FARM RESILIENCE TO CLIMATE CHANGE

The role of farmer entrepreneurship, farmer organizations and value chain collaboration

Daniel Kipkurui Kangogo

Propositions

1. Farmer entrepreneurial orientation is a critical determinant of farm resilience to climate change. (this thesis)

2. Membership in a farmer organization is a necessary but not a sufficient condition for improving farm resilience. (this thesis)

3. The term “smart” in climate-smart agriculture should not refer to the technology used but to the knowledge and competencies of the farmer.

4. The impacts of agricultural development projects that do not take farmers’ aspirations into account last only as long as the life of a project.

5. Social media platforms are more influential than journal publications in stimulating multidisciplinary collaboration and knowledge exchange among scientists.

6. Doing a PhD during a pandemic requires a strong social support system more than mental resilience.

Propositions belonging to the thesis, entitled

Farm Resilience to Climate Change: The role of farmer entrepreneurship, farmer organizations and value chain collaboration

Daniel Kipkurui Kangogo
Wageningen, 25 January 2022

Farm Resilience to Climate Change

The role of farmer entrepreneurship, farmer organizations and value chain collaboration

Daniel Kipkurui Kangogo

Thesis Committee

Promotor
Dr W.J.J. Bijman
Associate professor, Business Management & Organisation Group
Wageningen University & Research

Co-promotor
Prof. Dr Domenico Dentoni
Professor of Business, Resilience & Transformation
Montpellier Business School (MBS), Montpellier Research in Management (MRM)
University of Montpellier, France

Other members

Prof. Dr Erwin Bulte, Wageningen University & Research

Prof. Dr Miranda Meuwissen, Wageningen University & Research

Prof. Dr Markus Hanisch, Humboldt-Universität zu Berlin, Germany

Dr Thomas Lans, HAN University of Applied Sciences, Nijmegen

This research was conducted under the auspices of the Wageningen School of Social Sciences (WASS).

Farm Resilience to Climate Change

The role of farmer entrepreneurship, farmer organizations and value chain collaboration

Daniel Kipkurui Kangogo

Thesis

submitted in fulfilment of the requirements for the degree of doctor

at Wageningen University

by the authority of the Rector Magnificus,

Prof. Dr A.P.J Mol,

In the presence of the

Thesis Committee appointed by the Academic Board

to be defended in public

on Tuesday 25 January 2022

at 4 p.m. in the Aula.

Daniel Kipkurui Kangogo

Farm Resilience to Climate Change: The role of farmer entrepreneurship, farmer organizations and value chain collaboration

PhD thesis, Wageningen University, Wageningen, the Netherlands (2022)
With references, with summary in English

ISBN: 978-94-6447-042-0
DOI: https://doi.org/10.18174/558578

Table of Contents

Chapter 1

General introduction

1.1 Climate change and smallholder farming

Climate change is one of the greatest challenges facing humanity today. It is already affecting the lives of people across the globe in diverse ways (IPCC, 2021). First, climate change affects food production through yield losses leading to reduced global food security. Second, climate change affects farm income levels with a negative effect on development particularly for the countries whose economies depend mainly on agriculture (Schmidhuber and Tubiello, 2007). Third, evidence continues to emerge linking climate change to peace and security through different ways including migration patterns and resource scarcity which may result in conflicts among communities (Klomp and Bulte, 2013; O'Loughlin *et al.*, 2012). Additionally, frequent occurrence of climate change events such as hurricanes and tsunamis destroy infrastructure limiting the movement of goods and people.

In sub-Saharan Africa (SSA), climate change is already causing devastating effects that challenge the achievement of sustainable development goals (Barrett *et al.*, 2017). Climate change manifests itself in different ways including an increase in the frequency and intensity of extreme weather events such as prolonged droughts, unpredictable rainfall, increasing in temperature and floods, all of these have negative effects on agricultural productivity. Prolonged droughts and warmer temperatures reduce soil moisture and nutrients leading to low crop production (Clements *et al.*, 2011). Similarly, prolonged droughts and warmer temperatures impact negatively on livestock production by reducing the availability of pasture and water which lead to emaciation in animals and reduced milk production (Sejian *et al.*, 2015).

Regardless of the type of climate change incidence, what is clear is that climate change brings substantial welfare losses especially for smallholders who depend on agriculture for their household food security and livelihoods (Ojo and Baiyegunhi, 2020). Smallholders are particularly affected by climate change because of their limited access to production resources which make it difficult for them to respond and adapt to the climate change effects (Amadu *et al.*, 2020). Additionally, the overreliance on rain-fed agriculture by the smallholders especially in SSA make them highly vulnerable to climate change effects.

The future climate projections for Kenya show inconsistencies with some projections predicting a future increase in drought frequency and severity (Tan *et al.*, 2020) and others projecting an increase in rainfall and floods (Maidment *et al.*, 2015). This indicates that smallholders will need to adapt to the uncertain future. One of the potential ways for smallholders to adapt to climate change is through the application of climate risk management strategies (Hansen *et al.*, 2019).

1.2 From climate risk management to resilience

Climate risk management involves risk identification, analysis and design of response strategies to reduce vulnerability (Chavas *et al.*, 2010). From a theoretical standpoint, researchers view climate risk management as a static approach that presupposes that farmers know the specific climate risk events, probability and intensity of occurrence and thus, they can plan their response strategies. While this view of risk management is useful and offers the potential to reduce both the magnitude of the impacts, the assumption that farmers know the specific climate risks, probability and intensity of occurrence is unrealistic (van Winsen *et al.*, 2014), particularly in SSA where weather forecast reports and information are scarcely available, inaccessible and often unreliable.

Furthermore, farmers face a myriad of other challenges in addition to climate change. For instance, farmers face economic challenges relating to price fluctuations, meeting the diverse consumer demands and quality requirements; social challenges such as gender inequality in access to production resources; and health challenges such as the COVID19 pandemic (Guido *et al.*, 2020). The nature of these challenges are largely uncertain with the probability and intensity of occurrence being unknown. This means that the use of static risk management strategies to minimize farm risks may be ineffective (Darnhofer, 2014; Pannell *et al.*, 2000).

In response to the ineffectiveness of climate risk management as a response to climate change, the concept of resilience has emerged taking centre stage in policy, development and research to improve farmers' ability to adapt to the multiple challenges they face (Czekaj *et al.*, 2020; Darnhofer *et al.*, 2016; Meuwissen *et al.*, 2019). At the farm level, resilience refers to the ability to ensure the provision of farm functions while facing multiple shocks and risks through strengthening the absorptive, adaptive and transformative capacities (Meuwissen *et al.*, 2019; Walker *et al.*, 2004). The resilience concept has resulted in the development of the "resilience thinking" a theoretical approach that emphasizes that socio-ecological systems, including farms, are dynamic and interdependent across time and space (Darnhofer, 2010; Ge *et al.*, 2016). Resilience thinking facilitates the understanding of farms as complex systems facing multiple and unpredictable changes. According to Darnhofer (2014) and Slijper *et al.* (2020) the resilience concept represents a shift from static and short-term risk management theoretical approaches towards building and strengthening the absorptive, adaptive and transformative capacities.

The term capacity within the resilience field denotes the ability to identify opportunities, mobilize and (re)organize resources to absorb, adapt or transform in presence of shocks (Czekaj *et al.*, 2020; Darnhofer, 2014). Specifically, absorptive capacity is the ability to cope with the expected and unexpected shocks without a change in farm structure and functions (Béné *et al.*, 2014). This capacity is important in response to smaller shocks. Adaptive capacity is the ability to adjust in the face of changing conditions (Folke *et al.*, 2010). It calls for changes in the composition of inputs and the adoption of new farm technologies and practices. On the part of the farmer as the farm manager, adaptive capacity requires the ability to establish priorities, mobilize the necessary resources including collaborating with other farmers, use past experiences and seek new knowledge and information to adapt the farm to the changing farming environment (Darnhofer, 2014). Accordingly, Marshall *et al.* (2013) describe adaptive capacity as the farmers' potential to convert the existing resources into effective adaptation strategies. This may entail tapping into the farmer's agency and cognitive traits such as risk-taking behaviour and leveraging on the relationships with buyers of farm produce (Darnhofer *et al.*, 2016). Transformative capacity is the ability to implement radical changes on the farm to deal with severe shocks (Meuwissen *et al.*, 2019). It may involve the transition into new systems such as a shift from potato value chain to dairy value chain where new resources, practices and inputs are required (Darnhofer, 2014). Overall, the type, frequency and magnitude of risks faced by farmers determine the type of capacity needed to build farm resilience.

Two forms of resilience can be identified: general resilience which is the ability of a system to absorb, adapt or transform to all kinds of shocks; and specific resilience which is the ability of a system to resist, adapt or transform to a specific shock (Folke *et al.*, 2010). To build and assess specific resilience, Carpenter *et al.* (2001) propose the following questions which provide a guideline; resilience *of what*? resilience *to what*? and resilience *for what purpose*? In addition, Meuwissen *et al.* (2019) added the following two questions to clarify what specific resilience entails; these are *what resilience capacities*? and *what strengthens those capacities*? This thesis examines specific resilience following five analytical steps as shown in Figure 1.

Figure 1. Framework for examining farm resilience to climate change, adapted from Meuwissen *et al.* (2019)

1.3 Farmers' adaptive capacity

Within the broader farming system defined as a population of individual farm systems with varied resource bases, enterprise patterns, facing similar constraints and for which similar development interventions would be appropriate (Giller, 2013), a farm is a unit made up of the farmer – with his/her preferences, aspirations and capacities; and the physical farm. Farms can be understood as complex systems in which the farmers themselves play important roles with their management knowledge and skills, their preferences, attitudes and personal relationships, which all together determine the choice as to the strategies and operations of the farm (Darnhofer *et al.*, 2011; Perrin *et al.*, 2020).

With regard to farm resilience, the farmers' adaptive capacity plays a central role as it represents the farmers' potential to plan and organize the farm, experiment and learn from previous experiences, seize opportunities and convert existing resources into effective adaptation strategies (Marshall *et al.*, 2013). Gupta *et al.* (2010) define adaptive capacity as the characteristics of individuals that facilitate response to the impacts of climate change through the adoption of planned measures or encouraging creative and proactive responses. The focus on adaptive capacity in this thesis has been chosen for two reasons.

First, given the multiple and increasing occurrence of unpredictable climate change events, the capacity of farms to absorb the risks is no longer a feasible strategy (Ge *et al.*, 2016); farmers need to adapt and thus, they need to build and/or strengthen their adaptive capacity (Cinner *et al.*, 2018; Vanschoenwinkel *et al.*, 2020). Second, while transformation may be a potential strategy to respond to climate change, smallholders lack the resources necessary to transition to new systems. Additionally, transforming into a new system is a highly risky strategy for smallholder farms as it requires the development of new relations, additional resources, new technologies, knowledge and practices.

While adaptive capacity is a necessary and an important determinant of the farmer's ability to adapt to climate change through influencing the adoption of climate adaptation strategies, the level of farmers' adaptive capacity remains low in developing countries (Arslan *et al.*, 2015; Asfaw *et al.*, 2016). Existing studies have identified several factors that determine farmer adaptive capacity, including access to knowledge and extension, human and physical capital, financial resources, farmer cognitive traits, managerial ability and market access (Cinner *et al.*, 2018; Grothmann and Patt, 2005; Lim *et al.*, 2021; Smith *et al.*, 2000). However, these factors are limitedly available particularly for the smallholders in SSA, leading to the low adoption of climate change adaptation strategies (Amadu *et al.*, 2020).

To this end, the thesis has demonstrated that the need for farmers to adapt to climate change is indispensable, yet the farmers' adaptive capacity in SSA remains low. The thesis, therefore, aims to provide insights into the potential mechanisms for improving the farmers' adaptive capacity. We contribute to the emerging scholarship that has identified the importance of the adaptive capacity for climate change adaptation (Asfaw *et al.*, 2016; Cinner *et al.*, 2018; Vanschoenwinkel *et al.*, 2020) and provide recommendations for the policy and development community.

Understanding the role of adaptive capacity and the mechanisms through which the farmers' adaptive capacity can be improved is important at least for three reasons. First, adaptive capacity is not a static characteristic of the farmer (Smit and Wandel, 2006), it can be influenced through various pathways. Thus, understanding the possible avenues through which farmers' adaptive capacity can be improved has important implications from both academic and policy viewpoints. Second, policies and development interventions that emerge from understanding the factors that enhance or constrain adaptive capacity could improve climate change adaptation. Third, climate change adaptation studies such as Vanschoenwinkel *et al.* (2020) assume that the availability of more adaptation options to farmers increases the likelihood of adoption yet, this assumption ignores the role of farmers' adaptive capacity. Therefore, deliberate efforts to understand and account for the role of farmers' adaptive capacity in climate change adaptation may contribute to eliminating this assumption. Eliminating the assumption is important for providing targeted policies and designing impactful development interventions.

Building farmers' adaptive capacity increases resilience by enabling the adoption of climate adaptation strategies (Matewos, 2020). These adaptation strategies include climate-smart agriculture (CSA) – a strategy which is increasingly being promoted by both governmental and non-governmental organizations as a means to meet the "triple-win" benefits of simultaneously increasing production and food security, adapting agriculture to climate change while improving climate change mitigation (FAO, 2010). CSA involve among others, better access to farming information and skills, timely access to production input and services, shifts in production techniques, improved market governance, and expanded insurance and safety net programmes to maintain productivity under climate shocks (Lipper *et al.*, 2014). Even with the promising benefits of CSA practices, the adoption levels remain low in SSA due to the farmers' limited adaptive capacity (Arslan *et al.*, 2015; Asfaw *et al.*, 2016).

1.3.1 Pathways for improving farmers' adaptive capacity

Existing literature has identified factors that increase farmers' adaptive capacity (Asfaw *et al.*, 2016; Cinner *et al.*, 2018; Malakar, 2012; Patnaik and Das, 2017; Phuong *et al.*, 2018). For instance, Cinner *et al.* (2018) identified five domains necessary for building farmers' adaptive capacity (a) the assets that people can draw upon in times of need, (b) the flexibility to change strategies, (c) the ability to organize and act collectively, (d) learning to recognize and respond to change, and (e) the agency to determine whether to change or not (for detailed explanation see Cinner *et al.,* 2018). These existing studies have only identified the factors that increase farmers' adaptive capacity without an explicit focus on the mechanisms through which it is achieved (Petersen-Rockney *et al.*, 2021).

This thesis explores the mechanisms through which farmers' adaptive capacity can be enhanced. Three mechanisms are identified, these are (1) the farmer cognitive traits such as the farmer entrepreneurial orientation (EO), (2) membership of a farmer organization, and (3) the farmer-buyer relationship. Collectively we refer to these mechanisms as the pathways for improving farmers' adaptive capacity. This thesis focuses on these three pathways because conceptual studies have postulated relationships between entrepreneurship and resilience (Akinbami *et al.*, 2019; Korber and McNaughton, 2018); between business relationships, partnerships and resilience (Manyise and Dentoni, 2021; Rosenstock *et al.*, 2020); and between farmer organizations and climate resilience (Bardsley and Bardsley, 2014; Washington-Ottombre and Pijanowski, 2012), however, these relationships have not been empirically tested.

First, relating to the farmer cognitive traits pathway, we draw from the work of Grothmann and Patt (2005) and Lockwood *et al.* (2015) who show that holding other factors constant, the cognitive traits explain why some people exhibit adaptive behaviour while others remain vulnerable when faced with challenges. Following this line of thought, Barzola Iza and Dentoni (2020) in Uganda and Etriya *et al.* (2019) in Indonesia identified farmer EO as one of the cognitive traits. They show that farmers who exhibit entrepreneurial behaviour are better able to adapt to farm challenges and their farms and perform better both in terms of technology adoption and farm income. This thesis contributes to this stream of literature by studying the role of farmer EO in enhancing farmers' adaptive capacity. The rationale is that farmer EO improve farmers' adaptive capacity by enabling farmers to pursue entrepreneurial activities such as the adoption of CSA practices (Eshima and Anderson, 2016).

Second, membership of a farmer organization pathway extends the work on the role of institutional innovations such as farmer organizations (FOs) (Washington-Ottombre and Pijanowski, 2012), kinship networks (Di Falco and Bulte, 2013; Hulke and Revilla Diez, 2020) and climate-resiliency field schools (Chandra *et al.*, 2017) in climate change adaptation. FOs support smallholders to access production inputs by reducing the transaction costs, increasing bargaining power and enabling access to lucrative markets (Bardsley and Bardsley, 2014; Bizikova *et al.*, 2020; Fischer and Qaim, 2012b). While the role of FOs in supporting the smallholders is well established in agricultural development literature (Hao *et al.*, 2018; Ji *et al.*, 2019; Ma and Abdulai, 2019), most of the studies assume that membership alone results in the observed benefits to member-farmers. This thesis contributes to this emerging literature and argues that it is not only membership but also access to services provided by the FOs that enhance the farmers' adaptive capacity.

Third, the farmer-buyer relationship pathway is anchored on the strategic management and organisational literature (Blau, 1964; Granovetter, 1985). The basic idea is that businesses do not operate in isolation, instead, business performance and adaptive capacity are influenced by the business relationships that they are embedded in. A wide range of studies exists that examine the role of buyer-seller relations on different aspects of businesses (Jajja *et al.*, 2019; Marcos and Prior, 2017; Shahzad *et al.*, 2018). These studies indicate that the relationships between buyers and sellers enable exchange parties to access resources, facilitate joint planning collaboration, provide incentive alignment, joint knowledge creation and adapt to changes facing the businesses. This thesis focuses on the specific type of relationships between farmers and buyers which has received limited attention particularly in terms of supporting smallholders adaptation to climate change (Canevari-Luzardo *et al.*, 2019). Taking the farmers' perspective, and drawing on the social exchange theory, we examine the role of farmer-buyer relationship on climate change adaptation among the smallholder potato farmers in Kenya.

The overall hypothesis is that farmer entrepreneurial orientation, membership and access of FO services, and the specific relationships between farmer and buyer enhance the farmers' capacity to adapt to climate change. Thus, the thesis specifically explores:

a) *the role of farmer entrepreneurial orientation in influencing smallholder farms adaptation to climate change*
b) *the role of membership of farmer organizations in influencing smallholder farms adaptation to climate change*
c) *the role of farmer-buyer relationship in influencing smallholder farms adaptation to climate change*

The remainder of this chapter proceeds as follows. In section 1.4 an overview of the research context which is the smallholder potato farming in Kenya is presented. Section 1.5 presents the theoretical framework applied in the study. Section 1.6 presents the specific research questions followed by the overall methodological framework in section 1.7. This introduction chapter concludes with an outline of the thesis structure in section 1.8.

1.4 Overview of the smallholder potato farming in Kenya

Agriculture is the most important sector for Kenya's economy contributing about 30% to the gross domestic product (GDP). Within the agriculture sector, potato (*Solanum tuberosum*) is the second most important food crop after maize and potato farming plays an important role for both household livelihood and food and nutrition security. Potato accounts for about 23% of the total value of horticultural produce (Kyallo *et al.*, 2017).

The main potato producing regions are the highlands of Central, Eastern and Rift Valley with a majority of the producers being smallholder farmers producing on less than 2 ha of land (Kaguongo *et al.*, 2013). In addition, the labour-intensive nature of potato farming makes it one of the main sources of employment for rural dwellers. Approximately 2.5 million people are employed along the potato value chain as casual labourers, farmers, traders, middlemen, transporters, processors and vendors (Kaguongo *et al.*, 2013).

Generally, potato is grown in a monocropping system with a small percentage being intercropped with other food crops such as maize, beans and other horticultural crops. In almost all the potato producing regions, production occurs under a rainfed system. As such, there are two main potato growing seasons, the long rains between April to July and the short rains between October to December. However, this may vary slightly from one region to another. In the potato growing regions, potato is one of the main cash crops, therefore farmers with small land sizes grow potatoes season after season on the same piece of land due to lack of sufficient land to practice recommended crop rotation (Gildemacher *et al.*, 2009b).

Despite the importance of potato farming to both household and national economy, increasing production is hindered by the lack of good-quality seed (Okello, Zhou*, et al.*, 2018), the effects of climate change (Parker *et al.*, 2019) and the buildup of soil-borne pests and diseases (Gildemacher *et al.*, 2009b). The lack of access to good-quality potato seed implies that farmers rely on recycled seed which is often from own savings or purchased at local markets contributing not only to low yields but also a continuous spread of soil-borne diseases. These constraining factors may explain in part the trend in potato production in Kenya as shown in figure 2.

