicious cycle of poverty. The poor in rural semi-arid and dry areas are the most vulnerable and require relevant support to build their resilience to climate change. Lack of adaptive capacities is one of the major limiting factors of rain-fed agricultural production in smallholder farming systems (Waongo, Laux and Kunstmann 2015). The crop planting date, a low-cost agricultural management strategy aiming to alleviate crop water stress can contribute to enhance agricultural decision-making, particularly as a climate change adaptation strategy. By considering the crop water requirements throughout the crop growing cycle using a process-based crop model in conjunction with a fuzzy rule-based planting date approach, location-specific planting rules were derived for maize cropping in Burkina Faso (BF). Additionally, the lack of relevant weather-related information which is overtly understudied represents an important issue to consider in the adaptation process. Adaptation is now recognised as a key policy option for reducing the negative impact of climate change (Kurukulasuriya and Mendelsohn 2008). Farmers will be negatively affected if they do not adjust to changing climate conditions (Mendelsohn, Nordhaus and Shaw 1994). Hence, a better understanding of farmers' perception of climate change, ongoing adaptation measures, and the related decision-making process are important to inform policy-makers (Bryan et al. 2013; Bryan et al. 2009).

Talking about the decision-making process, smallholder farmers shape their adaptive response to climate change based on their prior experience and knowledge. This traditional or common decision-making process is associated with a high level of uncertainty about future changes, implying high vulnerability. The challenge is therefore to engage smallholder farmers so that they are fully aware of future climate conditions and are able to take informed production decisions based on their experience and knowledge in relation to both past and future climate.

Previous studies (Roudier et al. 2014) found that providing farmers with relevant climate-related information is likely to help them shape (better) their adaptive response. Roudier et al. (2014) posited that climate forecasts have shown potential for improving the resilience of African agriculture to climate shocks even though there are some uncertainties about how farmers would use such information in crop management decisions and how beneficial this will be to them. Using results of simulation exercises conducted through participatory research with farmers from two agro-ecological zones of Senegal (West Africa), Roudier et al. (2014) concluded that climate forecasts could help farmers adapt to climate variability, especially by capitalising on anticipated favourable conditions. Reportedly maize producers in northern Benin are willing to pay for having information about climate change predictions and documented adaption strategies. Indeed, providing farmers with climate related information could raise their awareness on climate change and further enhance their capacity for (better) adaptation. Yet, this will require a mechanism to be set-up that could help to gather climate weather-related information and transfer such information to farmers.

Though the expected results are quite clear and sound straightforward, there may be gaps between providing smallholder farmers with weather-related information, having them make informed production decisions, and recording improved agricultural production. Indeed, setting-up a mechanism to gather weather-related information and sharing such information with farmers could be complex and tricky. Against this backdrop, the present study aimed to explore possible impact pathways of a hypothetical intervention which consists in providing smallholder farmers with weather-related information. The central research question is: what could be the theory of change of building smallholder famers' resilience to climate variability through access and use of weather-related information? Framed differently, what are the inputs, activities, outputs, outcomes and impacts involved in facilitating smallholder farmers' access to weather information and what are the related assumptions?

The remainder of the article is organised in four main sections, including a description of the study zone and the methodology, presentation and discussion of the results and their limitations, a note on perspectives, and a concluding note summarising the findings.

Methodology

This section presents the study zone and the specific methodology developed and used to carry out the research.

Study zone

The case study was conducted in three villages (i.e. Ina, Pedarou and Beroubouay) of the municipal area of Bembèrèkè in North Benin. Bembèrèkè is located between 09°58' and 10°40' latitude north, and 02°04' and 03° longitude east. The area covers about 3,348 square kilometers. The population is up to 131,255 people (INSAE, 2013). About 74.2 per cent of the population live in rural areas and have agriculture as their main livelihood activity. The production systems are mostly slash-and-burnbased with the use of rudimentary tools such as the hoes, cutters, etc. The rates of mechanisation, use of improved seed and extension services are still low though there have been some improvements over the past ten years. The common crops cultivated include: yams, maize, cotton, rice, cassava and sorghum.

The municipal area of Bembèrèkè was primarily selected as it represents one of the major and typical agricultural production areas of Benin. In that respect, Bembèrèkè has the advantage of ensuring good external validity of the results. Figure 1 presents the map of the study area.