In terms of market access, potato farmers in Kenya face challenges given their smallholder nature and geographic location away from the market; these challenges diminish farmers bargaining power while increasing their transaction costs (Gildemacher *et al.*, 2009b). Generally, the informal markets dominate the potato trade in Kenya. These informal markets are characterized by the presence of middlemen who often collude to distort market information, create information asymmetry and thus exploit the farmers in the chain (Fintrac, 2015).

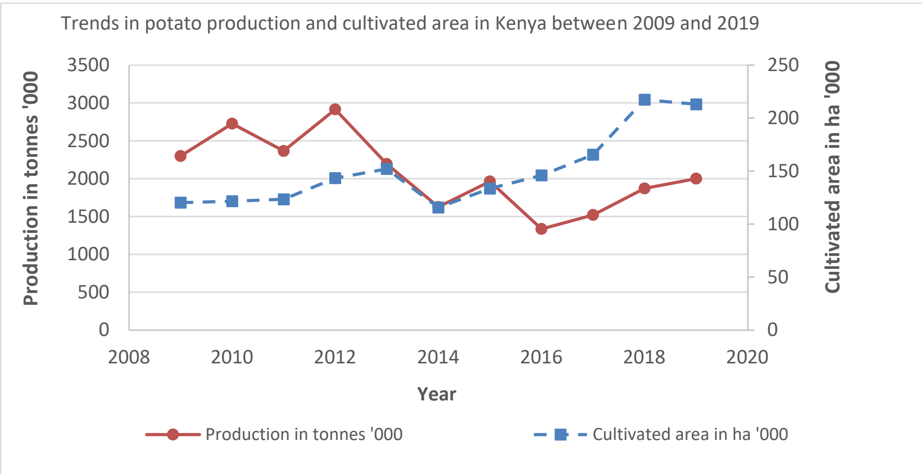

Figure 2. Trends of potato production and the cultivated area in Kenya between 2009 and 2019 (FAOSTAT, 2019)

Given the existing potato market structure, the county governments and development organizations such as the International Potato Centre (CIP) have been promoting the formation of farmer organizations of different forms, including farmer cooperatives and informal farmer groups, to help farmers solve their production and marketing problems (CIP, 2017). The CIP report shows that through farmer organizations, farmers benefit from the economies of scale and increased bargaining power which reduce the production and marketing costs. Specifically, farmer organizations facilitate bulk purchasing of production inputs and collective selling of the produce (Fintrac, 2015; Kaguongo *et al.*, 2008).

1.5 Theoretical framework

To understand the different pathways and how they may enhance the farmer adaptive capacity, we draw on the theories of entrepreneurship, farmer organization and buyer-seller relationship.

1.5.1 Entrepreneurial Orientation

In the context of a rapidly changing business environment, some businesses have been shown to adapt more than then others. Entrepreneurship has been argued to be one of the characteristics that enable some businesses to adapt more than others (Dias *et al.*, 2019; Fitz-Koch *et al.*, 2017). Within the agricultural sector, entrepreneurship is defined as the process of recombining agricultural resources innovatively to create opportunities for value creation and to respond to emerging needs (McElwee, 2011; Morris *et al.*, 2017). Within the entrepreneurship literature, the concept of entrepreneurial orientation (EO) has gained traction as a means to understand both firm and individual entrepreneurial behaviour (Lumpkin and Dess, 1996; Rauch *et al.*, 2009). EO refers to the joint expression of the three dimensions of risk-taking, innovative and proactive behaviour in attempts to pursue opportunities or overcome challenges (Covin and Lumpkin, 2011). EO is thus a strategic posture reflecting the practices and behaviour that allow farmers to act entrepreneurially, for instance, in the face of climate change.

The risk-taking dimension is the propensity to take calculated risks involving committing resources to activities with uncertain outcomes (Rauch *et al.*, 2009). The innovativeness dimension is the ability to deviate from established practices and technologies towards supporting new ideas, often through learning and experimentation (Lumpkin and Dess, 1996). Proactiveness, the third EO dimension, reflects the ability to anticipate and act upon future threats and opportunities. Different from reactive traits (Brzozowski and Cucculelli, 2016), proactive traits are associated with an orientation towards searching for or creating new opportunities. Hence, proactive farmers usually are those that engage in new practices or technologies before other farmers do.

Viewed as behaviour, entrepreneurship can be conceptualized as a cognitive trait relating to the farmer's decision-making style (Boudreaux *et al.*, 2019; Dessart *et al.*, 2019). Cognitive traits are behavioural in nature and relate to learning and reasoning, these include aspects such as the farmer's risks preferences associated with a particular farm practice or technology (Dessart *et al.*, 2019). While a vast amount of literature has investigated the role of cognitive traits specifically farmer risk preferences on adoption decisions (Huang *et al.*, 2014; Isik and Khanna, 2003; Jianjun *et al.*, 2015), a focus on only risk preferences does not provide a complete picture of the cognitive traits. Application of the EO allows for the investigation of other cognitive traits specifically farmer innovativeness and proactiveness.

Relating to adaptive capacity and farmer EO, Eshima and Anderson (2016) have shown that through pursuing entrepreneurial activities to overcome challenges and/or take advantage of opportunities actors (farmers) enhance their adaptive capacity. For instance, Pérez-Luño *et al.* (2011) and Morris *et al.* (2017) find that farmer entrepreneurship increases the ability to adopt new practices and technologies. It is thus important both for theory and climate change adaptation approaches to understand the influence of farmer EO dimensions (risk-taking, innovativeness and proactiveness) on the adoption of climate adaptation strategies among smallholder farmers.

1.5.2 Farmer Organization

Farmer organizations (FOs) are forms of collective action that are a voluntary collaboration of farmers to pursue shared objectives (Meinzen-Dick *et al.*, 2004). From a value chain perspective, FOs represent *horizontal collaboration* where farmers who are at the same level of the value chain collaborate for mutual benefits. This voluntary collaboration of farmers can take different legal forms including farmer cooperatives, unions, limited companies, self-help groups, informal groups among others (Bijman *et al.*, 2016). Penrose-Buckley (2007) describes these farmer collaborations as businesses that provide business-oriented services to the members.

The central tenet of FOs is to overcome the high transaction costs and market failures that characterise smallholder farming systems in developing countries (Bernard and Spielman, 2009; Fischer and Qaim, 2012b). There are at least four ways through which FOs can overcome the high transaction costs and improve market access. First, FOs improve smallholders bargaining power, which enables farmers' entry into new markets and negotiate for better terms of trade (Kruijssen *et al.*, 2009; Shiferaw *et al.*, 2011). Second, FOs enable smallholders to accrue the benefits of economies of scale. This is crucial for farmers to access farm inputs such as fertilizers and seeds at lower costs; economies of scale also enable farmers to access lucrative markets by taking control of large volumes (Devaux *et al.*, 2009). Third, through FOs, farmers can access productions services such as extension (Wossen *et al.*, 2017), affordable credit (Santos *et al.*, 2021; Twine *et al.*, 2018) and new farm technologies and practices (Abebaw and Haile, 2013). Fourth, in settings prone to risks such as climate change, incomplete markets and idiosyncratic risks, FOs act as a mechanism for risk pooling, which makes the risks bearable for the resource-constrained farmers (Cherry *et al.*, 2015). In addition, FOs provide avenues through which capacity building, peer learning and experimenting can be implemented (Di Falco *et al.*, 2019).

While the above studies provide important insights into the role of FOs, we note that the studies have largely been mechanistic in the way they treat membership, that is, a farmer is considered either a member or non-member such that the impacts observed are attributed exclusively to membership. This is problematic for two reasons, first, it assumes that once a farmer joins a FO benefits are guaranteed, this is not always the case, instead, farmers need to access the services provided by FOs to accrue the benefits membership. For instance, relating to membership and benefiting from the FOs, Pascucci *et al.* (2011) showed that membership varies depending on access to the benefits provided by FOs to members, they identified two membership categories; (i) membership with product delivery – *strong membership* and (ii) membership without product delivery – *soft membership*. Besides, Bernard and Spielman (2009) and Mwambi *et al.* (2020) found that some FO members based on their gender, poverty levels and location are excluded from the governance (decision-making) of the FOs. We argue that member exclusion may have implications for their access to FO services. The foregoing imply that the impacts of FOs may be over or underestimated in the presence of the assumption that once a farmer joins a FO, benefits are guaranteed. Second, policy recommendations that are derived from assuming that once a farmer joins a FO benefits are guaranteed may be misguided especially if the policies advocate solely on the formation and/or joining FOs without a consideration on the provision and/or access of FO services. In an attempt to bridge this knowledge gap we suggest that in addition to evaluating membership, access to FO services need to be taken into account to fully understand the impact of FOs.

This thesis explores the role of membership and access to FO services on the adoption of climate change adaptation strategies. For a detailed review of FO services and their impacts on smallholders in SSA see Bizikova *et al.* (2020). Three services including access to credit, extension and market have previously been examined albeit independently and often not as provided by FOs (Pan *et al.*, 2018; Wossen *et al.*, 2017). In this thesis, the three services when provided by FOs are considered. The rationale is that membership and access to the identified services enhance the farmers' adaptive capacity and thus improve the adoption of climate change adaptation strategies.

1.5.3 Buyer–Seller relationship

Exchange relationships between buyers and sellers have received ample emphasis in the relationship marketing literature where the buyer-seller exchanges are viewed as ongoing relationships rather than as discrete events (Dwyer *et al.*, 1987). From a value chain perspective, a buyer-seller relationship represents *vertical collaboration* where businesses from different levels of the chain collaborate for mutual benefits (Bijman *et al.*, 2006).

In a buyer-seller relationship, governance is an essential element that determines the outcomes of the relationship, reduces uncertainties and conflict, and provides incentives for relationship-specific investments (Benton and Maloni, 2005). Governance can take two forms of governance: formal or informal (Liu *et al.*, 2009). On the one hand, transactional governance are those that are implemented through contracts that stipulate the expected behaviour, as well as the rights and obligations of the exchange parties (Williamson, 1979). On the other hand, informal governance focuses on the role of social relations in guiding (economic) behaviour (Granovetter, 1985).

Increasingly and in contexts where contract enforcement is weak, informal governance is being used to curb opportunistic behaviour to thus strengthen the buyer-seller relationship (Kim, 2000). Generally, informal governance regulates buyer-seller relationships by taking advantage of social relations that are developed and maintained between exchange parties. These social relations include power-dependence between exchange parties (Jean *et al.*, 2012), relational commitment (Shahzad *et al.*, 2018) and relational satisfaction (Murphy and Sashi, 2018). One of the advantages of informal governance over transactional governance is that they help fill the institutional voids that exist in contexts such as those in sub-Saharan Africa where contract monitoring and enforcement is limited.

From the social exchange theory stance, social mechanisms give rise to socially constructed and accepted rules, behaviour and reciprocity which in turn discourage opportunism and promote long term relationships (Cropanzano and Mitchell, 2005). For instance, where a buyer-seller relationship is characterized by good collaboration, exchange parties benefit from reduced transaction costs while increasing the incentive for relationship-specific investment (Liu *et al.*, 2009; Murphy and Sashi, 2018).

Drawing from the work of Canevari-Luzardo *et al.* (2019) we advance the argument that the outcome of farmer-buyer relationship within agri-food value chains are associated with the farmers' adaptive capacity. There are at least two ways through which a farmer-buyer relationship is associated with the farmers' adaptive capacity. First, in a collaborative farmer-buyer relationship, buyers may provide farmers with a guaranteed market and also mediate between farmers and customers by providing information such as customer demands (Canevari-Luzardo, 2019). Additionally, buyers ensure that farmers access lucrative markets and receive stable prices, these have two complementary effects (i) act as an incentive for investment in climate change adaptation strategies and (ii) the income can be ploughed back into the adoption of climate change adaptation strategies. Second, in some farmer-buyer relationships, buyers may support farmers to adapt by providing inputs such as drought-tolerant seed varieties, credit or production equipment (González-Mon *et al.*, 2019).

In sum, taking farmers' perspective, a farmer-buyer relationship may enable farmers to develop the confidence to: (i) invest their limited resources to adapt and manage the climate risks; (ii) plan and reorganize their farms to deal with climate change; and (iii) enhance their interest in adapting to climate change (Marshall *et al.*, 2014).

1.6 Research questions

The objective of this thesis is to explore and empirically assess the pathways through which farmers' adaptive capacity can be enhanced to improve climate change adaptation among smallholder farms. To achieve this objective, four research questions are examined. This section briefly discusses the knowledge gaps that give rise to the four research questions.

We begin with the premise that the resilience of social-ecological systems such as farms is determined by three capacities: absorptive capacity, adaptive capacity and transformative capacity (Béné *et al.*, 2014; Darnhofer, 2014; Walker *et al.*, 2004). The specific focus of this thesis is on adaptive capacity as the principal driver of farm resilience.

Existing studies have identified limited adaptive capacity as the main reason for the low level of climate change adaptation among smallholder farms (Arslan *et al.*, 2017; Lim *et al.*, 2021). Whereas recent studies such as Cinner *et al.* (2018) have proposed factors necessary for building adaptive capacity, questions remain on the pathways through which these factors influence adaptive capacity. Thus, Chapter 2 of this thesis explores the pathways through which farmers' adaptive capacity can be influenced. Specifically, it addresses the following research question:

Research question 1 (RQ1): *What are the determinants of farmers' adaptive capacity and how can it be improved?*

In response to the low adaptive capacity of smallholders, there is a surge in the number of studies that provide recommendations on how to improve adaptive capacity (Cinner *et al.*, 2018). The recommendations include access to technical assistance, access to financial, human and physical capital

(Yohe and Tol, 2002). In addition, a recent meta-analysis indicates that farm and farmer characteristics contribute to farmers' adaptive capacity in developing countries (Ruzzante *et al.*, 2021). While the above-mentioned factors are important in improving farmers adaptive capacity, the role of farmers' psychological characteristics has received little emphasis resulting in an incomplete overview of the factors enhancing or constraining climate change adaptation (Dessart *et al.*, 2019). According to Fazey *et al.* (2007), psychological characteristics may constrain or enhance social-ecological resilience by inhibiting or supporting learning. One specific psychological characteristic that remains underexplored is the farmer cognitive traits (Eakin *et al.*, 2015; Grothmann and Patt, 2005). An example of a farmer cognitive trait is farmer entrepreneurial orientation (EO), which constitutes the three dimensions of risk-taking, innovativeness and proactiveness (Lumpkin and Dess, 1996). In other sectors of the economy such as small and medium enterprises, it has been demonstrated that EO enable businesses to thrive in turbulent times (Engelen *et al.*, 2014; Jocic *et al.*, 2021). However, to date, the role of EO continues to receive little attention in the context of smallholder farming facing climate change. To the best of our knowledge, this is one of the first studies to empirically test the role of farmer EO in climate change adaptation. Chapter 3 of this thesis contributes to filling this knowledge gap:

Research question 2 (RQ2): *Does farmer entrepreneurial orientation matter for smallholders' adaptation to climate change?*

Rural development literature presents the farmer organization as an institutional solution to overcome high transaction costs and facilitate access to production resources for resource-constrained smallholder farms in developing countries (Bernard and Spielman, 2009). FOs have been shown to facilitate access to production inputs (Mutonyi, 2019; Ragasa and Golan, 2014), provide access to markets (Fischer and Qaim, 2012a; Markelova and Mwangi, 2010), promote the adoption of new farm technologies (Abebaw and Haile, 2013; Ainembabazi *et al.*, 2017) and the adoption of food safety measures (Kirezieva *et al.*, 2016; Mwambi *et al.*, 2021). A new stream of literature is emerging on the potential roles of FOs in climate change adaptation. Recent studies posit that the role of FOs in facilitating access to production resources improves farmer adaptive capacity, which in turn contributes to climate change adaptation (Di Falco and Bulte, 2013; Hulke and Revilla Diez, 2020; Lim *et al.*, 2021).

While these studies provide useful information about the role of FOs in smallholder farming settings, they have been largely mechanistic in how they treat FO; that is, they assume that the membership decision alone results in the observed impact on the members. This assumption does not provide insights into the mechanisms through which the impact of FOs emerge. For instance, Pascucci *et al.* (2011) have shown that membership does not necessarily imply access to FO services, some farmers are members without access to the FO services. Therefore, there is a need to understand *how* FOs influence farm outcomes (Abate, 2018; Minah and Malvido Pérez Carletti, 2019). Chapter 4 attempts to fill this knowledge gap by answering the following question:

Research question 3 (RQ3): *How do membership and access to FO services impact on smallholders' adaptation to climate change?*

Farmers' adaptive capacity depends on access to sufficient resources and the farmer incentive to invest (Yohe and Tol, 2002). One of the ways through which farmers' adaptive capacity may be enhanced within the agri-food value chain is by leveraging on the relationships between farmers and buyers (Canevari-Luzardo *et al.*, 2019). Specifically, collaborative relationships between farmers and buyers may help farmers to access the resources and information beyond the farm (Spielman *et al.*, 2010). However, how the farmer-buyer collaboration in the value chain may influence farm resilience remains under-explored (Fleming *et al.*, 2014; Lim-Camacho *et al.*, 2016). This thesis attempts to fill this knowledge gap and explores not only the question of *whether* farmer-buyer relationship can improve farmers adaptive capacity, but more importantly *how* the farmer-buyer relationship improves the ability of smallholder farms to adapt to climate change.

Research question 4 (RQ4): *Do farmer-buyer relationship influence smallholders' adaptation to climate change?*

1.7 Methodology

This study was carried out in two counties of Kenya namely Meru and Nakuru, which are among the main potato producing counties (Kaguongo *et al.*, 2014). Meru county is located on the eastern windward side of Mt. Kenya about 225 km (140 miles) northeast of Nairobi. The main potato producing sub-counties in Meru include Buuri, Imenti Central, Imenti North, Imenti South, Igembe Central and Igembe South. Nakuru is located in the great rift valley and about 156 km (97 miles) west of Nairobi (see Figure 3). The main potato producing sub-counties include Njoro, Molo, Kuresoi South, Kuresoi North, Rongai, Bahati, Gilgil, Naivasha and Subukia.

To answer the research questions enumerated above, both qualitative and quantitative research methods were used. In Chapter 2, a literature review is presented to answer research question 1 (RQ1). The literature review identified the potential pathways through which farmers' adaptive capacity can be enhanced to improve farm resilience. The general assumption of Chapter 2 is that enhanced farmers' adaptive capacity improves farm resilience to climate change. The chapter concludes with propositions on how farmers' adaptive capacity can be enhanced.

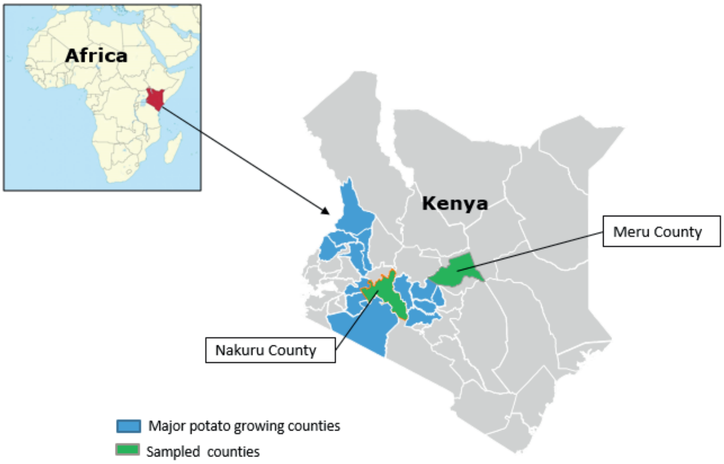

Figure 3. Map of Kenya showing the study sites of Meru and Nakuru counties

To answer research questions RQ2 to RQ4, the thesis relies on survey data collected between June to August 2019 through a one-on-one interview with potato farmers in Meru and Nakuru counties of Kenya. A multistage sampling procedure was used to select farmers. In the first stage, Meru and Nakuru counties were purposively selected being two of the leading potato-producing counties in Kenya. Within these two counties, locations (*since 2010 referred to as wards*) with high potato production were selected in consultation with the county extension officers. In particular, Kisima, Timau and Kibirichia locations were selected in Meru county, while Keringet and Molo locations were selected in Nakuru county. Second, we acquired the list of potato farmer groups within the sampled locations with the help of the extension officers. From these lists we selected target farmer groups; 39 groups were randomly selected from the locations in Meru county and 18 groups were randomly selected from the locations in Nakuru county. Therefore, a total of 57 potato farmer groups were selected. Third, we acquired the lists of the farmers in all the sampled groups and applied a proportional random sampling procedure to select individual farmers to be interviewed.

Given that we did not have lists of farmers that were not members of farmer groups, we randomly interviewed non-group-member farmers in the villages of member farmers. To do this systematically, the enumerators were told to, after interviewing every second selected group member, to skip two households and interview the third household (only if this household was a non-member). Although this may not yield a perfect random sample, this approach has previously been applied in an attempt to attain a representative sample in the absence of a population list and with resource constraints (McCord *et al.*, 2015). In total, 792 potato farmers were interviewed comprising 500 group members and 292 non-members. A structured questionnaire was used to collect data on a range of topics including farmer and farm characteristics, farmer EO, potato production, access to services, and value chain relations.

To answer RQ2, Chapter 3 of this thesis draws on the entrepreneurial orientation literature to examine the role of farmer risk-taking, innovativeness and proactiveness in the adoption of climate adaptation strategies, specifically climate-smart agriculture (CSA) among the smallholder potato farms. Together with the county government agricultural extension officers, we identified CSA practices that are relevant for potato farming. Six practices were considered in this thesis, these are; irrigation, changing cultivation calendar, use of certified potato seed, crop rotation, soil testing and intercropping. These CSA practices were categorised based on the main resources required for their adoption. Since farmers can adopt a combination of CSA practices to achieve various outcomes, multivariate probit models are employed to estimate the role of farmer EO and other determinants of CSA adoption.

In Chapter 4, RQ3 is answered drawing from the theoretical implications of economic organisation theory. Given the argument that group membership alone does not sufficiently explain the impact of FOs on the adoption of CSA, our data allowed for the disaggregation of farmers based on access and use of FO services. Three services were considered: market, credit and extension. To estimate the impact of these services, a doubly robust inverse probability weighted regression adjustment (IPWRA) approach with conditional analysis to account for the heterogeneity in membership and access to the different services was employed.

The last research question, RQ4, is answered in chapter 5 by employing a structural equation modelling (SEM) approach. In this chapter, the question of *whether* and *how* of farmer-buyer relationship is associated with farmers adaptive capacity is explored drawing from the social exchange theory (SET). SEM provides the flexibility to test various associations between the different aspects of farmer-buyer relationship and adaptive capacity and further allows for mediation analysis.

Each of Chapters 2, 3, 4 and 5 can be read independently as they entail separate contributions to the climate change adaptation and resilience literature. However, there are important cross-cutting themes leading up to three core messages: (a) farmer EO plays an important role in climate change adaptation, (b) membership of a farmer organization and access to FO services play important roles in improving climate change adaptation, and (c) farmer-buyer relationship when mediated by farmer EO play important roles in improving climate change adaptation. The synthesis of the findings, the policy and management implications, and the suggestions for future research are provided in Chapter 6.

1.8 Thesis outline

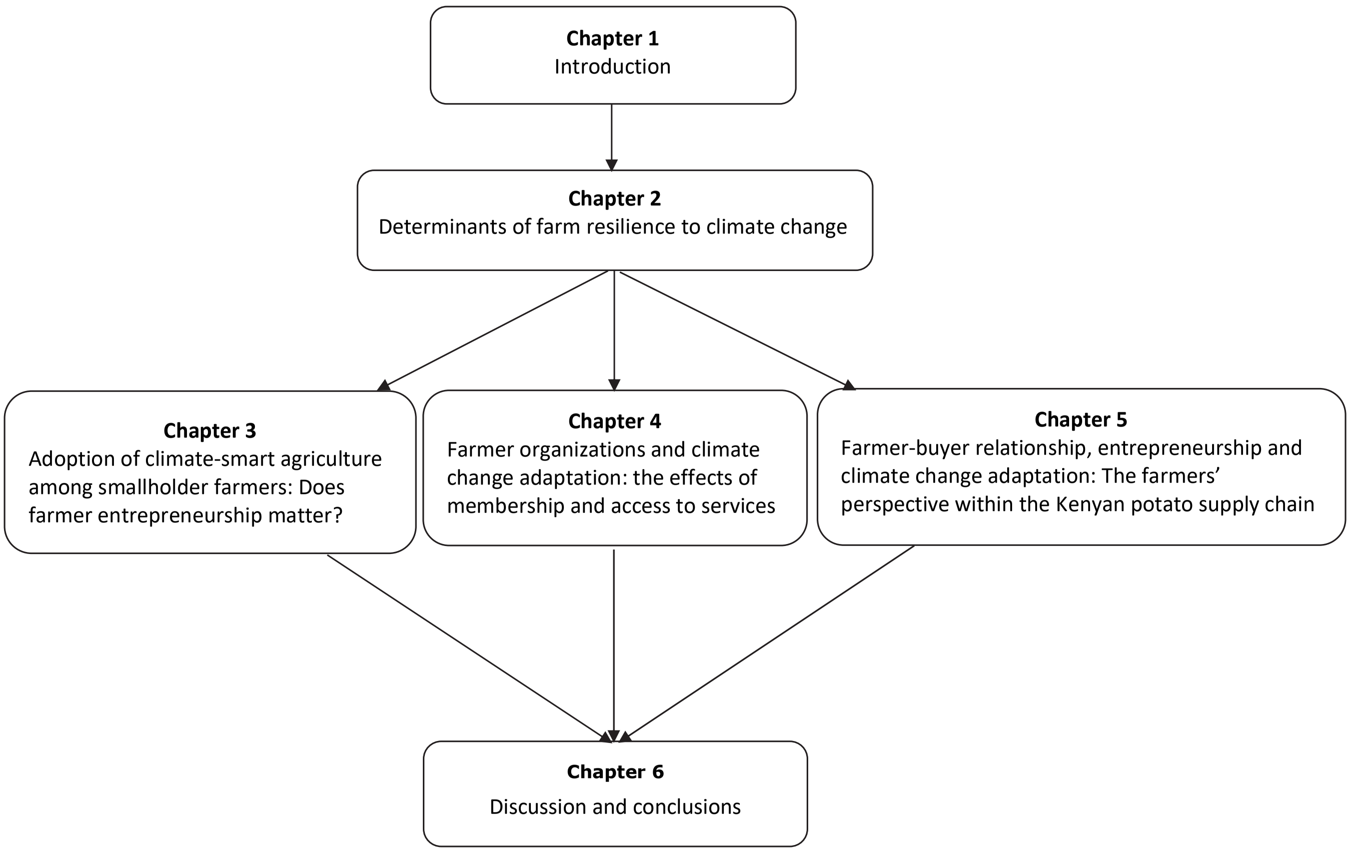

Figure 4. Thesis outline

Chapter 2

Determinants of farm resilience to climate change: the role of farmer entrepreneurship and value chain collaboration

Abstract

The concept of resilience has gained traction in academic, policy and development discourse in recent years, yet its conceptualization and application at the farm level has received little attention. For instance, recent policy recommendations present farm resilience as a silver bullet in dealing with agricultural risks and uncertainty, and in achieving sustainable agri-food systems. Yet, the question of what determines farm resilience in a smallholder farming setup remains fuzzy. To address this knowledge gap, we, first, develop a novel conceptual framework based on farmers' adaptive capacity as a determinant of farm resilience. The emphasis on adaptive capacity responds to a conceptual weakness inherent in studies that present socio-ecological systems such as farms as static systems. Second, based on a literature review we propose farmer entrepreneurship, membership in a farmer organization and farmer-buyer relationship as potential pathways for improving the farmers' adaptive capacity and thereby farm resilience. Based on our conceptual understanding, we recommend approaches that augment farmer entrepreneurship, support farmer organizations and strengthen farmer-buyer relationship.

Keywords

Resilience, adaptive capacity, entrepreneurship, farmer organizations, and farmer-buyer relationship

This chapter is published as:

Kangogo, D., Dentoni, D., & Bijman, J. (2020). Determinants of farm resilience to climate change: the role of farmer entrepreneurship and value chain collaboration. *Sustainability*, 12(3).

2.1 Introduction

Because of the globally alarming news on climate change and its impact on agriculture, transitions towards more ecologically sustainable agri-food systems call for a deep re-thinking of farming practices (Sultan and Gaetani, 2016). Yet, despite the environmental alarms, both farmers and their value chain partners experience major difficulties in making changes towards more sustainable practices. This calls for a deeper understanding of farmers' motivations and barriers to the development of environmentally sustainable practices (Mancini, 2019). With respect to the farmers' motivations, a rich body of literature has focused on the adoption of sustainable agricultural practices (Kassie *et al.*, 2015; Zeweld *et al.*, 2017). However, a knowledge gap persists in understanding how farmers continuously adapt their farming practices to unpredictably changing environmental conditions. Attempts to fill this knowledge gap is important in order to come up with policies that support farms given the unpredictable climatic conditions that farmers continuously face.

This paper conceptualizes the determinants of farm resilience to shed light on when, why and how farmers continuously adapt their farming practices in response to climate change shocks. According to Campbell *et al.* (2014) building farm resilience has become a prerequisite for farms that are operating in the face of unpredictable climate shocks. In general, resilience refers to the ability of a system to absorb disturbance and reorganize while undergoing change so as to still retain essentially the same function, structure and identity (Walker *et al.*, 2004). Following this, resilience is viewed as an essential building block for sustainability in the face of growing complexity and uncertainty (Carpenter *et al.*, 2012). At the farm level, resilience refers to the ability of farms to persist, adapt or transform in response to climatic, social and economic shocks (Meuwissen *et al.*, 2019). This ability of farms to adapt can be improved through internal and external interventions (Maleksaeidi *et al.*, 2016), and tapping into farmer characteristics which facilitate self-organization and innovative problem solving (Carpenter *et al.*, 2001).

In general, Gitz and Meybeck (2012) identified three strategies for building resilience. These strategies are reducing exposure, reducing sensitivity and increasing adaptive capacity.

a) Reducing exposure implies reducing the likelihood of a particular risk occurring as well as the severity. This strategy makes a distinction between climatic and non-climatic shocks. For some non-climatic shocks, it may be possible to reduce the likelihood of their occurrences and severity at the farm level while this is difficult for climatic shocks.
b) Reducing the sensitivity of the farm to shocks implies an identification of the likely risk and developing response mechanisms to reduce the impacts. For instance, sensitivity to drought can

be reduced by developing and using drought-tolerant varieties. This strategy requires that the likely risks are measurable, yet this is not always possible at the farm level.

c) Increasing adaptive capacity implies enhancing the ability of farmers to respond promptly and effectively to the effects of climate change, for instance through the use of novel management practices and innovative technologies (Freduah *et al.*, 2019; Joseph, 2018). Farmers' adaptive capacity is associated with increasing the options to manage climate change and improving decision-making under uncertainty (McCarthy *et al.*, 2018).

We focus on farmers' adaptive capacity defined as the human potential to convert and reconvert existing resources into effective adaptation strategies (Marshall *et al.*, 2013). In other words, adaptations strategies taken by farmers in response to climate change are a manifestation of their adaptive capacity (Smit and Wandel, 2006). At the farm level, adaptive capacity is a prerequisite for building farm resilience to climate change (Fazey *et al.*, 2007). Specifically, farmers' adaptive capacity is a function of the ability to access, organize resources, and linkages to organizations that influence the access to the necessary resources (Brown and Westaway, 2011; Yohe and Tol, 2002).

While farmers' adaptive capacity as a means of building and/or strengthening farm resilience is important, it has so far received little attention in climate change adaptation research. We contribute in two ways to this research gap and the ongoing conceptual development of farm resilience. First, focusing on farmers' adaptive capacity rather than farm performance measures represent a new sustainable paradigm as it shifts the analysis from static outcome indicators such as income and yields to process indicator such as farmer adaptive capacity. In this way, farmers adaptive capacity at the farm level is viewed as a characteristic of the farmer and the relations that farmers develop to prepare and respond to the impacts of climate change (Gupta *et al.*, 2010). Secondly, to explain how farmers' adaptive capacity can be influenced, we build upon the so-far disconnected literature on farm resilience (Darnhofer *et al.*, 2016; Jacobi *et al.*, 2015), supply chain resilience (Behzadi *et al.*, 2017; Falkowski, 2015), entrepreneurship (Adomako *et al.*, 2016; Barzola Iza *et al.*, 2019; Vlasov *et al.*, 2018) and farmer organizations (Doughty, 2015; Gooch and Warburton, 2009; Ratner *et al.*, 2014).

We emphasize the role of the farmer since climate change adaptation behaviour is determined by the characteristics of the farmer including the cognitive process of the farmer (Grothmann and Patt, 2005; Nguyen *et al.*, 2016), which also includes entrepreneurship (Amankwah-Amoah *et al.*, 2019). Therefore, to understand farmers' adaptive capacity as the potential to convert and reconvert existing resources into effective adaptation strategies, there is a need to incorporate the farmer cognitive factors, particularly entrepreneurship in the assessment. In addition, value chain collaboration both horizontal collaboration among farmers through farmer organizations (Agrawal, 2008) and vertical collaboration between farmers and the buyers of farm produce through farmer-buyer relationship (Canevari-Luzardo, 2019) also contribute to improving farmer adaptive capacity. We conjecture that a) farmer entrepreneurship, b) membership of farmer organizations (FOs) and c) the nature of farmer-buyer relationship play powerful roles in shaping farm resilience through their influence on the farmers' adaptive capacity.

Considering farmer entrepreneurship, membership in farmer organizations (FOs) and the nature of farmer-buyer relationship as pathways for improving farmers' adaptive capacity responds to the calls to identify approaches that enhance the ability of farms to adapt to climate change. First, farmer entrepreneurship entails how farmers proactively adapt, take calculated risks and innovate in response to stimuli from both internal and external environments (Barzola Iza *et al.*, 2019; Lumpkin and Dess, 1996). Second, the FOs represent the role of collective action in supporting farmers' adaptive capacity (Frank and Penrose-Buckley, 2012; Washington-Ottombre and Pijanowski, 2012). Third, the nature of farmer-buyer relationship represents the potential mechanism through which the market systems build farmers ability to adapt to climate change (Canevari-Luzardo, 2019; Kuhl, 2018). Regardless of the type of collaboration that farmers are embedded in, Pelling *et al.* (2008) argue that organizational and governance structures are central for adaptive capacity. On the one hand, the organizational structures provide space for farmers to interact, communicate, experiment and learn from each other in attempts to respond to changes facing their farms (Manyise and Dentoni, 2021). On the other hand, governance structures are how relationships are governed to encourage adaptation (Armitage and Plummer, 2010).

Our conceptual framework extends the work of Vroegindewey and Hodbod (2018) and Canevari-Luzardo *et al.* (2019) on taking a relational view of climate change adaptation through taking advantage of value chain collaboration. It does this by identifying farmers' adaptive capacity as a key determinant of farm resilience.

2.2 An illustration of the determinants of farm resilience: Potato farming in Kenya

To support our conceptual work, we refer to an illustrative example from potato farming in Kenya. Potato is the second most important crop in Kenya after maize. Potato is grown both as a food and cash crop by smallholder farmers who produce mainly under rain-fed farming conditions. Like with other crops, potato growing is already crippling with the effect of climate change including unpredicted rainfall and frequent droughts. This has forced potato farmers to adapt in different ways including the adoption of climate-smart agriculture practices such as intercropping which conserves moisture, increases soil fertility, spreads the risk of crop failure and reduces the cost of renting land as different crops can be grown in the same plot; changing potato planting dates, investing in irrigation among other options. The Kenya climate-smart agriculture implementation framework 2018-2027 (MoALF, 2018) contains a comprehensive list of climate-smart agriculture practices currently being promoted in Kenya. While adoption levels of these practices continue to grow, the levels still fall below 50% for most of the practices (Bernier *et al.*, 2015; World-Bank and CIAT, 2015). Our household survey among a sample of Kenyan potato farmers indicates that irrigation, soil testing for crop and fertilizer recommendation, changing of planting dates and soil and water conservation measures were adopted by about 31%, 21%, 49% and 36% of farmers respectively.

Interestingly, we observed that inhabitants of urban areas are renting land to grow potatoes in rural areas particularly where they can invest in irrigation. These new entrants in potato farming produce potatoes mainly under irrigation and in the varieties that are demanded in urban markets.

There is an emerging development in the farmer groups where potato farmers are strengthening their farmer organizations through formalizing them into stronger units such as cooperatives. These stronger and more formal units not only allow member farmers to take advantage of collective activities in times of adverse climatic events but also allow them to tap into resources and services from non-governmental organizations, county governments and other stakeholders. In Meru county, for instance, several small potato farmer groups merged to form a potato cooperative. The cooperative now provides farmer members with opportunities to access credit, good quality seed (certified seed and in the variety that is demanded in the market), buy crop insurance policy, access training through cooperative field extension officers and opportunities to participate in contract farming models. In some cases, the contractor provides its farmers with advice and inputs, especially certified seeds in the varieties that it requires. This takes the burden away from the farmers and encourages further investment in potato production despite the effects of climate change. Contract farming models underscore the role played by the farmer-buyer relationship in influencing farmer adaptive capacity.

From this illustrative example and focusing on the farmer as the key farm decision-maker, we can deduce three determinants of farm resilience. First, farmers need to make deliberate investments in climate adaptation strategies such as the adoption of climate-smart agriculture (CSA) practices. However, the adoption of the CSA practices not only depend on the farmer and farm characteristics but also on underlying psychological factors (Hyland *et al.*, 2018; Okello, Zhou*, et al.*, 2018). Such psychological factors include farmer entrepreneurship (Ansah *et al.* (2019). Using our illustrative example, for inhabitants of urban areas to venture into potato farming in rural areas given their limited farming experience represent their entrepreneurship mindset, specifically the innovativeness, proactiveness and risk-taking behaviour. The same argument applies to the existing farmers who experiment with CSA practices such as intercropping, irrigation and changing potato planting times given that these are not common practices in their current context. Bernier *et al.* (2015) studying gender and institutional aspects of CSA Practices in Kenya identified farmer innovativeness, education level, access to credit, membership in community organization among others as significant determinants of the adoption of CSA in Kenya. The table below shows the differences between adopters and non-adopters of irrigation on the variables age, gender, years of education, farm size, membership in farmer organization and contract farming using empirical data from potato farmers in Kenya.

Table 1 Definition and descriptive statics for the variables.

Variable		**Irrigation adopters**	**Non-adopters**
Age (years)		50.4	49.2
Gender	Male	65.7%	47.2%
	Female	34.3%	52.8%
Education (years of schooling)		9	9
Farm size (Acres)		2.9	3.0
Membership in FO	Member	70.2%	60%
	Non-member	29.8%	40%
Contract farming	Contract	40.4%	15.2%
	Non-contract	59.6%	84.8%

Source: Authors based on a household survey among potato farmers in Kenya 2019.

The table shows that the adopters and non-adopters of irrigation differ in a) gender with male farmers adopting more than female farmers, b) membership in farmer organizations with members adopting more than non-members.

Second, farmers need support from various stakeholders to learn and invest in adaptation strategies. This calls for farmers to engage in collaboration both horizontal with other farmers and vertical with the buyers of farm produce. With respect to horizontal collaborations, we relate this with membership in FOs. Through membership, farmers benefit from access to services and resources necessary to adapt to the changing climate (Agrawal, 2008). For instance, farmers need credit to invest in drought-tolerant seed varieties, training on how to implement CSA practices and access stable and lucrative markets. Individually, smallholder farmers may not have the ability to access these resources, but collectively with other farmers, they benefit from pooling of resources, access to information and learning from the experiences of others. This is reflected in our potato farming illustration where farmers join FOs such as cooperatives that allow them to access resources and services.

Third, the relationships that farmers build with their buyers may lead to change in the farmer's production, investment, and marketing decisions (Canevari-Luzardo *et al.*, 2019). More precisely, a business relationship characterized by collaborative engagement between farmers and buyers may trigger farmers to engage in adaptation strategies like investing in new productive assets, adopting CSA practices, and switching crops. Strong farmer-buyer relationships create space for cooperation, information and risk sharing, and mutual learning providing a competitive advantage for both the farmers and the buyers involved. For instance, Bijman (2008) show that when farmers and buyers engage in contract farming arrangements, farmers benefit from certainty to sell their products, higher income, improved access to inputs, credit and technical assistance. These are necessary for improving farmer adaptive capacity (Vincent, 2007). In our illustration, farmers that have strong relationships with buyers benefit from assured markets, access to certified seeds in the varieties that are demanded in the market and technical assistance.