Figure 1: Map of the municipal area of Bembèrèkè

Research approach

The study applied a qualitative approach to explore the impact of providing weather-related information on smallholder farmers' performance. It is broadly acknowledged that qualitative research is primarily exploratory research though it might also become explanatory research. Qualitative research can potentially serve one or more of the following objectives: a) gain initial deeper understanding of a phenomenon (i.e. a problem, a new or existing situation or behaviour, a process, etc.) and its internal (and sometimes external) dynamics through the underlying reasons, driven forces and/or motivations; b) provide insights into a phenomenon or help to motive and/or develop interventions, ideas and hypotheses for potential quantitative or further qualitative research.

There is a range of qualitative methods but common ones include unstructured or semi-structured data collection techniques such as focus group discussions (FGDs), individual interviews and particularly in-depth interviews (IDIs), and participation and observation. It is important to note that each technique is known to be particularly suited to dealing with a specific type of data. For instance, FGDs are viewed as most effective in collecting data on the social and cultural norms of a group and in generating broad pictures of a phenomenon. IDIs are typically recommended when it comes to gathering information on individuals' personal histories, perspectives, perception and experiences. They are also widely used to collect sensitive information. Participation and observation are often used to collect data on naturally occurring behaviours in their usual contexts.

Following the central research question of the present study, a qualitative research approach built upon FGD techniques for data collection was used. According to Babbie (2011), FDGs are a qualitative data collection method to systematically and simultaneously interview a group of individuals through guided discussion. FGDs do not only generate information on collective views but also reveal a rich understanding of the experiences and beliefs that lie behind those views (Akter et al. 2017). As the overall purpose of the study was to understand possible impact pathways of an intervention which consists in providing smallholder farmers with weather-related information and develop a theory of change (ToC), the remainder of the methodology focused on the ToC development process, including both the data collection and data analysis methods.

Development of theory of change

The study used a qualitative approach to do an ex-ante analysis of possible impact pathways of a hypothetical intervention that would consist in providing smallholder farmers with weather-related information. In that respect, a ToC was developed. A ToC is broadly defined as a comprehensive description and illustration of how and why a desired change (i.e. improvement of a situation or a process, change of a behaviour, etc.) is expected to happen in a particular context.

A two-stage approach was used in the frame of this study. This included first the development of a 'naïve' intervention ToC through a desk review. Then the 'naïve' intervention ToC was improved/validated through a field study.

The desk review: development of a 'naïve' ToC

This first version of the ToC was developed based on previous studies (on climate change adaptation, use of ICTs in agriculture, etc.) and the extensive researchers' field experience (Figure 2).

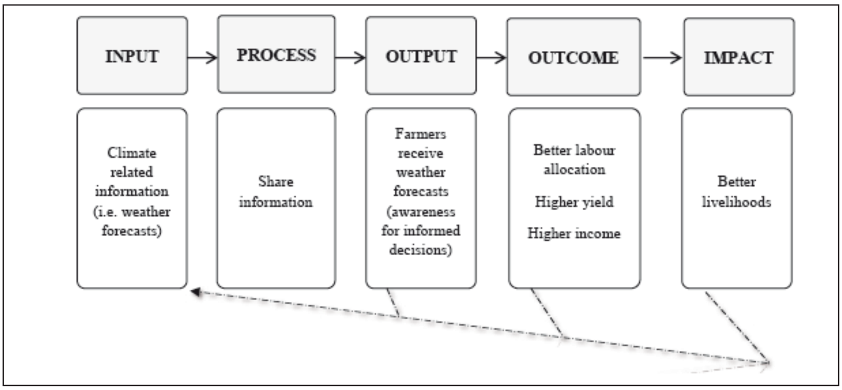

Figure 2: 'Naïve' ToC

The 'naïve' ToC suggests that providing farmers with weather-related information will help them to better allocate their production resources and this will result in higher yield and income. The ultimate impact is that farmers will have better lives (i.e. livelihoods). The process described through this ToC relies on building the social capital of the smallholder farmers through information and knowledge (here related to weather). Both information and knowledge can then be used/applied by farmers to improve the ways they run their production systems. The arrows at the bottom of the diagram indicate a continuity loop. Indeed, with better livelihoods, smallholder farmers could be more independent or empowered to access by themselves weather-related information and improve other aspects of their daily life. For instance, by purchasing a phone, a TV, internet or any other devices or services to access information. They can also afford training to better understand and use weather-related information. All this will further help smallholder farmers improve their efficiency in production resources allocation with net positive effects on yield and income. The 'naïve' ToC was further revised and validated in the field with agricultural extension officers and smallholder farmers through interviews and FDGs organised between March and April 2018.