Hence, as our illustrative example shows, it is worth zooming into farmers' adaptive capacity as a plausible determinant of farm resilience. In turn, it is possible to hypothesize that farmer entrepreneurship, membership in FOs and farmer-buyer relationship may shape farmers' adaptive capacity. In the following four sections, we review each of these core concepts.

2.3 Farmers' adaptive capacity

Farmers' adaptive capacity to respond to climate change is critical for reducing farm vulnerability and building farm resilience (Freduah *et al.*, 2019). It represents the pre-conditions that reflects the learning, the flexibility to experiment and adopt innovations in response to a broad range of challenges (Gunderson, 2000). Vincent (2007) defines adaptive capacity as a vector of resources and assets that represent the resource base from which adaptation and investment decisions can be made. Accordingly, Cinner *et al.* (2018) identified five domains that are necessary for building adaptive capacity for resilience. These are the assets that people can draw upon in times of need, the flexibility to change strategies, the ability to organize and act collectively, learning to recognize and respond to change and the agency to determine when and how to change. Additionally, past research has shown that an actor's adaptive capacity is shaped by interacting processes that occur at multiple scales, including membership of FOs and farmer-buyer relationship (Frank and Penrose-Buckley, 2012).

To stimulate adaptive capacity, Armitage (2007) suggests that the following areas need to be understood, (a) the cross-scale relationships and networks among actors in a system; (b) the existing and evolving power relationships among actors; (c) the intangible resources such as trust that influence and shape collaboration and learning; and (d) the extent to which cultural norms and values are consistent with collective action and collaborative learning. This implies that improving adaptive capacity requires an understanding of the social, organizational and institutional context (Angeler *et al.*, 2019). Moreover, efforts to build adaptive capacity need to occur at multiple levels (Dentoni *et al.*, 2019) since the effectiveness of these efforts is affected by the interactions among various levels.

At the farm level, the farmer's ability to diversify the farm, adopt drought-tolerant crop varieties and implement irrigation has the potential to improve farm resilience. However, farmers' adaptive capacity is dependent on a conducive institutional environment, for instance, access to extension services and finance (Douglass-Gallagher and Stuart, 2019; Smit and Wandel, 2006). Faced with weak institutional support, farmers will largely depend on their ability to test and experiment, recognize and respond to opportunities, and manage risk (Burke and Emerick, 2016).

Also, the type of relationships that farmers have with their suppliers of inputs and buyers of outputs affects the farmer adaptive capacity. Darnhofer *et al.* (2010) in studying the influence of markets on farmers' adaptive capacity in Sweden, found that interaction between farmers and buyers create mutual understanding. They argue that with mutual understanding between farmers and buyers, farmers develop confidence and are more willing to invest in various adaptation strategies.

The potato farming example from Kenya illustrates how farmers' adaptive capacity may drive investment decisions for farm resilience. In Meru county of Kenya, we have observed farmers beginning to grow potato under irrigation given the prevalence of droughts in the recent past. Previously, irrigation was only applied to vegetables. However, not all farmers that have access to water irrigate their potato fields, others instead choose to reduce the area under potato. This observation suggests that not all farmers can adapt to climate change. The example also leads us to ask the question, what drives some farmers to adapt while others do not.

2.4 Farmer entrepreneurship

We put forward the argument that in turbulent environments such as farming in the context of climate change, farmer entrepreneurship partly explains why some farmers better adapt to climate change than others. In particular, it is entrepreneurship orientation (EO) that differentiates between farmers that adapt and those that do not (McInnis-Bowers *et al.*, 2017).

Taking the example of a potato farm, the farmer makes use of the human potential to decide on farm investment decisions to achieve desired goals. However, coupled with uncertainties, the farm investment decisions are constrained by the personality traits, preferences and competencies (Darnhofer, 2010). One of the often-cited personality traits that distinguish farmers in decision-making is risk perception (Below *et al.*, 2012; Tucker *et al.*, 2010). If we view a farmer as an entrepreneur, the logic also should follow that proactiveness and innovativeness additionally influence farmers' decisions (Vlasov *et al.*, 2018). Therefore, we argue that the higher the farmer EO, the higher the level of farmer adaptive capacity.

As part of the EO construct, innovativeness is the ability to deviate from established practices and technologies towards supporting new ideas through learning and experimentation (Lumpkin and Dess, 1996). For farmers, this entails the adoption of farm innovations such as the introduction of new management and cultivation practices (Groot *et al.*, 2016). Proactiveness is the ability to anticipate and act on future needs. It includes introducing product varieties in advance of others, thereby benefiting from a first-mover advantage (Lumpkin and Dess, 1996). This presupposes that farmers with forward-looking characteristics capitalize on emerging opportunities that result from the change. In addition to innovativeness and proactiveness, risk-taking behaviour, as a third dimension of EO, implies the ability to invest resources in risky activities and processes.

From the illustrative example, the farmers that invest in the purchase of certified potato seed (often constituting a large portion of potato production costs) can be said to be risk-takers, particularly those who invest in potato varieties without an assured market of the produce. In addition, farmers that apply irrigation on potato fields can be said to be engaging in process innovation and thus they can be viewed as innovative farmers relative to farmers that choose to keep the status quo of irrigating vegetables or those that reduce their potato area. Finally, farmers exhibit proactive characteristics when they are among the first to step into irrigating potato fields, especially where this is not common for this crop.

By incorporating farmer EO as a factor influencing farmer investment decisions on climate change adaptation strategies (see Figure 1), we extend the work of Grothmann and Patt (2005) who propose a socio-cognitive model of adaptation that compensates for the weaknesses of adaptation theories. While Grothmann and Patt (2005) only focused on risk perception, in this paper we add the two other EO dimensions, proactiveness and innovativeness. This leads us to the following proposition:

P_1. Farmer EO positively influences farmers' adaptive capacity and thus farm resilience.

The conceptual framework (Figure 1) proposes the pathways through which farmers' adaptive capacity enhances farm resilience. This framework provides the conceptual basis upon which future empirical studies may test the relationship among determinants of farm resilience.

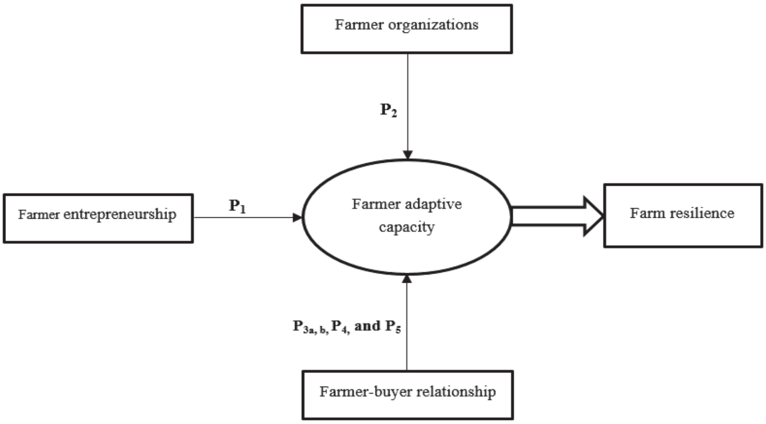

Figure 1. *Authors' conceptualization of the determinants of farm resilience*

2.5 Farmer organizations

A farmer organization (FO) refers to a voluntary collective action organization owned and controlled by farmers to pursue common interests (Meinzen-Dick *et al.*, 2004). A FO can take different forms including cooperative, association, self-help group and marketing group (Bijman *et al.*, 2016). These are forms of self-organization that may provide services that help farms to become resilient (Carpenter *et al.*, 2001). Currently, understanding of the nuanced role of FOs in supporting adaptation to climate change remains sketchy (Boyd *et al.*, 2008). Yet, FOs are critical in providing the farmer with learning, legitimacy, governance, diffusion of innovation and information necessary in adapting to changes.

FOs act as sources of information, learning platforms and social support that farmers can rely on when dealing with climate change (Tompkins, 2005). This implies that farmers' adaptive capacity emerges from organizational contexts where farmers meaningfully interact, learn and collaborate. FOs are flexible in responding to the complexity and dynamics of member needs, create linkages with other actors and provide space for knowledge generation and sharing (Kearney and Berkes, 2007).

A typical example of how the services provided by FOs may influence farmers' adaptive capacity is through extension services, which provide farmers with learning opportunities that enhance their adaptive capacity for farm resilience (Jacobi *et al.*, 2013). In this way, FOs provide farmers with a space to experiment and innovate as a group or individually (Borda-Rodriguez and Vicari, 2015). Particularly, experimentation enables farmers to adapt to the continuously changing environment (Bentley, 2006) as it produces innovations and generates local knowledge that improves farmers' adaptive capacity (Leitgeb *et al.*, 2011). Innovation relies on access to finance, information and other resources, which can be accessed through participation in supportive institutions such as FOs, especially for resource constraint smallholder farmers. In addition, FOs through their extension services facilitate exchange programs for learning between experienced and less experienced farmers.

At the farm level, the outcome of extension services is increased adoption of farm practices innovations, for instance, crop rotation and the introduction of new crop varieties. FOs facilitate farmers to adopt new farming practices by providing access to technologies, finance and technical backstopping during the adoption process (Kummer *et al.*, 2012; Pelletier *et al.*, 2016). Additionally, FOs facilitate the marketing of farm produce through their bargaining role, enabling farmers to access lucrative markets. This has a direct impact on farmers' revenues, which can be reinvested in adaptation measures (Borsky and Spata, 2018). Jung (2017) showed that local organizations enhance actors' capacity to recover from catastrophic events through providing access to critical resources, information and joint response planning.

The case of Kenyan potato farming highlights the importance of FOs for farm resilience. We observe that farmers are members of FOs mainly to access inputs and services which may help them adapt to climate change. In addition, FOs facilitate farmers to obtain access to resources and services from private businesses, NGOs and county governments. In Meru, for instance, we observed that small village level farmer groups merged to form a potato cooperative, which provides member farmers with access to credit and certified potato seed in varieties that is demanded by specific buyers. Farmers are also able to insure their crops, access extension and training through the cooperative field extension officers and enter into a contract farming arrangement. These resources and services have the potential to help farmers to invest in climate adaptation strategies thereby building farm resilience. Based on this literature and corroborated by the illustrative example, we develop the following proposition:

> **P$_2$.** Membership in and access to services provided by FOs improve farmers' adaptive capacity which, in turn, strengthens farm resilience.

2.6 The nature of farmer-buyer relationship

In a rapidly changing environment, creative and flexible means to counter the changes are being sought. Some response mechanisms have been leveraged on trading relations (Fischer and Hartmann, 2010), such as transaction relations between farmers and their buyers (Irwin and Campbell, 2015; Kuhl, 2018). These relationships between farmers and their buyers are by nature self-organizing and continuously evolve to adapt to opportunities and challenges (Campbell *et al.*, 2014). Emerging farmer-buyer relationship are determined by the nature of the product, the market requirements, the market channel characteristics and the external environment in which the farm operates (Dlamini-Mazibuko *et al.*, 2019).

In general, buyers and sellers have the opportunity and freedom to switch their trading partners. However, for some products and given the market conditions facing businesses a switch is not always an option. For instance, buyers whose business competitive edge depend on a specific crop (i.e., potatoes) have no choice but to nurture the relationship with the crop farmers by supporting them, including helping them in their adaptations strategies. Without good relationships with buyers, farmers may decide to switch to other crops. Strong farmer-buyer relationship help to overcome coordination dilemmas by enhancing the ability to align expectations for mutual benefits (Mesquita and Lazzarini, 2008). For instance, with a strong farmer-buyer relationship, buyers may provide farmers with inputs and credit in a check-off system allowing them to implement climate adaptation strategies that ultimately benefit both farmers and buyers.

In the past, farmer-buyer relationships have been studied in light of improving farm performance (Xhoxhi *et al.*, 2018) or adjusting farm production to changing market and policy environments (Wang *et al.*, 2011). These studies show that farmer-buyer relationships facilitate information exchange, joint decision-making, resource and risk sharing, and joint learning which improves actors' adaptive capacities (Scholten and Schilder, 2015). As such, attention to farmer-buyer relationship contributes to overcoming the one-sided focus on farm resilience (Darnhofer *et al.*, 2016). Farmer-buyer relationships are also taking place within the Kenya potato farming sub-sector. We have shown in our example that in cases where potato farmers enter into contracts with buyers, the contractor may provide farmers with advisory services on potato production and inputs such as certified potato seed. This reduces the burden on farmers and encourages further investment in climate adaptation strategies such as investment in irrigation. Contract farming arrangements underscore the role played by the farmer-buyer relationship in influencing farmers' adaptive capacity for strengthening farm resilience (Azumah *et al.*, 2017).

Taking this relational view implies that farm resilience will depend on coordinated responses between the farmers and buyers. These coordinated responses, in turn, depend on the strength of the relationship between farmers and buyers (Chen *et al.*, 2011; Dlamini-Mazibuko *et al.*, 2019). The nature of the trading relationship influences the willingness of farmers and buyers to invest in interdependent activities. For farmers, if the relationship with buyers is important for their investment decision, then the questions that arise are, a) what relational aspects are most important to enhance the farmer adaptive capacity? and b) what are the mechanisms through which farmer-buyer relationship influence farmer adaptive capacity? In an attempt to answer these questions, we propose an adaptation of the commitment-trust theory from relationship marketing (Morgan and Hunt, 1994).

Within the social exchange theory, farmer-buyer relationship may be described in terms of four relational constructs: trust, commitment, power dependency and satisfaction (Batt, 2003; Chen *et al.*, 2011). Previous studies have shown that trust positively influences commitment which drives actors to invest in the relationship (exhibited in their interdependent businesses), which in turn can positively influence business resilience (Mandal and Sarathy, 2018). Wu *et al.* (2012), in applying the commitment–trust framework, found that higher trust levels improve the quality of interaction between trading parties thereby reducing uncertainties and minimizing the likelihood of an actor exiting the trading relationship.

While it has been shown that the relational aspects in a farmer-buyer relationship influence business performance, we argue that the relational aspects are equally important in explaining farm resilience. In a farmer-buyer relationship, the relational aspects influence the investment decisions that farmers make and the practices that they perform on their farms in response to climate change. Srinivasan *et al.* (2011) argue that faced with uncertainties, robust supply chain relationships play a role in developing capabilities to deploy resources to achieve the desired outcome –adaptive capacity. Argued this way, a farmer-buyer relationship anchored on trust, relational commitment, power symmetry and relational satisfaction improve adaptive capacity and thus the farmers' willingness to make farm investments that improve adaptation to climate change.

In this paper, we present our conceptual thoughts on how the relational aspects in a farmer-buyer relationship influence farmers’ adaptive capacity and thus farm resilience. We note, however, that farmer-buyer relations do not exclusively enhance farmers’ adaptive capacity but are complementary to other factors such as the farmer EO and the membership in FO (see Figure 1).

In a farmer-buyer relationship, trust arises from constant and detailed information exchange and creates benefits for both the farmer and the buyer. It reflects the extent to which a trading partner has the confidence and belief that the counterpart is honest and benevolent (Anderson and Narus, 1990). Accordingly, trust has been shown to have positive effects on attitudes, perceptions, behaviours, and performance outcomes (Dirks and Ferrin, 2001). Trust between trading partners enable joint responsibility for each other's business success, shared planning and flexibility with respect to changes (Johnston *et al.*, 2004). In farmer-buyer relationship, the presence of relational trust facilitates commitment which influences farmers' investment decisions. In this way, trust can be said to safeguard against opportunistic behaviour and reduce transaction costs (Batt, 2003). Based on this we make the following proposition

P_{3a}. Trust in farmer-buyer relationship influence the relational commitment

Relational commitment is defined as the extent to which trading partners devote time and resources to the ongoing trade relationship since they consider the relationship to be important (Morgan and Hunt, 1994). It is a measure of the strength of the business relationship and explains the survival of the relationship in turbulent times (Masuku *et al.*, 2003). Where relationships are characterised by a high level of commitment, parties are willing to enter transaction-specific investments that support business resilience. In a farmer-buyer relationship, commitment influences whether farmers and buyers invest in their business for mutual benefits. Therefore, from a farmer's perspective, commitment plays a central role in shaping the farmer adaptive capacity. In Kenya, for instance, Macchiavello and Morjaria (2015) show that even with supply uncertainties, flower farmers were willing to continue investing in the flower production as long as they perceived that their buyers were committed to the trading relationship. While we argue that relational commitment in the farmer-buyer relationship is important for farmer adaptive capacity, we note that decisions to commit to the relationship are influenced by the opportunity cost of the next best alternative. In our case, we expect that relational commitment in farmer-buyer relationship influence farmer adaptive capacity.

P_{3b}. Relational commitment in farmer-buyer relationship influence the farmer adaptive capacity.

Relational satisfaction is defined as the extent to which trading partners view the trading relationship as fulfilling and gratifying (Geyskens and Steenkamp, 2000). Where farmers faced with climate change are satisfied with the trading relationship with their buyers, their commitment to the relationship increases and this allows for investment in adaptation strategies. We, make the following proposition.

P$_4$. Relational commitment in farmer-buyer relationship mediates the link between relational satisfaction and the farmer adaptive capacity.

Lastly, power dependency refers to the ability of a company to influence the intentions and actions of its trading partner (Benton and Maloni, 2005). The way the powerful partner in a trading relationship chooses to exercise its power will have an impact on the commitment of the other partner. If it is perceived that a partner is using power to achieve mutual benefits, trading partners develop trust which increases commitment in the trading relationship. This in turn triggers investment in the business. On the other hand, if a partner is perceived to be using power opportunistically for personal gain, conflicts may arise as mistrust develops. This impedes commitment and discourages investment thus inhibiting adaptation to changes facing the business. This dynamic suggests that

P$_5$. Relational commitment in farmer-buyer relationship mediates the link between power dependency and the farmers' adaptive capacity.

2.7 Discussion and suggestions for testing the proposed framework

In this paper, we present a novel conceptual framework for understanding farm resilience to climate change. We build upon the existing literature on entrepreneurship, farmer organizations and farmer-buyer relationship to explain the pathways through which farm resilience can be strengthened.

First, we reiterate what has been established in the literature, that is, climate change continues to pose a major impact on farm businesses. To counter adverse effects, there is an urgent need to build farm resilience. Building farm resilience to climate change requires that stakeholders come up with strategies that improve farmers' adaptive capacity (Mashizha, 2019). We present farmers' adaptive capacity as a key determinant for strengthening farm resilience. Specifically, we view farmers' adaptive capacity as a prerequisite for adaptation to take place and thus for resilience building (Fazey *et al.*, 2007). However, the question that remains unanswered is: How can the farmers' adaptive capacity be strengthened or weakened? To answer this question, we take a farmer perspective and ask what do farmers need to adapt to climate change? Generally, farmers need to make investment decisions to adapt to climate change such as the adoption of climate-smart agricultural practices.

These investment decisions depend on farmer socioeconomic and cognitive characteristics (Cohen *et al.*, 2016), and the collaboration both horizontally and vertically that farmers have with other farmers and the buyers of farm produce respectively. We identify entrepreneurial orientation (as a farmer cognitive traits), membership in farmer organizations and the nature of farmer-buyer relationship as pathways for improving the farmers' adaptive capacity and thereby farm resilience. We apply our conceptual framework to a specific example of potato farming in Kenya to explore how the framework may be used, how the determinants of farm resilience may be assessed and to open a debate for further discussion. This framework reveals important considerations that are often ignored in climate change adaptation studies. Notably, that achieving farm resilience is a long-term social process rather than a technical challenge.

The proposed conceptual framework can be operationalised and tested empirically in diverse farming contexts. First, the measures of each of the identified determinants of farm resilience need to be adapted to fit the context under study. For the farmer EO, we adapt the conceptualisation of EO as the farmers' decision-making proclivity favouring entrepreneurial activities (Covin and Lumpkin, 2011; Lumpkin and Dess, 1996). With regard to membership in farmer organizations, we propose measures that explore the internal governance structure of the FO and the services that the FOs provide to its members. Karadzic *et al.* (2014) show that adaptive responses are shaped by membership in producer organizations, the internal organizational structures and learning processes. Lastly, we propose an adaptation of the work of Batt (2003) on measures of the farmer-buyer relationship in an attempt to explain the investment decisions that farmers make in the face of climate change.

In sum, as studies on farm resilience grow, incorporating not only the role of the farmer but also, the complex interactions and relationships taking place at the farm level contribute to overcoming the narrow view on farm resilience.