The field study: FGDs to improve and validate the ToC

The purpose of this stage of the methodology was to walk selected respondents through the 'naïve' ToC and get their perspectives on areas of improvement. FGDs mainly involved farmers and agricultural extension officers. Both men and women were selected in the groups. Each FGD was composed of seven to eight people, including farmer leaders (five to six) and agricultural extension officers (up to two). The composition of each focus group was made based on criteria such as gender and experience in agriculture and of course willingness and informed consent to participate in the study. It is important to note that local ethical approvals were secured before the research was conducted.

In total, three FGDs were organised; one in each village. The group discussions were conducted and moderated by researchers following the general guidelines provided by Ritchie and Lewis (2012 [2003]). Indeed, beyond the composition of the group, the moderation techniques and communication processes are quite crucial to ensure good results. In practice, each discussion was organised in several participatory activities or steps: introduction of the research and the objective of the exercise; introduction of participants in the FGD and ice-breaking activity; presentation of the format and the rules of the discussion; opening discussion on the perception of and adaptation to climate change; introduction and discussion on the hypothetical intervention (the possibility of having access to weather information), the different channels or media that can be used and what kind of weather-related information could be useful; discussion around how weather-related information provided via mobile phone SMS could help smallholder farmers to take informed decisions and further improve agricultural performance; and concluding discussion.

In terms of process and methodological approach, the idea of the FGDs was not to share/present at the beginning of the discussion the 'naïve' ToC but, rather, to ask open questions on what inputs, activities or outputs need to be in place to deliver useful and impactful weather-related information to smallholder farmers. A few key questions that guided the debate were: What weather-related information is useful for you to take informed production decisions? How can you possibly access the information? How can you use the information to improve your production decisions and, further, your agricultural performance? Participants in FGDs were given enough time to interact with each other, to discuss and to reach some consensus when required.

Data analysis

Data collected through FGDs were transcribed and later on analysed using qualitative methods. As argued above at the beginning of the methodology section, qualitative research helps researchers delve deeper into the social reality on the ground and identify key inputs and outcomes that can contribute to better understanding of the impact pathways. For this purpose, an inductive approach was used during the course of this research. At first, inductive theory does not require strong pre-defined research hypotheses and theories. It starts with either questions addressed to key stakeholders or observations, and the key theories are constructed based on the findings. More specifically, it involves the search for patterns from observations and the development of explanations – theories – for those patterns through series of hypotheses and then generating meanings from the data in order to identify patterns and relationships to build a theory (Bernard 2011; Saunders, Lewis and Thornhill 2012).

Three techniques were used in this research in a complementary manner. These are: discourse analysis, thematic analysis and grounded theories. The use of qualitative descriptive approaches such as content analysis and thematic analysis is suitable for researchers who wish to employ a relatively low level of interpretation, in contrast to grounded theory in which a higher level of interpretive complexity is required (Vaismoradi, Turunen and Bondas 2013). Content analysis describes the characteristics of the data by capturing the answer to each question as well as the underlining reasons. It has been applied in this research to analyse text information in order to determine trends and patterns of the data as well as the underlying relationship. Thematic analysis approach is a method for identifying, analysing and reporting key patterns (themes or thematic) within data (Braun and Clarke 2006) and organising the analysis around the aforesaid patterns. This approach is useful in summarising findings, and where relevant, presenting them in the form of figures. As for grounded theory, this is applied in social sciences research for the purpose of constructing theories and is based on identification of patterns, changes and underlining effects. It is useful when the research intends to develop a theoretical account to facilitate discussions of the features of the topic under study and is firmly based on data collection (Martin and Turner 1986). It applied in our case since we intend to build a thorough theory of change for the hypothetical intervention of interest.

Based on these combined techniques, the researchers together with key informants present during the meeting summarise each discussion from each FGD to have a common understanding and to make sure of the accuracy of the information provided. Key important aspects from the discussions were summarised on billposting and everyone agrees on its contents. This facilitates further analysis by the researchers themselves. After fieldwork, the first step was to go through all the FGDs and further summarise information along key thematics such as inputs, activities, outputs, outcomes and impacts as well as the assumptions. Afterwards, the findings from all FGDs were put together, depending on the relevance of the information to the study in order to provide a short report of the possible inputs, delivery chains and impact pathways that can be related to the hypothetical intervention. During that process, specific findings were derived as the results of the analysis of information captured through FGDs.

Results and discussion

The results are organised around the key components of a typical ToC. These include inputs, activities, outputs, outcomes and impacts as well as the assumptions that need to be in place so that the causal chain works well.