2.8 Policy, managerial and theoretical implications

Our proposed framework contributes to the value chain, entrepreneurship and farmer organization literature by pointing out how they may support farmers' adaptive capacity to manage farm resilience. We provide insights into what constitutes farm resilience within a smallholder farming setup and how it can be strengthened in a developing country context. From the literature review, we first suggest that policy and managerial efforts need to be directed to the approaches that influence farmer entrepreneurship – enabling farmers to be innovative, trigger their risk-taking behaviour and enabling them to act proactively. Second, FOs need to be supported endogenously by member farmers or exogenously by outside parties such as governments agencies or NGOs. The support enables the FO to deliver the key services necessary to build farmers adaptive capacity. Third and lastly, there is a need to advocate for a strong farmer-buyer relationship characterized by trust, relational satisfaction, symmetric power dependency and relational commitment. Strong farmer-buyer relationships trigger investment decisions by both buyers and farmers for mutual benefit.

These conceptual findings lead to general implications for development practitioners, managers and policy makers. For development practitioners, this review points to the need to target their development interventions towards supporting farmer entrepreneurship, FOs and advocating for building strong farmer-buyers relations. For policy makers, this review provides an indication of the policies that can be formulated or reformulated to strengthen farm resilience. For managers, we point to the potential ways of coping with and adapting to climate change.

Chapter 3

Adoption of climate-smart agriculture among smallholder farmers: Does farmer entrepreneurship matter?

Abstract

Climate change poses significant challenges to agriculture, with serious impacts on smallholder farmers' food security and livelihoods. Climate-smart agriculture (CSA) is being promoted to facilitate climate change adaptation and mitigation. While there is evidence that CSA supports smallholders' adaption to climate change, the rate of CSA adoption remains low, particularly in sub-Saharan Africa. Previous studies have explained the low adoption based on generic factors such as farm, farmer, institutional and location characteristics, yet little is known about the role of farmers' cognitive traits. This study investigates the influence of farmer entrepreneurial orientation, a cognitive trait reflecting a farmer's innovativeness, proactiveness and propensity to take risks. We use data from smallholder potato farmers in Kenya and estimate a set of multivariate probit models to analyse the adoption decisions. Results show that risk-taking positively influences the adoption of irrigation, changing cultivation calendar, use of certified seed, crop rotation and soil testing. Proactiveness is positively related to the use of irrigation, changing the cultivation calendar and use of certified seed, while it is negatively related to intercropping. Contrary to our hypothesis that innovative farmers are more likely to adopt CSA practices, we find a negative relation between innovativeness and the use of certified seed. After categorizing CSA practices based on the main resources required, we find that risk-taking is positively associated with the adoption of practices that require a high intensity of skilled labour and financial resources. Innovativeness is negatively associated with practices that require a high intensity of financial resources. Lastly, we find proactiveness to be positively associated with the adoption of finance-intensive practices but negatively associated with unskilled-labour-intensive practices. These findings imply, first, that development practitioners should consider the interrelations among CSA practices and farmer entrepreneurial orientation in designing development interventions. Second, policy-makers need to create an environment conducive to farmer entrepreneurship as an indirect way to support the adoption of appropriate CSA practices.

Keywords: Climate-smart agriculture; Farmer entrepreneurship; Adoption; Multivariate probit; Kenya

This chapter is based on an article published as:

Kangogo, D., Dentoni, D., & Bijman, J. (2021). Adoption of climate-smart agriculture among smallholder farmers: Does farmer entrepreneurship matter? *Land Use Policy*, 109.

3.1 Introduction

Global food production is under serious threat from climate change. Particularly in sub-Saharan Africa (SSA) where agriculture is an important sector for economic development, climate change adds another layer of challenges to agricultural production and rural development (Maggio and Sitko, 2019). In Kenya, the main climatic challenges facing smallholder farmers include frequent droughts, periodic floods and unpredictable rainfall patterns, which continue to pose a threat to food and livelihood security (Ochieng *et al.*, 2016). In response to these challenges, various mitigation and adaptation strategies such as climate-smart agriculture (CSA) have been developed and promoted to improve farm productivity and enhance food security (FAO, 2013). However, smallholder farmers in SSA continue to suffer from the effects of climate change, because of their limited adaptive capacity (Asfaw *et al.*, 2016).

CSA encompasses practices and technologies that have the potential to achieve the “triple-win” of increasing food security and incomes, climate change adaptation and mitigation (Campbell *et al.*, 2014). While CSA has been presented as having the ability to deliver synergistic mitigation-adaptation-development outcomes and therefore appeals to policy and development practitioners, no single CSA practice has been shown to deliver the triple-win benefits. Instead, the potential to achieve triple-win is through careful combinations of different CSA practices (Ellis and Tschakert, 2019). Despite the potential benefits, CSA practices in developing countries are not achieving their full potential given the low levels of adoption (Westermann *et al.*, 2018). Factors that explain the low adoption of CSA practices include farm and farmer characteristics, and institutional constraints (Bernier *et al.*, 2015) as well as the characteristics of the practices themselves (Senyolo *et al.*, 2018).

While various farm and farmer characteristics have been studied relating to the adoption of CSA (Amadu *et al.*, 2020; Yegbemey *et al.*, 2013), the role of farmers’ cognitive traits in adoption decisions remains underexplored (Dessart *et al.*, 2019). Cognitive traits are behavioural or psychological in nature and relate to learning and reasoning: they include, for example, farmers’ perception of costs and risks preferences associated with a particular practice (Dessart *et al.*, 2019). Notably, cognitive traits can be shaped as people develop them over time, for instance, through targeted training programmes (Palich and Ray Bagby, 1995), or learning individually or collectively from past experiences. So far, and for decades since the work of Feder *et al.* (1985), studies on farmers’ cognitive traits have largely focused on how risk preferences (the tendency to choose an action or activity with high risks) influence technology adoption decisions (Huang *et al.*, 2014; Isik and Khanna, 2003; Jianjun *et al.*, 2015). Yet, in addition to this literature stream, we suggest that farmers’ risk preferences are not the only cognitive traits driving innovation adoption. Other cognitive traits include perceptions about the benefits of innovations, as well as aspirations, intentions and attitudes (Dessart *et al.*, 2019; Serebrennikov *et al.*, 2020). In terms of literature on farmers' cognitive traits, the theory of planned behaviour (TPB) and theory of reasoned action (TRA) (Arunrat *et al.*, 2017; Borges *et al.*, 2016; Martínez-García *et al.*, 2016) have been widely used to explain farmers' innovation adoptions. These theories pay more attention to understanding the process of innovation adoption with little emphasis on the link to the outcome of adoption, which is the ultimate purpose of the innovation.

To contribute to these literature strands in understanding how farmers' cognitive traits influence innovation adoption, in this paper, we hypothesise that farmer entrepreneurship plays a relevant role in decisions to adopt CSA practices. This happens when potential innovation adopters face uncertain environments such as climate change (York and Venkataraman, 2010). We specifically hypothesise that farmers' entrepreneurial orientation (EO), which reflects not only their risk preferences but also their innovativeness and proactiveness, might represent an important driver of their innovation adoption (Gellynck *et al.*, 2015). Specifically, risk-taking signifies the willingness to commit significant resources to activities for which the outcomes are uncertain. Innovativeness is the tendency to deviate from established practices and technologies and the willingness to follow new ideas and practices, through learning and experimenting. Lastly, proactiveness reflects the ability to anticipate and act on emerging opportunities and threats by developing and introducing new ideas and practices before others (Lumpkin and Dess, 1996). This hypothesis aligns with the recent land use policy literature which suggests that entrepreneurship supports farmers in adapting to environmental challenges (De Rosa *et al.*, 2019; Pindado *et al.*, 2018).

Therefore, our focus on farmers' EO adds a valuable explanation, relative to the extant literature, on explaining and predicting farmers' innovation adoption. Recent studies have shown that, when facing both economic and environmental challenges, some farmers are more capable to adapt than others. This heterogeneity in the ability to adapt has been attributed to farmer EO (Barzola Iza and Dentoni, 2020; York and Venkataraman, 2010). For example, the findings of Barzola Iza and Dentoni (2020) indicate that farmers' innovativeness supports the adoption of new farm practices by taking up new ways of farm organisation emerging from access to new information, they refer to this as process innovation. Furthermore, Etriya *et al.* (2019) showed that more entrepreneurial farmers have better farm performance both in terms of technology adoption and income.

Rooted in the strategic management literature, EO might be of specific importance for farmers facing climate-change challenges as they can no longer continue farming as usual: they have to adapt their farming practices to the unpredictably changing environment. One way of adapting is through investment in CSA practices. While this points to the importance of farmer risk-taking behaviour in decisions to invest in CSA practices, exclusive focus on risk-taking behaviour is not sufficient, farmers need to be innovative and proactive (entrepreneurial) in their production decisions when facing climate-change challenges (York and Venkataraman, 2010). For instance, farmer innovativeness has been shown to exert a positive influence on the adoption of water-saving technologies in Italy (Pino *et al.*, 2017). At the farm level, this reflects process innovation, the act of adopting new farm practices and executing new information (Barzola Iza and Dentoni, 2020).

With respect to climate change adaptation, Kangogo *et al.* (2020) proposed based on the theory that higher farmer EO increases farmers' adaptive capacity and, in turn, their propensity to adopt climate change adaptation strategies at the farm level. As defined by Adger *et al.* (2004), adaptive capacity is the ability of a system to modify its characteristics or behaviour in order to cope better with existing or anticipated shocks. Relating to adaptive capacity as a behavioural characteristic, Grothmann and Patt (2005) describe it as the capacity to learn and to respond flexibly to environmental and socioeconomic changes. EO is the manifestation of proactive and innovative behaviour coupled with a readiness to pursue opportunities under uncertainty (Wiklund and Shepherd, 2005). Following these definitions, Eshima and Anderson (2016) have shown that EO contributes to increased adaptive capacity through pursuing entrepreneurial activities. Accordingly, the joint exhibition of innovative, proactive and risk-taking behaviours creates opportunities to respond to needs and challenges (adaptive capacity). In this paper, we test the hypothesis that farmer EO increases farmers' capacity to adapt to climate challenges as manifested by the adoption of CSA practices.

Given this societal and scientific background, this paper addresses the questions of whether and how farmer EO influences the adoption of CSA practices. We use a novel dataset from smallholder potato farmers in Kenya, where we assess both farmer entrepreneurship and a set of control variables.

In testing the hypotheses about farmer EO as a driver of CSA adoption, we contextualise entrepreneurship using a case of smallholder potato farming in Kenya to understand when, why and how entrepreneurship is important (Welter, 2011). The potato-farming context is particularly relevant since potatoes represent a so-far understudied crop in relation to CSA practices. The current literature on the adoption of CSA practices has mainly addressed cereal crops such as maize (Amadu *et al.*, 2020; Kassie *et al.*, 2015) and rice (Ojo and Baiyegunhi, 2020; Trinh *et al.*, 2018). Evidence on the adoption of CSA practices in potato farming remains underdeveloped, yet potato is highly susceptible to climate change (Parker *et al.*, 2019). In Kenya, potato farming contributes significantly to household income and food security (Parker *et al.*, 2019). Hence, understanding potato farmers' decisions to adopt CSA practices is of key importance to policy-makers and development practitioners, as it lays a foundation for the design and implementation of impactful policies and interventions.

The benefits of CSA practices hinge on farmers adopting multiple practices simultaneously to maximise the synergies among CSA practices. Methodologically, some studies have analysed the adoption of farm practices as a combination of multiple practices, thus unravelling the salient relationships between different practices as either complements or substitutes (Gebremariam and Tesfaye, 2018; Teklewold *et al.*, 2019; Wainaina *et al.*, 2016). Other studies use a count of practices that farmers have adopted as a proxy of the intensity of adoption (Kpadonou *et al.*, 2017; Muriithi *et al.*, 2018). The weakness of the latter approach is the assumption that adopting more practices is better than adopting fewer practices. In an attempt to overcome this limitation, we adapted a typology proposed in Amadu *et al.* (2020) that focuses on the intensity of resources required to effectively adopt a CSA practice.

The contribution of this paper is threefold. First, the paper extends the literature on determinants of adoption beyond the generic characteristics such as farmer, farm and institutional to include cognitive traits which have received less attention to date. Second, the paper identifies farmer EO as a specific set of cognitive traits that encompass farmer innovativeness, proactiveness and risk-taking behaviour and explores how these traits influence CSA adoption. Third, building upon the typology developed in Amadu *et al.* (2020), the analysis relates the three dimensions of farmer EO to the CSA categories based on the main resources necessary for adoption.

The remainder of the paper is structured as follows. Section two presents the theoretical framework underlying this study. Section three presents the data and the empirical model. Section four provides the results and discussion of the main findings, and in the final section, we present the conclusion and implications of this study.

3.2 Theoretical Framework

3.2.1 CSA practices

Climate-smart agriculture refers to practices that increase productivity and income, build farm resilience and mitigate climate change by reducing greenhouse gas emissions (FAO, 2013). At the farm level, the adoption of CSA practices is context-specific influenced by institutional factors, resource availability and prevailing climate conditions (Lipper *et al.*, 2014). Regardless of the context under consideration, the level of farmer adoption of CSA practices signifies the farmer’s adaptive capacity (Asfaw *et al.*, 2016), which in turn depends on the resources that a farmer can access and his/her ability to combine resources (Cinner *et al.*, 2018). Following this, the adoption of CSA practices may be explained by the level of farmer entrepreneurship defined as the process of recombining agricultural resources innovatively to create opportunities for value creation and to respond to emerging needs (Shane and Venkataraman, 2000).

Faced with climate change challenges, farmers are increasingly adopting multiple adaptation practices with complementary effects (Amadu *et al.*, 2020; Teklewold *et al.*, 2019). Adopting a combination of practices enables farmers to maximise synergies among CSA practices. This also enables farmers to diversify and improve production in the face of overlapping challenges such as low soil fertility and climate change (Khanna, 2001). Within the farm technology adoption literature, it has been shown that different socioeconomic, institutional and environmental factors influence the adoption of CSA practices (Teklewold *et al.*, 2019). Yet, the effect of farmer cognitive traits such as farmer entrepreneurship remains understudied resulting in an incomplete overview and limited theoretical understanding of how and why these factors affect adoption decisions (Dessart *et al.*, 2019).

3.2.2 Adoption of agricultural innovations and farmer entrepreneurship

Theories on the adoption and diffusion of agricultural innovations have generally centred around three perspectives. First, theories that focus on the characteristics of the innovation explaining when and how diffusion and adoption occur (Rogers, 2003). Relevant determinants are the level of learning investment, initial investment cost and additional labour required when adopting a farm innovation (Senyolo *et al.*, 2018). Second, theories that relate to the farmer's adoption intention and behaviour, such as the TPB (Ajzen, 1991). As to the farmer's adoption intention, Barnes *et al.* (2019) studied the adoption of precision agricultural technologies and found that attitudinal difference, such as optimism towards the economic benefits of technology leads to an increase in the probability of adoption. Third, theories that focus on the expected utility, using a random utility framework (Dorfman, 1996). While the premise of expected utility theory is to maximize utility taking into account the various adoption constraints including labour and capital among other production constraints, such theories do not explicitly take into account the cognitive and behavioural characteristics that may hinder adoption (Hess *et al.*, 2018).

Relative to the foregoing theories, in this paper we challenge the notion that smallholder farmers are typical price takers and passive decision-makers. On the contrary, we argue that smallholder farmers continuously adapt to changing circumstances that affect their farming businesses (Morris *et al.*, 2017). These changing circumstances may be social, economic or environmental including climate change. The process of adapting to these changes require that farmers act entrepreneurially (McElwee and Smith,

2012) and thus the cognitive traits of risk-taking, innovativeness and proactiveness play important roles (Etriya *et al.*, 2019). The combination of these traits has been referred to as EO (Lumpkin and Dess, 1996).

Broadly speaking, farmer entrepreneurship refers to the process of recombining resources innovatively to pursue opportunities towards the achievement of economic and social goals (Fitz-Koch *et al.*, 2017; Shane and Venkataraman, 2000). Viewed this way, entrepreneurship is a cognitive trait related to the farmers' decision-making styles (Dessart *et al.*, 2019). In Finland for instance, Mikko Vesala *et al.* (2007) show that when faced with pressure to restructure farming, entrepreneurial identity is part of the solution. Based on farmer self-categorisation as an entrepreneur or not and how this affects farm diversification, Mikko Vesala *et al.* (2007) focus on eight dimensions of entrepreneurial identity, namely economic values, innovativeness, growth-orientation, risk-taking, self-efficacy, optimism and personal control. They find that compared to traditional farmers, the entrepreneurial farmers perceive themselves as growth-oriented, risk-takers, innovative, optimistic and having more personal control over their farms. These cognitive traits shape how farmers combine resources such as labour, knowledge, skills, finances and physical capital. Hence, entrepreneurial farmers are usually among the first to engage in novel farming and business practices by taking calculated risks and acting innovatively (Barzola Iza *et al.*, 2019).

As the first dimension of EO, innovativeness is the ability to deviate from established practices and technologies towards supporting new ideas, often through learning and experimentation (Lumpkin and Dess, 1996). For farmers facing climate change challenges, innovativeness may induce them to try out CSA practices. As a second EO dimension, proactiveness implicates the ability to anticipate and act on future threats and opportunities. Different from reactive traits (Brzozowski and Cucculelli, 2016), proactive traits are associated with an orientation towards searching or creating new opportunities. Hence, proactive farmers usually are those that first engage in new processes and practices or developing new products. When facing climate change, proactive farmers might foresee and act upon opportunities and threats.

The third EO dimension is the propensity of taking calculated risks (or risk-taking). Taking calculated risks involves committing resources to ventures or activities for which returns are not assured (Rauch *et al.*, 2009). Risk-taking farmers might invest more resources in the adoption of CSA practices, while risk aversion results in under-investment and thus low adoption (Hansen *et al.*, 2019).

This operationalisation of farmer entrepreneurship allows for exploration of the role of the specific dimensions of farmer EO in the adoption of a set of specific CSA practices. The following hypotheses are tested:

H1. More risk-taking farmers are more likely to adopt CSA practices.

H2. More innovative farmers are more likely to adopt CSA practices.

H3. More proactive farmers are more likely to adopt CSA practices.

In addition to the role of farmer EO in farm technology adoption decisions, context-related issues are also important for farmer adoption decisions (Welter and Gartner, 2016). In the adoption of precision farming tools in Italy, Vecchio *et al.* (2020) define three categories of context-related issues. The first issue (the *who*) relates to the social and demographic characteristics of the farmer, including age, gender, education level, years of farming, involvement in off-farm activities. Considering age, gender and the level of education, evidence shows that relatively younger farmers, men and those with higher levels of education have a higher probability of adopting new farming practices (Kassie *et al.*, 2015; Wainaina *et al.*, 2016). The second issue (the *where*) relates to the structural characteristics of the farm such as farm size. Previous studies show mixed findings on farm size and technology adoption. While some have found that larger farms are more likely to adopt (Teklewold *et al.*, 2013; Trinh *et al.*, 2018), others have found no such effect (Zeweld *et al.*, 2020) or found positive effects for some technologies and negative for others (Kassie *et al.*, 2015). These findings indicate that farm size has a differential effect on the adoption of farm technologies. The last issue (the *why*) relates to the farmer's intrinsic motivation to adopt new farming technologies (Greiner and Gregg, 2011). In this paper, we focus on the *who* question, and instead of focusing only on the social and demographic characteristics of the farmer, we include cognitive traits. We also explore the role of the *where* issue by including variables relating to the farm itself and the institutional environment in which the farm operates.

3.3 Methodology

3.3.1 Data and sampling procedure

The data used in this study come from a farm household survey that was conducted from June to August 2019 among smallholder potato farmers in Kenya. While potatoes are grown in almost all arable parts of Kenya, the main potato-producing counties are Meru, Elgeiyo Marakwet, Bungoma, Nakuru, Narok, Bomet, Nyandarua, Nyeri, Taita Taveta and Kiambu. The top five counties in terms of the land under potato cultivation are Meru, Nyandarua, Nakuru, Elgeiyo Marakwet and Kiambu, with Meru and Nakuru accounting for over 30% of the land used for potato (Kaguongo *et al.*, 2014).

A multistage sampling procedure was used to select farmers. In the first stage, Meru and Nakuru counties were purposively selected being two of the leading potato-producing counties in Kenya. Within these two counties, locations (*since 2010 referred to as wards*) with high potato production were selected in consultation with the county extension officers. In particular, Kisima, Timau and Kibirichia locations were selected in Meru county, while Keringet and Molo locations were selected in Nakuru county. Second, we asked the ward extension officers to provide us with the list of potato farmer groups in their locations. From the lists we randomly selected target farmer groups; 39 groups were randomly selected from the locations in Meru county and 18 groups were randomly selected from the locations in Nakuru county. Therefore, a total of 57 potato farmer groups were selected. Third, we acquired the lists of the farmers in all the selected groups and applied a proportional random sampling procedure to select individual farmers to be interviewed.

Given that we did not have the lists of non-group member farmers, we randomly interviewed non-group member farmers in the villages of group member farmers. To do this systematically, enumerators were asked that, after interviewing every second selected group member, to skip two households and interview the third household, only if the farmer was a non-group member. Although this may not yield a perfect random sample, this approach has previously been applied in an attempt to attain a more representative sample in the absence of a population list and with resource constraints (McCord *et al.*, 2015). In total, 792 potato farmers were interviewed comprising 500 group members and 292 non-members. A structured questionnaire was used to collect data on a range of topics including farmer and farm characteristics, farmer EO, potato production and marketing activities.

3.3.2 Empirical estimation strategy

Based on the collected, data potato farmers are faced with a range of CSA practices to choose from in their attempts to adapt to climate change. Farmers may adopt a single practice or a combination of practices depending on the climate change effects on their farms and the available resources. The adoption decision can thus be modelled using either univariate or multivariate models. However, where adoption of more than one practice is possible, it is necessary to model the decisions using a multivariate technique to account for the interdependence among practices. We, therefore, use a multivariate probit (MVP) econometric technique which models the influence of a set of explanatory variables on the adoption of different CSA practices while allowing the error terms to freely correlate. Part of the correlation in the error terms accounts for the relation among CSA practices as being either complementary or substitutive (Belderbos *et al.*, 2004). Failure to account for the interdependence among the practices may lead to inefficient and biased estimates (Green, 2008).

The MVP model was formulated using six dummy variables representing the CSA practices applied by farmers (see below for more information on these practices). The MVP model is characterised by a set of binary dependent variables *k* that is equal to 1 if the i^{th} farmer adopts the CSA practice K[1] and 0 otherwise, such that:

$$Y_{ik}^{*} = X_i\beta_k + \varepsilon_i, \qquad k = 1, ..., 6. \tag{1}$$

and

$$Y_k = \begin{cases} 1 \; if \; Y_{ik}^{*} > 0 \\ 0 \; otherwise \end{cases} \qquad k = 1, ..., 6. \tag{2}$$

where *k* denotes the available CSA practices.

In equation (1), the assumption is that the i^{th} farmer has a latent variable Y_{ik}^{*} which captures the unobserved preference associated with the k^{th} choice of CSA practice. The latent variable Y_{ik}^{*} is assumed to be a linear combination of observed characteristics (X_i) – the farmer and farm characteristics, farmer EO, and institutional characteristics that affect the adoption of k^{th} CSA practice as well as the unobserved characteristics ε_i. The vector of parameters to be estimated is denoted by β_k.

If the adoption of a specific CSA practice is independent of a farmer adopting another CSA practice, then equations (1) and (2) specify a univariate probit model. However, if adopting multiple CSA practices is possible, then it is realistic to assume that the error terms in equation (1) jointly follow a multivariate normal distribution with zero conditional mean, a unit variance and symmetric covariance matrix Ω given by:

$$\Omega = \begin{bmatrix} 1 & \rho_{12} & \rho_{13} & \rho_{14} & \rho_{15} & \rho_{16} \\ \rho_{21} & 1 & \rho_{23} & \rho_{24} & \rho_{25} & \rho_{26} \\ \rho_{31} & \rho_{32} & 1 & \rho_{34} & \rho_{35} & \rho_{36} \\ \rho_{41} & \rho_{42} & \rho_{43} & 1 & \rho_{45} & \rho_{46} \\ \rho_{51} & \rho_{52} & \rho_{53} & \rho_{54} & 1 & \rho_{56} \\ \rho_{61} & \rho_{62} & \rho_{63} & \rho_{64} & \rho_{65} & 1 \end{bmatrix} \tag{3}$$

ρ is the pairwise correlation coefficient between the error terms of any two adoption equations in the model. The sign and significance of ρ provide evidence of the nature of the relationship between adoption equations. A positive sign denotes a complementary relationship while a negative sign indicates that the practices are substitutes. This model specification with non-zero off-diagonal elements

[1]Irrigation; Change in Cultivation Calendar; Certified Seed; Crop Rotation; Soil Testing; Intercropping.

allows for correlation across the error terms in the latent equations and represents the unobserved characteristics that influence the choice of CSA practices.

The MVP technique models the probability of adopting individual CSA practices with no distinction being made about the nature of practice combinations where it is possible. There is evidence that farmers adopt a combination of CSA practices depending on the intensity of resources required for adoption (Amadu *et al.*, 2020). It is, therefore, necessary to understand the factors that lead to the adoption of a combination of CSA practices.

Consequently, the second part of our econometrics approach involves the application of an additional MVP technique to model the effect of farmer EO on farmers' adoption of different combinations of CSA practices. First, building on the typology of Amadu *et al.* (2020) we develop a categorisation of CSA practices based on the intensity of resources required for adoption. Following this, if the adoption of a specific CSA category is independent of a farmer adopting another CSA category, then this can be estimated through a univariate probit model. However, if adopting multiple CSA categories is possible, then it can be estimated through a multivariate probit approach. We estimate a MVP model given the possibility of farmers adopting different categories of CSA practices. The estimation follows the procedure described in equations 1 and 2 above. Finally, the unit variance and symmetric covariance matrix Ω for this estimation is given by:

$$\Omega = \begin{bmatrix} 1 & \rho_{12} & \rho_{13} \\ \rho_{21} & 1 & \rho_{23} \\ \rho_{31} & \rho_{32} & 1 \end{bmatrix} \qquad (4)$$

3.3.3 Descriptive statistics: Dependent and independent variables

The descriptive statistics for the CSA practices as dependent variables and all the explanatory variables including the farmer EO are presented in Table 1.

Dependent variables

For the analysis, we consider six CSA practices that relate to potato production and are increasingly practised in the study areas in response to climate change. The CSA practices were identified from existing CSA literature and validated by the agriculture extension officers in the selected counties to ensure that practices apply to potato farming. The first practice is irrigation, which is increasingly being used by farmers in Kenya to curb the effects of drought and heat. In our study sites, traditional labour-intensive furrow irrigation is commonly applied. While irrigated crops in Kenya are mostly high-value vegetables, the irrigation of potato fields is an emerging practice. Irrigation presents a risk to farmers because there is no guaranteed market for potatoes. The second practice is changing the cultivation calendar. This implies altering cultivation activities such as planting time in an attempt to respond to climate variability (Gebrehiwot and van der Veen, 2013). Farmers were asked whether they had significantly changed their potato cultivation calendar in the last cropping year because of uncertain rainfall patterns; this measure was adapted from Gebrehiwot and van der Veen (2013) and Yegbemey *et al.* (2014). Changing the cultivation calendar is risky because decisions such as when to plant and what crop variety to grow depend on the knowledge of the farmer and his/her access to information. For potato farming, the cultivation calendar is important given the sensitivity to moisture stress (Lynch *et al.*, 1995).

The third practice is the use of certified potato seed. Certified seeds are high-quality seeds with the potential for high yields, tolerant to heat stress and tolerant to pests and diseases (Parker *et al.*, 2019). In Kenya, the use of certified potato seed is low due to high seed and transport costs and limited supply (Okello *et al.*, 2016). In this study, we only considered the use of certified seed since it is not easy for farmers to tell whether the seed they buy from other farmers or local markets meets the standard requirements to be termed as “clean seed”. The certification process of clean seed in Kenya remains weak. The fourth practice is crop rotation, thus alternating between crops in successive seasons. Crop rotation helps minimise the build-up of crop-specific pests and pathogens such as potato cyst nematode (Barzman *et al.*, 2015). Crop rotation for potato is a knowledge-intensive practice requiring access to agronomic information. In Kenya, a typical cropping year has two potato growing seasons (Gildemacher *et al.*, 2009b). For crop rotation, it is a requirement that farmers should not plant potatoes in the same field in consecutive seasons. We asked farmers whether they planted potatoes in the same field in the last two seasons. The main crops grown in the study areas which farmers may use as rotation crops include maize, wheat, beans and cabbages. This measure was adapted from (Yaro *et al.*, 2014). The fifth practice is soil testing for fertilizer recommendation. This practice is necessary to enable farmers to apply the right fertilizer type in their fields. It aims to reduce the carbon emissions caused by excess fertilizer application (Chen *et al.*, 2013). Additionally, soil testing has been described as a gateway technology to the adoption of other agricultural technologies (Schimmelpfennig and Ebel, 2011). Soil testing is a finance-intensive practice as smallholder farmers do not have the necessary equipment to perform soil testing, hence they have to engage soil-testing companies. We asked farmers whether they had their soil tested in the last cropping year. This measure has been used previously (Liu *et al.*, 2019).

Intercropping is the last CSA practice considered in our analysis. It refers to the cultivation of one or more crops together with potato on the same plot. A typical example of intercropping is maize-legume intercrop for the benefit of nitrogen-fixing (Kassie *et al.*, 2013). Faced with climate change and limited land availability, smallholder potato farmers combine potato with other crops as a diversification strategy to meet their food and nutrition security and increase their income (Kidane *et al.*, 2017). Intercropping is a labour-intensive practice.

Independent variables

We explored literature on technology adoption to select a set of variables that affect farmers' technology adoption decisions. These include the generic variables such as farmer, farm and institutional characteristics as they have been used in previous adoption studies (Amadu *et al.*, 2020; Kpadonou *et al.*, 2017; Trinh *et al.*, 2018; Yegbemey *et al.*, 2013). Besides, we included data on farmer entrepreneurship to elicit the farmer's risk preferences, innovativeness and proactiveness (Etriya *et al.*, 2019; Verhees *et al.*, 2012).

To test the effect of the farmer EO dimensions (risk-taking, innovativeness and proactiveness) on CSA adoption, we adapted the EO measures that have been used previously in (Buli, 2017; Lumpkin and Dess, 2001) to our context. For each dimension, three questions were posed (See Table 1). The responses were recorded on a seven-point rating scale: 1 = completely disagree to 7 = completely agree. Detailed descriptions of the variables are shown in Table 1.

Table 1. Description of the variables

Variable	Description	Mean	Std. dev
Dependent variables			
Irrigation	Applied the practice: *1= Yes; 0= No*	0.31	0.46
Change in cultivation calendar	Applied the practice: *1= Yes; 0= No*	0.42	0.49
Certified seed	Applied the practice: *1= Yes; 0= No*	0.30	0.46
Crop rotation	Applied the practice: *1= Yes; 0= No*	0.44	0.50
Soil testing	Applied the practice: *1= Yes; 0= No*	0.22	0.41
Intercropping	Applied the practice: *1= Yes; 0= No*	0.36	0.48
Independent variables			
Farmer characteristics			
Sex	Sex of the farmer: *1= Male; 0= Female*	0.53	0.50
Age	Age of the farmer in years *(Years)*	49.55	12.67
Household size	Number of household members *(Number)*	4.63	1.93
Education	Years of formal education of the farmer *(Years)*	9.14	3.36
Years growing potato	Number of years growing potato *(Years)*	17.91	12.23
Farmer entrepreneurial orientation statements (on a scale of 1= Completely disagree to 7=Completely agree)			
Risk-taking			
I prefer to stick to my current farming practices rather than trying new ones [R]		3.76	1.77
With the current challenging farming environment, I prefer to avoid further investment in my farm [R]		3.86	2.50
I am always ready to try new farming practices		4.83	1.64
Innovativeness			
I like to use new farming practices		5.70	1.12
I often improve my farming practices		5.33	1.07
I like to have the latest information on farming practices		5.79	1.22
Proactiveness			
I respond more quickly to changes in the environment of my farm compared to other farmers		4.00	1.47
I am among the first farmers to adopt new farming practices in my village		4.18	1.47
I am constantly looking out for new ways to improve my farm.		5.19	1.37
Farm characteristics			
Land ownership	Land ownership status: *1= Owned: 0= Otherwise*	0.78	0.41
Land size owned	Total land owned by the farmer *(Ha)*	1.21	1.61
Information and knowledge			
Access climate info.	Farmer accessed climate information: *1= Yes; 0= No*	0.31	0.46
Credit	Received credit for farm operations: *1= Yes; 0= No*	0.22	0.42
Group membership	Is the farmer a member of potato farmer org: *1= Yes; 0= No*	0.63	0.48
Location			
County	County of the farmer: *1=Meru; 0= Nakuru*	0.59	0.49

Note: Std. dev refers to standard deviation.

3.3.4 Categorisation of CSA practices

Adapting the CSA typology of Amadu *et al.* (2020), we develop a categorisation of CSA practices that conceptually links CSA practices with the main resource required (Table 2). The first category comprises practices that require additional unskilled labour. This category generally requires farmers to perform basic tasks, such as opening and closing furrows during irrigation. The second category contains practices that require the knowledge and skills of the farmer. Knowledge-smart practices (Aryal, Jat*, et al.*, 2018) require knowledge on what crops to rotate with potato and how to change the cultivation calendar. The last category includes practices that mainly require financial capital. These are practices that farmers must pay for, such as certified seed and soil-testing services.

While developing a typology is a step towards understanding the drivers and barriers of CSA adoption, we acknowledge its limitations, such as the difficulty to assign items to distinct categories (Collier *et al.*, 2012). We solve this by highlighting the most essential resource, that is, the resource that is required in high intensity and without which the practice cannot be adopted. This way of categorisation has recently been used to categorise CSA practices in Malawi (Amadu *et al.*, 2020). This has led to a categorisation based on three types of indispensable resources: 1) unskilled labour, 2) skilled labour, and 3) finance

Table 2. Typology of CSA practices based on the main resource requirement

CSA practice		CSA category		
		Unskilled labour	**Skilled labour**	**Finance**
1	Irrigation	√		
2	Change cultivation calendar		√	
3	Certified seed			√
4	Crop rotation		√	
5	Soil testing			√
6	Intercropping	√		

3.3.5 Principal component analysis

To reduce the farmer EO statements to a small number of variables, principal component analysis (PCA) was conducted. PCA is a linear transformation that reduces a set of variables into a smaller number of variables referred to as principal components. In PCA each successive principal component accounts as much as possible to the remaining variability in the data (Linnenluecke *et al.*, 2013). Dimension reduction using PCA has been used in previous studies on understanding farmer entrepreneurial orientation (Etriya *et al.*, 2019), farmer social capital (Zhou *et al.*, 2018), consumer food attitudes (Bechtold and Abdulai, 2014) and level of household capabilities (Kihiu, 2016).

In this study, PCA was used to extract the underlying factors of farmer EO which consist of nine items. The identified factors were then used as explanatory variables in the empirical models. The PCA results of the nine farmer EO statements indicated that three components should be retained. We retained components with eigenvalues greater than 1 and applied varimax rotation to determine the category of items (Kaiser, 1958). Component 1 accounts for statements that relate to farmer innovativeness, component 2 includes statements that relate to farmer proactiveness, and component 3 are statements that relate to farmer risk-taking behaviour.

To assess the adequacy of the components extracted, we rely on statistical tests summarised in Table 3. The Cronbach alphas are 0.865, 0.819 and 0.719 for innovativeness, proactiveness and risk-taking components, respectively. All the values of Cronbach alphas are greater than 0.6, indicating a high degree of internal consistency. The Kaiser-Meyer-Olkin (KMO) shows the extent of correlation between the statements measuring each component. The KMO of 0.706 is considered satisfactory. The Bartlett test for Sphericity assesses whether the correlation matrix of the statements differs significantly from the identity matrix. For the PCA to be appropriate the aim is to reject the null hypothesis that the correlation matrix is the identity matrix. As shown in Table 3, the Bartlett Test is significant ($p < 0.000$) indicating a correlation between statements measuring farmer EO.

Using the extracted components, three dependent variables (innovativeness, proactiveness and risk-taking) were constructed for each household (the procedure is detailed in (Córdova, 2009).

Table 3. Principal component analysis for the farmer EO

Principal component	**% of variance explained**	**Cronbach alpha**	**Principal component statistics**
Component 1: Innovativeness	34.93	0.865	KMO = 0.703 Bartlett Test for Sphericity: p < 0.000
Component 2: Proactiveness	23.93	0.819	
Component 3: Risk-taking	17.67	0.833	

See the appendix Table A1 for the PCA component loadings for each item

3.4 Results and discussion

Table 1 shows the descriptive statistics of both the dependent and independent variables. The CSA adoption levels fall below 45% for all the practices (Table 1). This is consistent with previous studies, which have found that CSA adoption remains low in developing countries (Lipper *et al.*, 2014).

3.4.1. Adoption of multiple CSA practices: MVP model results

The MVP model estimates for the adoption of CSA practices are reported in Table 4. The Wald test statistic tests the null hypothesis that the regression coefficients in each equation are jointly equal to zero. The results, $\chi^2(90) = 735.33$; $p > \chi^2$ 0.000 indicate that the error terms across the adoption equations are correlated, and thus the null hypothesis is rejected. This is further supported by the significant likelihood ratio test which reports the significant pairwise correlation coefficient between error terms (Appendix Table A2). The consistency between the Wald test and the likelihood ratio test signifies the robustness of the results. The MVP model is therefore an appropriate estimator to predict adoption decisions. Further results unravel the interdependence between CSA practices. The results (see Appendix Table A2) show that on the one hand, certified seed and irrigation, soil testing and irrigation, changing cultivation calendar and crop rotation, changing cultivation calendar and soil testing, and soil testing and certified seed are used as complementary practices. On the other hand, intercropping and irrigation, and intercropping and certified seed are substitutes.

Table 4 shows the distinct effects of farmer EO dimensions on the adoption of CSA practices. Consistent with previous studies (Huang *et al.*, 2014; Isik and Khanna, 2003; Zeweld *et al.*, 2020), our results demonstrate that risk-taking positively drives the decision to adopt all practices except intercropping.

In our study areas, irrigation is largely applied to grow high-value vegetables such as cabbage, French beans, kale, carrot and garden peas. Irrigating field crops like potato is a new practice, involving two types of risks. First, potato requires more labour as it is often grown in large plots of land compared to high-value vegetables. Second, higher production due to irrigation brings forth a high market risk because the market is not guaranteed. This implies that risk-taking farmers are more likely to take the risk of applying irrigation in potato fields.

Like any other practice, changing the cultivation calendar is a risky strategy particularly when weather information is unavailable or unreliable. For instance, if a potato farmer changes the cultivation calendar and the onset of rains does not match with the planting dates, that farmer is likely to incur both yield and tuber quality loss. On the other hand, where a farmer can plant just before the rains start, holding other factors constant, the benefits of yield and tuber quality are assured. This may explain the positive relation between risk-taking and the changing cultivation calendar. Farmers that are willing to take risks are more likely to change the cultivation calendar. This is consistent with the findings of Yegbemey *et al.* (2014) who found that farmers in Benin adjusted their cultivation calendars even with limited access to advisory services and with no insurance.