Inputs

Here the discussion helped to identify weather-related information which smallholder farmers acknowledged as useful and relevant to consider in decision-making as far as agriculture is concerned. From the FGDs, factors that matter the most are rainfall (quantity and timing), drought and flood occurrence (timing and intensity) and wind (speed and direction). Other factors such as temperature and humidity were also mentioned but not rated as highly relevant though they could play a key role in the crops development cycle.

Rainfall-related information could potentially help farmers to take several decisions that would significantly minimise crop losses. For instance, with a better knowledge of the geographical and temporal distribution of rainfall or instances of droughts/floods, farmers can decide when to carry out specific activities such as sowing, application of fertilisers or pesticides. Many farmers pointed out that heavy rain right after the application of fertilisers or pesticides implies that the inputs are washed away, and the farmers would need to re-do the application. This potentially means losses in terms of both money (to buy fertilisers or pesticides) and time (cost of labour to apply fertilisers and pesticides). This also implies losses of transaction costs such as time and/or money to seek inputs into price information, to purchase inputs and move them from the markets/shops to the field, to seek and hire paid labour, etc.

Wind-related information can help to decide when and how to apply pesticides. It can also help to know whether or not the farmers should reinforce the plants (by adding more sand at the bottom for instance) to avoid physical damage.

Process

The literature on the use of ICTs in agriculture suggests a few tools such as the phone, videos, radio, television and computer. With the development of information technology, agricultural information dissemination models are constantly evolving. They vary from vary basic or simple tools to complicated and sophisticated techniques. Current agricultural information dissemination models include for instance web portals, voice- based service (i.e. call centers), text-based service (i.e. SMS), self-support online communities, interactive video conferencing services, mobile internet-based services, and the unified multi-channel service that utilises multiple methods to effectively disseminate information through telephones, computers and mobile phones. Considering the low infrastructure in rural areas, some channels might be more preferable or appropriate than others.

In the FGDs, possible and appropriate weather-information delivery mechanisms were explored. Though the focus of the study was on SMS, discussions were aimed at exploring alternative delivery mechanisms. In that respect, farmers highlighted a number of potential delivery channels through which they can be informed about weather-related information. These channels include:

- *Selected leaders in the village:* The advantage of this channel is that farmers are sure to be informed (thanks to the strong social network which characterised most of the rural areas in the study zone) but there might be some delays in getting the information. A given farmers' leader could be busy or can even forget to exchange with his/her fellow farmers. As a result, some farmers might not be informed on time or at all. There is also the risk of information distortion due to translation or reporting speech. Additionally, the asymmetry of information between farmers depending on their personal relationship with the village leaders is a potential risk. This could be a source of social conflict as new forms of clientelism between the village leaders and famers might appear.
- *Popular (community) meetings in the village:* This community approach has the advantage of informing all farmers at the same time but this might be difficult to implement in practice as it will be very time consuming especially if meetings should be on a regular basis like many

times per week. At the other end, weather information is typically quite dynamic and could require too many meetings, preventing farmers from attending to other business that could matter for them.

- *Door-to-door campaigning:* This could be an ideal approach to reach out to farmers but again is difficult to implement due to the nature and time-sensitive feature of weather information. Such an approach will also require a lot of logistics. For instance, there will be a need to know when farmers are at home, keeping in mind that some have their fields far away from the home state and can expend days in the fields before coming back home.
- *Phone calls:* This is the most powerful and direct channel. The disadvantages are that it is time and resource consuming (if calls have to be initiated by the famers themselves) and not all farmers might be quick to understand information given to them in oral form and by someone they might not know. In the event that calls were initiated by a third party and that smallholder farmers do not have to bear the costs, implementation could still be an issue. Farmers can be quickly overwhelmed with too many phone calls. They will also have issues in recalling the weather information especially if they did not note down the same. Here, the low literacy rates in most rural areas will be another constraining factor.
- *Mobile phone SMS:* Through SMS as a means of communication, farmers can get forecast information in real time. Depending on the language of the SMS, some farmers might not be able to decipher SMS contents. However, they can still get a relative to help with reading. Depending on how good farmers are as mobile phone users, a practical issue here is that the memories of the phones could quickly become full, making it impossible to receive new incoming SMS.
- *Radio and/or television:* These media are not frequently used by many farmers. Thus, it will be only a selected number of farmers who will be able to enjoy the weather-related information. On the other hand, radio, or at least television, typically works with energy which is not always a given in rural settings.
- *Internet:* The major advantage of this channel is that farmers could browse and check the information at any time. Internet also offers the possibility to share with farmers high-frequency information in real time. The major challenge remains accessibility as not all famers have internet let alone a smartphone. Additionally, some remote areas still lack internet coverage or do not have good coverage and therefore would be excluded.

- *Local or village kiosks:* The kiosks will work like access points where any farmers can go and get weather-related information. The issue here could be operating such kiosks. Most importantly, farmers often have their fields far away from the village and, sometimes, expend days in the field without coming back to the village. In such contexts, a fixed access point will not be appropriate.
- *Other channels:* Theses include newspapers, posters, documentary, etc. All these approaches were found to be difficult to implement in practice due to the nature and time-sensitive feature of weather information. Access to newspapers is limited if not absent in rural areas. Posters could be useful but might need to be in local languages. But even if they are readable, they won't be very effective in motivating behaviour changes and will be typically used to fix political or any other forms of advertisement. The dynamic nature of weather information will also make posters difficult to implement or at least very expensive as they will need to be updated very frequently. Documentary could require other forms of materials or tools such as radio or TV to be accessible.

The literature suggests that farmers do not generally receive forecast information in formats they can understand or through communication channels they find relevant, limiting the possibility of full use and measuring outcomes (Tall et al. 2014; Tall, Coulibaly and Diop 2018). To address this challenge, a participatory approach with farmers can be used to define the preferred format of the information and the most relevant channel of communication.

In the current study, farmers seemed to have a stronger preference for ICTs in general and particularly for mobile phone SMS. Indeed, ICTs offer a number of advantages and have a key role to play in bridging information gaps. They are not very expensive, and they can be used to reach a large number of people in real time. This prospect is extensively discussed later in the article.

Outputs and outcomes

Provided that useful weather-information and the right communication channels are identified and selected, the immediate output is that farmers are aware about climate forecasts. The expected outcome is that farmers would be fully able to take informed production decisions based on their experience and knowledge in relation to both the past and future climate. As argued above, farmers, by having access to adequate weather information (rainfall for instance), might know exactly when to plan and conduct specific activities, what and how many resources are needed.

Impacts

Following Chiappetta et al. (2015), ICT programmes in general and particularly information interventions could have impacts under two mechanisms: 1) they can increase farmers' production through use of better farming practices; and they can improve farmers' ability to negotiate better prices for their inputs and outputs. It is therefore expected that providing smallholder farmers with weather-related information would bring about potential benefits. Indeed, through informed production decisions, farmers will improve their agricultural performance. For instance, farmers would usually sow maize many times a year if there was not enough rain for the germination of the seeds. Not only labour is lost in this case but also production factors used in the activity along with related transaction costs. An informed decision would help to plan better the optimal period for sowing so as to avoid the drought spells. From the FGDs, the potential impacts identified through the group discussions can be summarised as follows:

- better plan the agricultural calendar as well as related farming practices;
- be more efficient in the allocation of labour and production resources;
- observe increases in yield, and;
- observe increases in income.

These impacts will result in a better life as famers would improve their food security and generate a surplus of income to afford non-food needs such as children's education, healthcare, etc.

Linking the salient features

From a global perspective, setting-up a mechanism to provide smallholder farmers with weather-related information requires some inputs. These include staff, some financial resources, and weather-related information. From inputs to outputs, a number of delivery channels could be used. Participants in the FGDs suggested using mobile phone SMS which they argued is the optimal channel in their socio-economic settings. Beyond the choice of delivery channels, it is important to ensure that beneficiary farmers are trained to understand the weather-related information shared with them. This is a critical aspect as there will be no results if farmers are unable to link or translate weather-related information into actual opportunities or threats (gains or losses) to their production systems.

Assuming that farmers are aware of the forecasts and can easily interpret them, they will better allocate their production resources (i.e. labour). One of the most illustrative examples is the sowing period: if farmers know when it will probably rain, they can better schedule their labour for seeding. Here, it is also assumed that a better allocation of production resources will lead to increase in productivity and therefore in yield and income. Increases in income can also have a feedback effect by increasing productivity as farmers can afford new or improved production equipment and technologies like tractors, improved seeds, etc. The ultimate outcome of this process is that farmers will have better living standards. As hypothesised in the 'naïve' ToC, there is a continuity loop between accessing weather-related information and better livelihoods. Better livelihoods enable smallholder farmers to be more independent or empowered to access by themselves weather-related information and eventually afford training to better understand and use weather-related information. This will amplify the expected positive impact on production resources allocation with net gains in terms of income.