Table 4. Coefficient estimates of the multivariate probit model for the adoption of individual CSA practices

Variable	(1) Irrigation		(2) Change in cultivation calendar		(3) Certified seed		(4) Crop rotation		(5) Soil testing		(6) Intercropping	
	Coef	Robust Std. Err	Coef	Robust Std. Err	Coef	Robust Std. Err	Coef	Robust Std. Err	Coef	Robust Std. Err	Coef	Robust Std. Err
Sex	0.468***	0.104	0.141	0.098	0.371***	0.104	0.198**	0.096	0.237**	0.112	-0.421***	0.105
Age	0.027	0.028	0.010	0.026	0.003	0.028	0.038	0.026	-0.021	0.028	-0.008	0.029
Age squared	-0.000	0.000	-0.000	0.000	-0.000	0.000	-0.000*	0.000	0.000	0.000	0.000	0.000
Household size	-0.043	0.030	-0.024	0.026	-0.002	0.027	0.005	0.025	-0.009	0.032	0.014	0.028
Education	0.014	0.017	0.026*	0.015	0.036**	0.017	0.008	0.015	0.041**	0.018	-0.015	0.016
Years growing potato	0.009	0.006	0.006	0.006	0.008	0.006	0.004	0.005	0.012**	0.006	-0.016***	0.006
Risk-taking	0.092**	0.039	0.215***	0.042	0.103***	0.039	0.111***	0.035	0.112**	0.047	0.007	0.035
Innovativeness	-0.055	0.039	0.025	0.036	-0.070**	0.039	0.029	0.035	-0.066	0.042	-0.018	0.038
Proactiveness	0.086**	0.039	0.068*	0.036	0.083**	0.039	0.014	0.035	-0.059	0.040	-0.366***	0.040
Land ownership	0.454***	0.130	0.051	0.117	0.229*	0.129	0.230**	0.116	0.241*	0.138	0.263**	0.130
Total land size	-0.016	0.033	0.007	0.030	0.055	0.038	0.075	0.048	0.116**	0.054	-0.174***	0.059
Access climate info	-0.038	0.110	0.487***	0.105	0.373***	0.109	0.194*	0.102	0.435***	0.112	-0.053	0.117
Credit	0.117	0.121	0.195*	0.116	0.303**	0.120	-0.008	0.116	0.357***	0.122	-0.099	0.132
Group membership	0.110	0.121	0.235**	0.115	0.353***	0.125	0.331***	0.112	0.337**	0.138	-0.545***	0.117
County	0.944***	0.120	-0.057	0.104	0.460***	0.114	0.068	0.103	0.104	0.125	0.223*	0.118
Wald chi^2 (90)	735.33***											
Observations	792											

*** p<0.01, ** p<0.05, * p<0.1

The use of certified seed and testing the soil represent two practices that require additional finance. Specifically, certified seed forms the largest proportion of potato production costs (Okello *et al.*, 2016). The risk associated with the investment in certified potato seed and testing the soil is higher in the face of adverse climatic change. The farmer may not be able to recover the investment costs, and the risk is even higher when seeds are purchased on credit. This explains our results that risk-taking farmers are more likely to adopt certified seed and soil testing practices. This is consistent with the findings of Kassie *et al.* (2013), who reported that risk-taking farmers are more likely to invest in improved seed varieties in Tanzania.

Crop rotation requires knowledge about which crop to rotate with potato, and in which rotation cycles. Crop rotation is associated with higher yields, improved soil fertility and reduced pest and disease incidence. Apart from the knowledge requirements, crop rotation is constrained by small land sizes, a characteristic of the majority of smallholder farmers. Crop rotation prescribes that potatoes can only be grown on a piece of land once every three seasons, therefore, a farmer can only grow potatoes on one-third of her land. This perhaps explains the positive relationship between risk-taking and the decision to apply crop rotation. Risk-taking farmers are willing to forego the short-term benefits of continuing potato farming without rotation for long-term benefits of high yields which result from appropriate crop rotation. In a recent study, Boyabatlı *et al.* (2019), demonstrate that while crop rotation planning is beneficial in the long run, the risk of short term revenue losses is inevitable. They argue that the losses may be minimised by efficient rotation planning which takes into account market dynamics and crops used in the rotation. This argument is consistent with Muriithi *et al.* (2018) who found that farmers with small farm sizes are less likely to apply crop rotation. We found that with small farm sizes, farmers practice limited crop rotation and mainly produce staple food crops. The limited crop rotation result from the inability of land constrained farmers (given the small farm sizes) to reduce the area under staple food crops in order to practice crop rotation. Attempts to reduce the area under staple food crops for rotation purposes puts the household food security at risk.

Contrary to our hypothesis that more innovative farmers are more likely to adopt CSA practices, we find a negative relation between farmer innovativeness and the use of certified seed. One possible explanation is that because of the high cost and limited availability certified potato seed, innovative farmers invest in learning and experimenting with on-farm potato seed technologies such as positive selection. Positive selection is a farm-level potato seed multiplication technique carried out by farmers in two steps (a) identifying and marking the best potato plants in the field, and (b) harvesting the marked plants and storing the tubers separately as seeds for the next season. This is a knowledge-intensive practice that requires farmers to be trained. If correctly applied, the yield increase in potato can be more than 100% compared to the common practice of recycling potato seed (Gildemacher *et al.*, 2012).

Finally, we find that farmer proactiveness is positively related to the use of irrigation, changing the cultivation calendar and use of certified seed, however, it is negatively related to the adoption of intercropping in potato growing. As proactiveness is the tendency to be a first-mover in attempts to respond to needs and take advantage of opportunities, proactive farmers are more likely to be the first to irrigate potato fields, change the cultivation calendar of their farms and use certified seeds (especially for crops such as potato where the majority of the farmers still use recycled seed). Our results corroborate the findings of Hansen (2015) who found that proactive behaviour is necessary for farmers to adapt technologies to their specific farm needs. In the Netherlands and Slovenia, Verhees *et al.* (2011) found that farmer proactiveness is the most influential EO dimension for farm performance.

Conversely, we find a negative effect of farmer proactiveness on the decision to intercrop potato with other crops. Existing literature identifies two main reasons for intercropping (Snapp *et al.*, 2010), these are; a) to ensure that they have a variety of crops for household food security needs, and b) to spread risk (such that when one crop fails because of insufficient rainfall, another crop may survive). While intercropping may be viewed as a beneficial practice, it may not apply to all crops. Some crops are recommended to be grown in monocropping systems to increase yields and for efficient application of other cultivation practices. We found that more proactive potato farmers do not practice intercropping, this is because they are market-oriented in their production decisions. This market orientation of more proactive farmers is further shown by the positive relation between proactiveness and practices such as the use of certified seed and the application of irrigation. On the other hand, less proactive farmers are more concerned with household food security than producing for the market, therefore, they intercrop their potatoes with other crops to increase household food diversity.

In addition to the effect of farmer EO dimensions on the adoption of CSA practices, we also discuss the effect of other control variables. First, beyond farmer EO, the gender of the farmer plays an important role in adoption decisions. Often in sub-Saharan Africa, women farmers are constrained in accessing productive resources and this explains why the adoption of farm innovations is lower for women farmers compared to that of their counterpart men (Kpadonou *et al.*, 2017). Our findings corroborate this argument. We find male farmers to be more likely to adopt irrigation, certified seed, crop rotation and soil testing. On the contrary, women are more likely to practice intercropping. Women in Sub-Saharan Africa mainly rely on own food production for their household food and nutrition security (Teklewold *et al.*, 2019).

Second, education is positively associated with the adoption of certified seed and soil testing, practices that require financial investment on the part of the farmer. Plausibly, more educated farmers are more informed about farm innovations, have more sources of income and thus less financial constraints to invest in financial-intensive innovations. This aligns with the findings of Wainaina *et al.* (2016) who found that more educated Kenyan smallholders are more likely to adopt improved maize seeds and fertilizer is given their knowledge and additional income sources. Third, as expected, we find that access to credit is positively associated with the adoption of financial-intensive practices these are certified seed and soil testing. This is in line with previous studies (Ojo and Baiyegunhi, 2020). It implies that financially constrained farmers may overcome this constraint by accessing credit services.

Fourth, land size is positively associated with the adoption of soil testing but negatively associated with intercropping. For instance, farmers with larger land sizes would be willing to invest in soil testing given their scale advantage. The finding of a positive relationship between land size and adoption decisions is consistent with previous findings (Kpadonou *et al.*, 2017). The inverse relationship between land size and intercropping suggests that small land size induces diversification (intercropping) particularly to meet household food needs. This is consistent with recent findings by Teklewold *et al.* (2019).

Fifth, in terms of membership in farmer organisations, we find a positive and significant relationship with changing the cultivation calendar, certified seed, crop rotation and soil testing. Membership in farmer organisations indicates how farmers are socially connected and their ability to access information and other services such as credit and market. Access to such services through membership in farmer organisations increase the farmers' adaptive capacity and thus, the probability of adoption of CSA practices. This is consistent with the findings of Ojo and Baiyegunhi (2020) and Kassie *et al.* (2013), who found a positive and significant relationship between adoption of agrochemical and varying planting and harvesting dates in Nigeria, and chemical fertilizer in Tanzania, respectively.

3.4.2. Adoption of the categories of CSA practices: Multivariate probit model results

We have categorised CSA practices into three groups reflecting the intensity of resource requirement (Table 2): unskilled labour, skilled labour and financial resources. Table 5 gives the multivariate probit model estimates predicting the effect of farmer EO dimensions on the decision to adopt the various categories of CSA practices.

Table 5. Multivariate probit model estimates for the categories of CSA practices

Variable	Unskilled labour-intensive CSA practices		Skilled labour-intensive CSA practices		Finance-intensive CSA practices	
	Coef	Robust Std. Err	Coef	Robust Std. Err	Coef	Robust Std. Err
Sex	-0.019	0.100	0.171*	0.100	0.335***	0.100
Age	0.019	0.026	0.026	0.026	-0.012	0.026
Age squared	-0.000	0.000	-0.000	0.000	0.000	0.000
Household size	-0.019	0.026	-0.007	0.026	-0.007	0.027
Education	0.003	0.016	0.030*	0.015	0.039**	0.016
Years growing potato	-0.003	0.006	0.006	0.005	0.011**	0.006
Risk-taking	0.048	0.034	0.219***	0.037	0.114***	0.036
Innovativeness	-0.048	0.036	0.047	0.036	-0.071*	0.038
Proactiveness	-0.203***	0.039	0.024	0.036	0.064*	0.037
Land ownership	0.470***	0.116	0.269**	0.119	0.299**	0.124
Total land size	-0.069*	0.036	0.003	0.038	0.092	0.057
Access climate info	-0.012	0.109	0.425***	0.111	0.443***	0.106
Credit	0.143	0.119	0.093	0.124	0.441***	0.117
Group membership	-0.304***	0.116	0.458***	0.114	0.353***	0.116
County	0.974***	0.109	-0.060	0.105	0.352***	0.109
Wald chi^2 (45)	496.84***					
Observations	792					

*** p<0.01, ** p<0.05, * p<0.1

The MVP results in Table 5 show that, first, risk-taking is positively associated with the adoption of practices that require a high intensity of skilled labour and financial resources. In other words, the probability of adopting practices that require skilled labour and financial resources is higher for farmers that are more risk-taking compared to risk-averse farmers. These resources require farmers to invest in assets that may not be within the farm, for instance, in searching for production knowledge or finance that is often sought from financial institutions. This finding is in line with Kassie *et al.* (2013), who found that risk-taking farmers in rural Tanzania were more likely to adopt practices that require financial resources.

Second, our results show that innovativeness is negatively associated with the adoption of practices that require a high intensity of financial resources. As farmers become more innovative, they pursue innovative ways to minimize financial investment, hence more innovative farmers are less likely to adopt finance-intensive CSA practices. This is in line with past evidence of Bowman and Zilberman (2013) that innovativeness allows farmers to pursue activities that reduce financial and physical risks and labour requirements while increasing income. Therefore, innovative potato farmers in Kenya are expected to reduce the adoption of finance-intensive CSA practices as they replace them with less finance-intensive practices. Furthermore, results show that, though not significant, innovativeness and adoption of skilled labour-intensive CSA practices are positively correlated (Table 5).

Third, we find that farmer proactiveness is negatively associated with the adoption of unskilled labour-intensive CSA practices but positively associated with the adoption of finance-intensive CSA practices. In other words, more proactive farmers are less likely to adopt practices that predominantly require unskilled labour and more likely to adopt practices that predominantly require financial investment. This might mean that proactive farmers constantly look for ways to improve their farms by continuously seeking agricultural information and training, thus providing them with knowledge and skills sufficient to invest in finance-intensive practices and avoid unskilled labour-intensive practices.

3.5 Conclusion and implications

As climate change is a challenge to food security and livelihoods worldwide, recent academic discussions on how farmers can adapt to climate change have focused on the adoption of CSA practices. In this paper, we aimed to contribute to explaining when and why the adoption of CSA practices occurs, by analysing farmer entrepreneurship, and more specifically by three dimensions of farmer EO (innovativeness, proactiveness and risk-taking) as the hypothesised drivers.

Our empirical results first revealed that farmers adopt multiple CSA practices simultaneously and in combinations as either complements or substitutes. Specifically, certified seed and irrigation, soil testing and irrigation changing cultivation calendar and crop rotation, changing cultivation calendar and soil testing, and soil testing and certified seed are complementary practices. Vice versa, intercropping and irrigation, and intercropping and certified seed are substitutes. Furthermore, the results provide empirical evidence for the role of farmer EO dimensions in the adoption of CSA practices. We show that the EO dimensions have a variety of effects. First, risk-taking increases the likelihood of adopting all the practices except intercropping, which show a non-significant effect. Second, innovativeness reduces the likelihood of adopting certified seed. Third, proactiveness positively influences the adoption of irrigation, changing cultivation calendar and certified seed, but has a negative effect on the adoption of intercropping. When the categories of CSA practices are considered, risk-taking has a positive effect on the adoption of skilled labour-intensive and finance-intensive CSA practices; innovativeness has a negative effect on the adoption of finance-intensive CSA practices; lastly, proactiveness has a positive effect on the adoption of finance-intensive CSA practices and a negative effect on the adoption of unskilled labour-intensive CSA practices. In relation to previous studies that have focused only on the farmer risk preferences, we show that while risk-taking behaviour is important, risk-taking alone is not sufficient in explaining farmers adoption decisions. Taking an EO perspective that accounts for risk-taking, innovativeness and proactiveness provide a deeper understanding of the adoption decisions.

This paper contributes to the literature on innovation adoption at the farm level. First, it unravels the effect of farmer EO on the adoption of CSA practices, the diverse effects of farmer EO on CSA adoption contribute to the ongoing debate around theorising and measuring EO either as a unidimensional or a multidimensional concept (Covin and Wales, 2012). We show that measuring EO as a multidimensional rather than a unidimensional concept reveals important cognitive traits of smallholder farmers that matter for their decision-making on CSA practices. At the same time, this is a step away from studies that focus only on generic factors such as farm characteristics, farmer characteristics and institutional constraints (Kpadonou *et al.*, 2017; Teklewold *et al.*, 2019). Second, it develops a categorisation of CSA practices based on the intensity of resource needs, thus overcoming the limitation of assuming that adopting more practices is better than fewer practices (Muriithi *et al.*, 2018; Teklewold *et al.*, 2013). Understanding how farmer entrepreneurship and resource needs affect the adoption of CSA practices lays a solid foundation for the design and implementation of more tailored policies and intervention programmes.

These findings lead to the following two recommendations for agricultural development practitioners and policy-makers. First, given the low rate of CSA adoption in potato farming, we suggest that entrepreneurship programmes in potato farming deserve policy attention as part of national and county government strategies for adaptation and resilience to climate change. In Kenya, potato is the second most important crop after maize contributing to household food and livelihood security (Muthoni and Nyamongo, 2009), and as such, potato production needs to increase even in the face of climate change. Additionally, focusing on CSA practices in potato farming is important as potato crop is more vulnerable to climate change as compared to other field crops (Lynch *et al.*, 1995). Thus, investing in the diffusion and adoption of CSA practices in potato farming is crucial. To accomplish so, our findings suggest that agricultural extension departments, development agencies and policy-makers need to integrate agronomic and entrepreneurship (i.e., social and business-oriented) knowledge in their training services for farmers. These services involving entrepreneurship knowledge provision might require important public (and perhaps private) investments, as – generally in Sub-Saharan Africa – farmers currently receive agronomic training with limited entrepreneurship training. Finally, along with training, policy-makers would need to develop and implement agricultural policies that support farmer entrepreneurship, for example, by facilitating market transactions and by creating a business climate conducive for farmers to innovate and take calculated risks. Such policy support can, for example, facilitate access to other support services such as credit, and encourage the formation and participation in farmer organisations which may provide diverse services such as credit, marketing and advisory services to smallholder farmers (Poulton *et al.*, 2010).

Second, our findings suggest that entrepreneurship training and education programmes dedicated to farmers must be tailored to influence the three dimensions of EO that we analysed: risk-taking, innovativeness and proactiveness. This means that to translate each of these three farmer EO dimensions into the adoption of appropriate CSA practices, access to specific support services is necessary. For instance, to stimulate the adoption of finance-intensive CSA practices, tailored training on risk management in relation to CSA adoption will be crucial, along with providing accessible and affordable credit facilities. While training on risk management in the CSA adoption enhances farmers' risk-taking behaviour, it is important to note that in general, the degree of risk-taking, innovative and proactive behaviours are not the same for all farmers. Thus, farmer training on entrepreneurship for climate adaptation should not be designed as a one-size-fits-all activity. Instead, tailored and incremental training that fits farmers' EO dimensions and their resources at hand would be more effective for the adoption of appropriate CSA practices. For example, training to farmers with low risk-taking behaviour may focus on CSA practices that bear low risks and require lower financial investments, while training to those with higher risk-taking behaviour may focus on how to take calculated risks while investing in financial-intensive practices. One approach to deliver such tailored and incremental training to different sets of farmers might be through a farmer field schools approach that encourages experiential learning activities and group experiments designed for different groups of farmers (Chandra *et al.*, 2017). This enables farmers to acquire the specific dimensions of EO that they need for adopting CSA practices together with the resources that they might need.

Our study is limited by two issues. First, the geographical coverage, as the study was conducted in two potato producing counties in Kenya, Meru and Nakuru. Future research to understand the effect of farmer entrepreneurship on the adoption of farm innovations would benefit from studying farmers in different agroecological zones with different climate, soil conditions and producing different crops to strengthen the generalizability of results. Second, the study used cross-sectional data, thus collected at one point in time. Future research needs to consider collecting panel data that will allow studying the farmers' evolution of the EO dimensions over time to better understand the entrepreneurial process and the effectiveness of interventions meant to improve farmer entrepreneurship. Furthermore, it may be relevant for future research to study the impact of the adoption of CSA practices on potato yield, income and household food and nutrition security. This is important because promoting the adoption of CSA practices with established benefits may trigger an increase in adoption. It also offers more information to practitioners on resource needs they should focus on in the design of development interventions.

Appendix

Table A1. Principal component loadings for farmer EO

Item	Component 1 (Innovativeness)	Component 2 (Proactiveness)	Component 3 (Risk-taking)
I prefer to stick with my current farming practices rather than trying new ones [R]			0.622
With the current challenging farming environment, I prefer to avoid further investment in my farm [R]			0.616
I am always ready to try new farming practices			0.481
Cronbach's alpha			*0.833*
I like to use new farming practices	0.588		
I often improve my farming practices	0.577		
I like to have the latest information on farming practices	0.549		
Cronbach's alpha	*0.865*		
I respond more quickly to changes in the environment of my farm compared to other farmers		0.638	
I am among the first farmers to adopt new farming practices in my village		0.615	
I am constantly looking out for new ways to improve my farm.		0.461	
Cronbach's alpha		*0.819*	

[R] the item was reversed before analysis

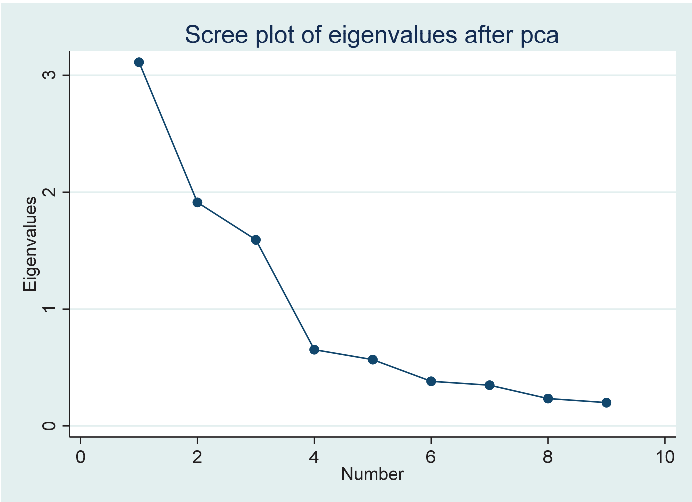

Figure A1. Scree plot showing the number of components retained after PCA

Table A2. Correlation coefficients of error terms after the MVP model estimation for individual practices

CSA practices	Irrigation	Change cultivation calendar	Certified seed	Crop rotation	Soil testing	Intercropping
Irrigation	1.000					
Change cultivation calendar	-0.051 (0.060)	1.000				
Certified seed	0.122** (0.061)	-0.047 (0.064)	1.000			
Crop rotation	-0.033 (0.058)	0.246*** (0.054)	-0.068 (0.058)	1.000		
Soil testing	0.118* (0.069)	0.163** (0.065)	0.198*** (0.066)	0.041 (0.064)	1.000	
Intercropping	-0.175*** (0.062)	0.061 (0.061)	-0.126* (0.070)	0.012 (0.061)	0.037 (0.074)	1.000

Likelihood ratio test $\chi^2(15) = 49.72$; p> χ^2 0.000

*** p<0.01, ** p<0.05, * p<0.1

Chapter 4

Farmer organizations and climate change adaptation: the effects of membership and access to services

Abstract

Adaptive capacity is an important determinant of climate change adaptation, yet the level of farmers' adaptive capacity in developing countries remain low. Farmer organisations (FOs) might provide potential pathways to strengthen farmer adaptive capacity. We analyse the role of three services, which FOs may provide to enhance the ability of farmers to adapt to climate change: access to credit, extension and output markets. Using survey data from smallholder potato farmers in Kenya, we assess if and when these FO services enhance farmers' adaptive capacity to adopt climate-smart agriculture (CSA) practices. To estimate the impact of membership and access to FO services on CSA adoption, we employ a doubly robust inverse probability weighted regression adjustment approach with conditional analysis to account for the heterogeneity in membership and access to the different services. We test the robustness of our results using propensity score matching, inverse probability weighting and regression adjustment estimation strategies. We find that FO membership combined with access to FO services increases CSA adoption. Market access has the largest effect on CSA adoption; yet, the conditional analysis reveals that farmers' access to extension acts as a catalyst for access to market and credit. Our findings suggest that, in a resource-constrained context, FOs strengthen farmers' adaptive capacity if they provide essential services that are prerequisites for investment in climate change adaptation. Importantly, if FOs do not offer extension, market or credit access equally among their members, they may risk increasing climate change adaptation inequality among farmers. Therefore, policies and development interventions should not only target the formation of FOs but also support FOs to provide the services that enable farmers to adapt to climate change.