Putting together the dots of the ToC suggests key assumptions which can be summarised as follows:

- climate related information is available at any time;
- financial resources available on time;
- forecasts are transmitted on time;
- network is available;
- farmers receive relevant and accurate weather-related information;
- farmers trust the forecasts;
- farmers understand how to interpret forecasts;
- farmers use the forecasts for decision-making; and
- farmers are rational.

It is important to note that within the framework of this research we could not explore further and test the different assumptions due to time and resource constraints. Our hope is that any evaluation work that will intend to share weather-related information with smallholder farmers will consider these hypotheses and collect data on them through a robust monitoring system. In so-doing, it will be possible to test qualitatively and/or quantitatively each of the above-mentioned assumptions. Figure 3 summaries the revised ToC, including the perspectives described above. It is important to note that this ToC was developed based on the assumption that mobile phone SMS are the preferred delivery channels.

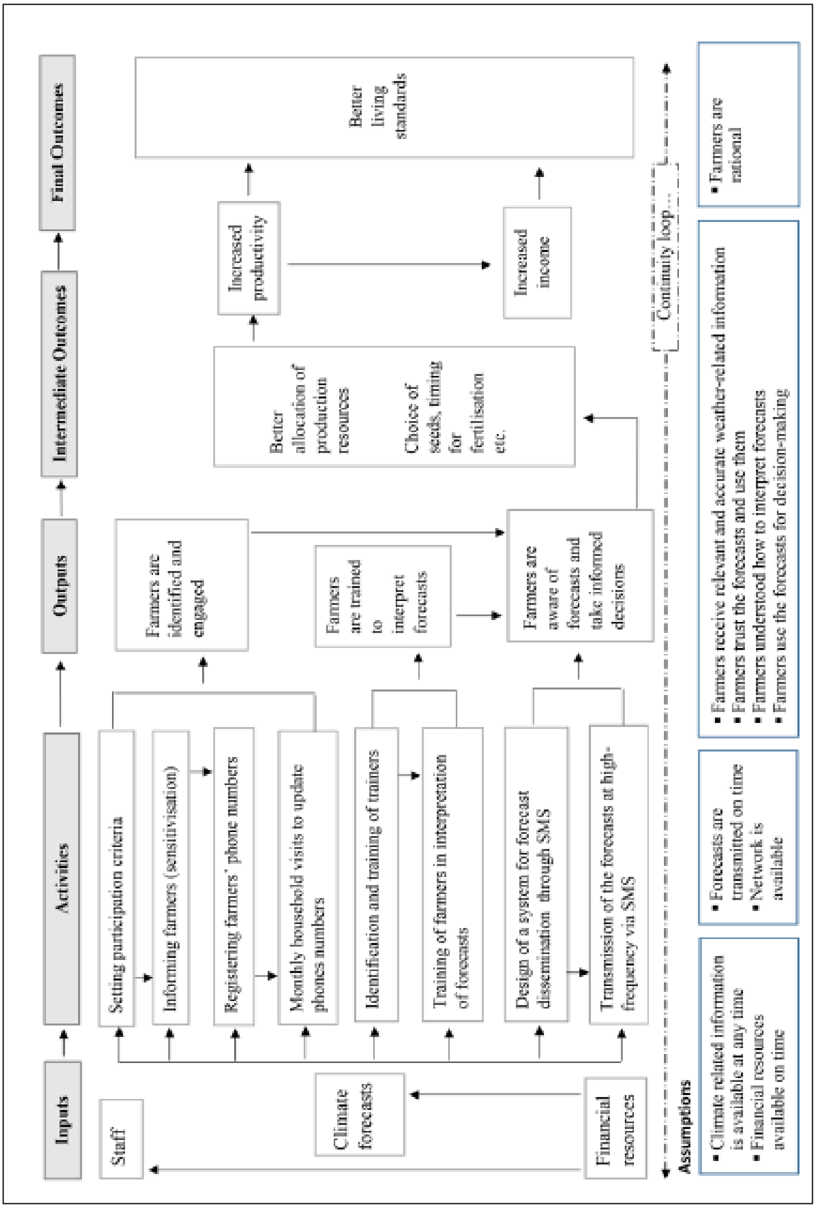

Figure 3: Revised ToC

Perspectives

To better engage with and frame the relevance of this work, it is useful to highlight the existing literature, starting from the context to where we are and the current trend.

From the context

Information and knowledge are essential if production systems are to respond to the evolving dynamics, constraints and opportunities of their environment, including to climate change. Information and knowledge can be described as critical production resources in any sector. Many international organisations such as the FAO and World Bank recognise the importance of information and knowledge as key inputs for economic development and growth that play a key role in ensuring food security and sustainable development (Oladele 2015).

Information and knowledge can help engagement with innovation and potentially increase productivity. In most production systems, innovation is often the result of informal learning processes, in which social networks play an important role, with farm managers learning by creating networks of colleagues and advisers (Gielen, Hoeve and Nieuwenhuis 2003). Yet, these social networks are not always fully equipped to generate certain types of information such as high-frequency weather forecasts and this suggests the need to find tools to engage with external information and knowledge. In that respect, ICTs can be used to enable, strengthen or replace existing information systems and networks (Oladele 2015).

Accelerating information flow, communication and the rapid development of technology is a new phenomenon named information and communication technologies (ICTs) (Koutsouris 2010). ICTs generally refer to an expanding assembly of technologies that are used to handle information and aid communication. These include hardware, software, and media for collection, storage, processing, transmission and presentation of information in any format (i.e., voice, data, text and image (Asenso-Okyere and Mekonnen 2012)).

According to Singh, Kumar and Singh (2015), ICTs promise a fundamental change in all aspects of our lives, including knowledge dissemination, social interaction, economic and business practices, political engagement, media, education, health, leisure and entertainment. The potential impact of ICTs in rural areas where agriculture remains one of the key pillars of livelihoods is largely agreed upon. According to Munyua (2007), information and knowledge play a central role in rural agricultural development; and it is readily accepted that increased information flow has a positive effect on the agricultural sector (Adamides et al. 2013). Indeed, ICTs are now used to promote and distribute new and existing farming information and knowledge which is communicated within the agricultural sector since information is essential for facilitating agricultural and rural development and bringing about social and economic change (Swanson and Rajalahti 2010).

The evolving literature on the use of ICTs in agriculture clearly suggests that information technology can have an important role in promoting several facets (economy, society, culture, etc.) of rural areas. ICTs can play a significant role in combating rural and urban poverty and fostering sustainable development through creating information rich societies and supporting livelihoods (Singh, Kumar and Singh 2015).

Where we are

Over the past decades, Africa has experienced a high uptake of ICTs, including mobile phones that have become an important tool for communication in rural areas (George, Simba and Zaipuna 2014; Asenso-Okyere and Mekonnen 2012; Mwombe et al. 2014). This new trend is changing the way farmers communicate and the way they access and exchange information, especially among younger generations (Odiaka 2015). It is also important to note that the fast penetration of ICTs comes along with new opportunities for African farmers to access a larger range of information and improve their knowledge and livelihoods (Aker & Mbiti 2010; Asongu 2015; Demombynes & Thegeya 2012). Nevertheless, collecting and disseminating information is often in itself difficult and costly. This could also depend on the nature of the information of interest. mation of interest.

Despite this broad consensus, the potential of ICTs as a means for knowledge sharing and transfer remains overtly poorly explored and underused. Attempts to understand and explain the mechanism and constraints of technological innovation adoption are not new. A few studies have looked at the drivers of ICTs in agriculture. According to Asenso-Okyere and Mekonnen (2012), factors that affect use of ICTs for agricultural extension include the policy environment, the rural setting, infrastructure and capacity problems, and the nature of local communities, including their ability to use the technology to access information for their work. Vosough, Eghtedari and Binaian (2015) highlighted that a majority of factors affecting adoption of ICTs are generic in nature and include cost effectiveness and speed of information transfer, organisational characteristics like business size, system characteristics such as the availability of and access to ICT services, and internal and external characteristics of the business household like education, past experience in using ICTs, attitude towards ICTs, business objectives and incomes, among others.

There are several micro-, meso- and macro-level advantages associated with the use of ICTs. ICTs are rapidly consolidating global communication networks and international trade with implications for people in developing countries (Oladele 2015). ICTs are believed to bring about social and economic development by creating an enabling environment (Asenso-Okyere and Mekonnen 2012). The literature suggests an overall understanding of how ICTs can have impacts through improvements in efficiency and increasing productivity. As described by Oladele (2015), the impact of ICTs can take place in different ways including improving efficiency in resource allocation, reducing transaction costs, and technical improvements that result in an outward shifting of the production function. In particular, through the provision of information from a source that is relative affordable, accessible and broadly available, ICTs can contribute to the reduction of uncertainty in activities and transactions, reduce the extent to which markets are thin, missing or incomplete, and reduce the extent to which information asymmetries can be exploited by the relatively informed to extract rent when transacting with the relatively uninformed.

The current trend

According to Asenso-Okyere and Mekonnen (2012), a promising area to do agricultural extension to reach large number of farmers is using ICTs (including mobile telephony, innovative community radio and television programmes, mobile phones in combination with radio, video shows, information kiosks, web portals, rural tele-centres, farmer call centers, video-conference, offline multimedia CDs, open distance learning, etc.). Following Asenso-Okyere and Mekonnen (*ibid.*), ICT-based agricultural extension brings incredible opportunities and has the potential of enabling the empowerment of farming communities. This matters for the need to strengthen smallholder farmers' adaptive response to climate change.

Emerging initiatives around the world suggest that there are broadly two types of ICT-based extension services: market information and other (non-market) interventions. The former type of services provide market information (mainly prices) and give farmers the potential to bargain and improve their incomes, to seize market opportunities through the adjustment of production plans and better allocation of production factors, and also to use the information to make choices about marketing (Asenso-Okyere and

Mekonnen 2012). The other extension services include financial, utilisation of best agriculture practices, research, weather, climate, and distribution and supply chain management. Very few initiatives are known to focus on weather-related information and this represents a promising investment area.

At this point, it is important to note that the main focus of ICTs application in agriculture is to meet the information need of farmers (Lokeswari 2016). The review of several applications and studies by the FAO (2017) suggests that information relayed by ICTs should be properly targeted and relevant if it is to affect farmers' production decisions. Contents of the message is crucial, and existing evidence suggests that content quality matters; and to have an impact, information must be provided to farmers locally. In that respect attempts to research agricultural information considered relevant to the needs of farmers in their socio- economic and political environment are an important prerequisite that the ToC approach developed and applied in this article could potentially help to meet.

The current work, by exploring possible impact pathways of a hypothetical intervention which consists in providing smallholder farmers with weather-related information, suggests a broad research avenue that could be worth investigating. Furthermore, a growing body of evidence suggests that in many circumstances ICTs, specifically mobile phones, are thought to increase access to both information and capacity-building opportunities for rural populations in developing countries, and that this brings tangible benefits (FAO 2017). Farmers can achieve higher crop yields, as they get access to timely and better-quality information on products and inputs as well as environmental and market conditions through ICTs (FAO 2017; Torero 2015). While such literature backs-up the findings of the present research, more quantitative or mixed methods research is needed to generate rigorous evidence.

Conclusion

We used a qualitative approach to explore possible impact pathways of a hypothetical intervention which consists in providing smallholder farmers with weather-related information. The results suggest that the intervention does have the potential to help farmers in taking informed production decisions and to further improve their agricultural performance. Previous evidence already showed through subjective design how weather-related information can increase farm productivity but fails to provide suitable delivery channels and possible other impacts pathways. Therefore, researchers should take the lead and conduct more thorough research on the possible impact pathways associated with providing weather information to smallholder farmers in developing countries. While development agencies, governments and research institutions intensively work to make and promote new adaptation options, providing weather information could help farmers to adjust their farming practices to the changing climate. This seems to be a relevant way of improving the resilience of rural households. Several adaptation options to climate change have been promoted in the recent past, including new seed varieties, changes in inputs and off-farm activities. However, most of these options have showed their limitations as food insecurity resulting from low production and failure of adaptive options to climate change is still an issue. Weather-related information can be made available and accessible in almost all countries in sub-Saharan Africa. Therefore, policy-makers need to define a clear strategy to value weather-related information. Initiatives should also be taken to support smallholders to engage and use weather-related information as a way to better adapt to climate change. Before reaching this ideal, it is important that the described possible impact pathways are tested rigorously through policy-oriented research in different socio-economic and environmental contexts.

Another important finding of this research lies in the different mechanisms through which the intervention can impact on farmers. While many intervention packages are pre-defined and based on a top-down model, this study suggests, from the intervention design stage, walking through a deep participatory process to engage with farmers' expectations, delivery channels and other programme aspects. By suggesting mechanisms through which farmers can be reached and by analysing advantages and weaknesses of each mechanism together, this study also appears as a strong case for providing information and knowledge that can help smallholder farmers meet current development challenges such as climate change. Indeed, there are several options, each with strengths and weaknesses that need to be specified. The best option would probably depend on the setting of the intervention area. The existing literature was also highlighted to better engage with and frame the relevance of this work.

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