Keywords: Farmer organizations, Climate-smart agriculture, Adaptive capacity, Climate change adaptation, Potato, Kenya

This paper is based on an article submitted to a journal as:

Kangogo, D., Bijman, J., Dentoni, D. & Cecchi, F. Farmer organizations and climate change adaptation: the effects of membership and access to services

4.1 Introduction

In sub-Saharan Africa, as in other parts of the world, climate change continues to be one of the major challenges facing agriculture and development. In Kenya, for instance, periodic floods, droughts and unpredictable rainfall patterns are the main climate challenges facing farmers. These challenges threaten household livelihoods and food security, particularly due to the farmer's limited adaptive capacity (Muller *et al.*, 2011). Farmers' adaptive capacity consists of the preconditions necessary to enable farmers to learn, anticipate and respond flexibly to environmental and socioeconomic changes, and take advantage of the opportunities that may arise (Grothmann and Patt, 2005; Smit and Wandel, 2006). Strengthening farmers' adaptive capacity is a precondition for effective climate change adaptation (Burke and Emerick, 2016; Eakin and Lemos, 2010). However, limited attention has been paid to understanding how farmers' capacity to adapt to climate change can be strengthened (Eakin and Lemos, 2006; Fernández-Giménez *et al.*, 2015; Wang *et al.*, 2013).

Cinner *et al.* (2018) identify five domains that strengthen adaptive capacity: the assets that can be drawn upon in times of need; the flexibility to change strategies; the ability to organise and act collectively; learning to recognise and respond to change; and the agency to determine when and whether to change. Recent studies, for instance, Lim *et al.* (2021) and Williams *et al.* (2019) showed that enhancing farmers' adaptive capacity is dependent on access to financial resources, climate and production knowledge, market and institutional support. In this paper, we study farmers' self-organisation in the form of farmer organisations as mechanisms that support smallholder access to resources necessary for climate change adaptation. Farmer organisations (henceforth FOs) are examples of local institutions of collective action (Ostrom, 1990) in which farmers jointly access production resources and services. They include a variety of membership organisations such as cooperatives, farmer self-help groups, farmer-owned companies, and farmer unions (Uphoff and Buck, 2006).

The role of FOs and their impact on smallholder farmers is well established in the agricultural development literature. FOs facilitate access to production inputs and services (Mutonyi, 2019; Ragasa and Golan, 2014), provide access to markets (Fischer and Qaim, 2012a; Markelova and Mwangi, 2010) and promote the adoption of new farm technologies (Abebaw and Haile, 2013; Ainembabazi *et al.*, 2017). Studies on FOs and smallholder climate change adaptation are still limited (Agrawal, 2008; Araral, 2013), yet growing evidence suggests that FOs play an important role in adaptation (Chandra *et al.*, 2017; Di Falco and Bulte, 2013; Di Falco *et al.*, 2019; Di Falco *et al.*, 2011; Eakin, 2005; Washington-Ottombre and Pijanowski, 2012).

To address climate change, farmers may adopt climate-smart agriculture (henceforth CSA), an approach that – at least in principle - aims to simultaneously increase agricultural productivity, food security and climate change adaptation (FAO, 2013). Yet, several challenges explain low CSA adoption and thus question CSA as a viable strategy for climate change adaptation in sub-Saharan Africa (Amadu *et al.*, 2020; Campbell *et al.*, 2014). First, the smallholder nature of African farming systems limits the widespread adoption of CSA practices. The smallholder nature implies that farmers face high transaction costs in accessing inputs and services as well as imperfect markets for their produce (Poulton *et al.*, 2010). High transaction costs have negative effects on CSA adoption (Araral, 2013). Second, smallholder farmers face high risks in accessing markets for their produce, risks associated with access to and cost of credit, and risks associated with insufficient knowledge and skills. These risks further complicate the ability of farmers to change their farming practices. Third, the adoption of CSA is both labour and knowledge-intensive and it requires financial investment and institutional support (Lipper *et al.*, 2014); however, individually, smallholder farmers are limited in the access to such necessary support.

In light of the smallholders' limitations, FOs might support climate change adaptation by providing farmers with access to essential resources and services (Khanal *et al.*, 2017; Yaro *et al.*, 2014). While so far only a few studies have explored the role of FOs in improving smallholders' adaptive capacity (Malakar, 2012), FOs may support climate adaptation by exposing their member-farmers to new practices that bolster context-specific knowledge (Armitage, 2005; Eakin, 2005; Fernández-Giménez *et al.*, 2015). For farmers to benefit from the support of the FO, they need to be members, they need to have access to the services offered by the FO (Bernard and Spielman, 2009), and they need to use the services. Existing evidence indicates that there are inequalities in access to FO services; these inequalities may be due to the farm's geographical location, gender of the farmer, and resources available to the household (Bizikova *et al.*, 2020). These inequalities have ripple effects that may contribute to widening the climate change adaptation inequality gap (Eriksen *et al.*, 2021).

Against this background, this paper seeks to make three contributions. First, we contribute to the scant literature on the impact of FOs on climate change adaptation at the farm level. Previous studies on the impact of FOs are largely mechanistic in treating the FO; they assume that membership alone results in the observed impact. This assumption does not provide insights into the mechanisms through which the impact emerges. Indeed, little effort has been devoted to understanding *how and when* FOs influence the adoption of farm technologies (Abate, 2018). Second, in an attempt to answer the questions of how and when FOs influence the adoption of farm technologies, we focus on the services that FOs provide to improve the capacity of farmers to adapt their farming practices to climate change. Specifically, we study the impact of access to and use of extension, credit and market services[2] on CSA adoption. In other words, we proxy adaptive capacity by farmers' access to extension, credit and market services. Existing literature has neither paid much attention to the impact of access to the different services nor to their synergy effects (Makate *et al.*, 2019). Third, this study employs the doubly robust inverse probability weighted regression adjustment (IPWRA) estimation method with conditional analysis to unravel the role of membership and access to FO services on the CSA adoption, and matching techniques to control for selection bias that may arise in estimating the impact of FO membership and access to FO services.

We exploit household survey data from smallholder potato farmers in Kenya to understand how membership and access to FO services affect CSA adoption. Potato farming provides an interesting case. First, in Kenya, potato is the second most important crop after maize, contributing to household food security and income, and its production is dominated by smallholder farmers (Okello, Lagerkvist*, et al.*, 2018). Second, potato is highly vulnerable to climate change so farmers need to adapt their production practices (Parker *et al.*, 2019).

The findings from this study have important implications for policy and research. First, if FOs have a positive impact on CSA adoption through the provision of or facilitating access to services, then there is a reason for policies that encourage the formation of FOs and support them to provide these services to members. Second, the distinct impact of access to various FO services on CSA adoption implies that in evaluating FOs, membership is a necessary but not a sufficient condition. Analysis of the impact of access to FO services can inform development practitioners on the support that FOs require to provide the services to their members.

The paper is structured as follows. In section 2 we briefly situate the study within the existing adaptation and FO literature. In section 3 we explain the methodology, including the analytical framework, data and estimation strategies. In section 4 we present the results and discuss the main findings. Finally, in section 5 we conclude the study with the implications of our findings.

[2] Use of the term access to credit, access to extension and market access imply that the farmer accessed and actually made use of the service(s).

4.2 Climate change adaptation, farmers' adaptive capacity and farmer organisations

Two strands of development literature on FOs and climate change adaptation have developed separately, yet are complementary. Adaptation refers to strategies – including practices, activities and decisions – that enable individuals, groups and systems to prevail in the face of change (Agrawal, 2010). At the core of this literature is the adaptive capacity, defined as the actor's or system's ability to experiment, learn and respond flexibly to socio-ecological changes (Grothmann and Patt, 2005; Smit and Wandel, 2006). Adaptive capacity is dynamic as it continuously co-evolves with the institutions and the individual actors that constitute socio-ecological systems (Robinson and Berkes, 2011; Smit and Wandel, 2006). Adaptive capacity can thus be improved over time, which makes it an important attribute to be studied from development, academic and policy viewpoints. It is, therefore, imperative to understand what factors enhance adaptive capacity (Clay and King, 2019; Thulstrup, 2015).

In resource-constrained settings, local institutions for collective action play a critical role in strengthening adaptive capacity (Armitage, 2005; Fernández-Giménez *et al.*, 2015; Rodima-Taylor, 2012). For instance, evidence from Vietnam suggests that embeddedness in local institutions of collective action determines the access to resources and knowledge, thus the ability to deal with collective problems (Hulke and Revilla Diez, 2020). In Rwanda, local institutions, specifically through the farmers' crop intensification groups, play an important role in shaping the smallholders' adaptation strategies by relaxing resource constraints which create incentives for climate change adaptation (Clay and King, 2019). Similarly, the local institutions among herders in Mongolia have been shown to play important roles in shaping and facilitating climate change adaptation (Wang *et al.*, 2013). In the Mongolian grasslands, communal pooling enhanced the adaptive capacity of herders by facilitating coordinated mobile grazing, purchase and storage of forage, and market opportunities.

In smallholder farming systems, FOs are examples of local institutions for collective action that provide rural farmers with access to knowledge, skills, inputs, services, networks and market opportunities. Access to these resources contributes to improving adaptive capacity by exposing farmers to new ideas and bolstering context-specific knowledge for adaptation (Armitage, 2005; Upton, 2012). Smallholders exhibit uneven access to resources resulting in unequal adaptive capacity (Thulstrup, 2015). Whenever limited access to services intersects with other factors such as the age and gender of the farmer, it may result in climate change adaptation inequality (Erwin *et al.*, 2021). With this evidence, it is plausible to hypothesise a relationship between FOs and climate change adaptation through access to FO services.

Recent empirical studies have explored the relationship between the local institutions for collective action and climate change adaptation. For instance, Di Falco and Bulte (2013) studied how risk-sharing networks in Ethiopia affect farmers' adoption of risk-mitigating strategies. They found that, first, compulsory risk-sharing within networks encourages free-riding among farmers, thus discouraging investments in adaptation strategies. Second, they showed that social networks may effectively substitute for the limited access to formal credit by providing opportunities to access informal credit. In another study, Di Falco *et al.* (2019) showed that social networks through peer effects in Ethiopia influenced farm-level decision-making on the adoption of climate change adaptation strategies. In Switzerland, Bardsley and Bardsley (2014) found that farmer cooperatives mitigate farmers' risks by providing access to cheaper technical and agronomic inputs than what is offered at prevailing market prices, which enables farmers to adapt to political, economic and environmental changes. In the Philippines, Chandra *et al.* (2017) showed that organising farmers in farmer field schools promoted farmers' adoption of CSA practices by lowering transaction costs with their input suppliers. In Burkina Faso, Castaing (2020) recently found that while FOs support farmers' adaptation to climate shocks through resource pooling to access credit, the large groups (many members) encouraged free riding and was associated with reduced investment in adaptation strategies. In Kenya, Washington-Ottombre and Pijanowski (2012) found that rural producer organisations through their collective action activities support the adoption of sustainable climate change adaptation strategies.

Yet, this literature has not analysed the specific impact of access to production resources, particularly those offered by FOs. In this paper, we estimate the impact of access to services from FOs specifically credit, extension, market and their synergies. To start addressing this gap, we draw from the broader literature on FOs supporting smallholders' technology adoption. First, this literature informs that technology adoption is limited by constraints in *access to credit* (Makate *et al.*, 2019; Nakano and Magezi, 2020). FOs relax credit constraints by providing farmers with opportunities to borrow at a low cost and sometimes informally without collateral (Castaing, 2020). Furthermore, FOs facilitate farmers' cost reduction through bulk purchasing which then provides an incentive for technology adoption (Shiferaw *et al.*, 2014).

Second, farm technology adoption largely depends on *access to agricultural extension* (Di Falco *et al.*, 2011). Access to extension is the main source of information and skills for farmers. Yet, when government agricultural extension departments are not delivering, FOs may take up this role to ensure that farmers receive the necessary farming information and develop their skills. A review of the state of agriculture and extension services in sub-Saharan Africa suggests that farmer field schools, social networks and information and communication technology (ICT)-based extension programmes help farmers reduce the information asymmetry related to technology adoption (Aker, 2011). In Uganda, for instance, access to extension was found to increase the adoption of new cultivation methods that require upfront financial investment (Pan *et al.*, 2018). A recent study in Malawi and Zimbabwe show that, comparatively, access to extension was more effective in promoting the adoption of CSA than access to credit (Makate *et al.*, 2019). In addition, this study found that simultaneous access to credit and extension has a synergistic effect on CSA adoption. In Nigeria, the impact of extension on technology adoption was higher for cooperative members with access to credit than members without credit access (Wossen *et al.*, 2017).

Third, *market access* is an important determinant of farm technology adoption. Market access enables farmers to produce a surplus that can be sold and to receive better prices for their produce. These outcomes improve farmers' incentive to invest in climate adaptation strategies (Kuhl, 2018). For instance, studies show that farmers are more likely to practice intercropping not only for soil fertility benefits but also if they have access to the market for the surplus produce and a market for the crop used as an intercrop with the main crop (Kamanga *et al.*, 2009; Waldman *et al.*, 2017). In Ethiopia, market access was significant in explaining farmer choices towards climate change mitigation (Alemayehu and Bewket, 2017). With market access, farmers are more likely to embrace farm innovations, as they expect returns from selling surplus produce to cover the investments in new farm practices including CSA (Thulstrup, 2015). Where farmers have no guaranteed access to the market, FOs may provide market opportunities, economies of scale in post-harvest expenses and bargaining power to reduce buyers' opportunistic behaviour (Bernard and Spielman, 2009).

Generally, we identify five ways through which FOs can support smallholder farmers in adapting to climate change. First, FOs support farmers to develop a collective view on climate change risks which in turn influences individual farmer perceptions and responses. Second, through the provision of agricultural extension services, FOs provide access to knowledge and skills necessary to effectively and efficiently respond to climate change. Third, FOs relax smallholders' credit constraints, thus facilitating investment in financial-intensive adaptation strategies. Fourth, FOs provide affordable access to farm inputs such as certified seeds. FOs achieve this (a) through their bargaining role, enabling farmers to access inputs at a lower cost, and (b) by providing information about the inputs market. Fifth, FOs support farmers to sell their farm produce. This can be achieved (a) through the bargaining role which enables farmers to access consistent and lucrative markets, and (b) by providing information about where to sell, when to sell and to which buyers.

In sum, part of the literature suggests that FOs, as local institutions for collective action, are the potential means of relaxing constraints that limit the adoption of CSA practices. Other literature focuses on the role of access to credit, extension and market in technology adoption. From these strands of literature, we consider the following proposition: access to credit, extension and market from FOs, individually and synergistically increase the ability of smallholders to adapt to climate change.

4.3 Methodology

4.3.1 Data and description of variables

The data for this study come from a household survey of smallholder potato farmers, conducted between June to August 2019 in Kenya. Potato is grown in almost all the arable highlands of Kenya. The top five counties in terms of land under potato cultivation are Meru, Nyandarua, Nakuru, Elgeiyo Marakwet and Kiambu, with Meru and Nakuru accounting for over 30% of the land used for potato (Kaguongo *et al.*, 2014).

Considering our interests in the impact of membership in FOs on the adoption of CSA practices, we focus on FOs which support potato production and marketing. A multistage sampling procedure was used to select a random sample of 792 farmers. In the first stage, Meru and Nakuru counties were purposively selected. Within these two counties, wards (i.e., districts) with high potato production were selected in consultation with the county extension officers. Specifically, Kisima, Timau and Kibirichia wards were selected in Meru county while Keringet and Molo wards were selected in Nakuru county. Second, we relied on the lists of FOs in the selected wards to randomly sample the FOs for the study. From the lists, 39 FOs were randomly selected in Meru county and 18 FOs were randomly selected in Nakuru county. In total, 57 potato FOs were selected. Third, for each selected FO, the list of members was acquired from which a random sample of farmers – proportionate to the group size – was interviewed.

Finally, since we did not have lists of non-group member farmers (control group), and given the resource constraints, we randomly chose non-member farmers in the same villages as the group member farmers to be interviewed. To do this systematically, enumerators were asked, after interviewing every second selected group member to skip two households and interview the third household only if the farmer was a non-group member. Although this may not yield a perfectly random sample, this approach produces a more representative sample in the absence of a population list and with resource constraints (McCord *et al.*, 2015). From the total sample of 792 potato farmers interviewed, 500 were FO members (treated) and 292 non-members (control). A structured questionnaire was used to collect data on a range of topics including farmer and farm characteristics, access to FO services, potato production and marketing activities.

4.3.2 Variable description and measurement

Outcome variables

The outcome variables include the adoption of CSA practices. In reality, a single practice may not sufficiently achieve the triple-win objectives of CSA, therefore, proponents of CSA advocate for practice combinations. This implies that practice is considered CSA if it helps deliver one or more of the CSA objectives (Bell *et al.*, 2018). Specifically, the CSA practices considered in this study are those relating to potato production identified in consultation with the extension officers. They include irrigation, changing of cultivation calendar, use of certified seed, crop rotation, soil testing and intercropping. The CSA practices related to land use enable farmers to effectively cope with distinct climatic shocks and adaptively respond to current and future climatic changes (Clay and King, 2019). The adoption of the CSA practices was measured as dummy variables following previous studies (Kassie *et al.*, 2015; Makate *et al.*, 2019; Teklewold *et al.*, 2019; Wainaina *et al.*, 2016). The variable takes a value of 1 if a farmer adopted the practice and 0 otherwise. We further constructed a CSA adoption index which is a measure of the number of CSA practices that a farmer adopted. This index has previously been used as an indicator of farmer CSA adoption intensity (Amadu *et al.*, 2020b; Aryal, Rahut*, et al.*, 2018) Table 1 presents a detailed description.

Explanatory variables

We draw on the existing literature on determinants of membership in FOs and determinants of access to farm production services to identify a comprehensive set of covariates for this study (Abate, 2018; Amadu *et al.*, 2020; Di Falco and Bulte, 2013; Khanal *et al.*, 2017; Makate *et al.*, 2019; Wossen *et al.*, 2017). Table 1 presents the description and statistics for the selected explanatory variables.

Treatment variables

We consider a broad set of treatment variables. First, FO member-farmers are compared to non-members, providing the impact of membership on CSA adoption. Second, instead of confining our analysis to only FO members versus non-members, we drop the non-member farmers subsample and proceed with the analysis with only the FO member-farmers subsample. Members with access to credit, extension and market are compared to member-farmers without access to these services. Additionally, members with access to a combination of services are compared to members who did not access specific service combinations. This allows us to exploit the impact of access to specific FO services including the various service combinations on the CSA adoption. We deal with potential biases that may arise from comparing these samples using a wide range of econometric techniques which we will discuss at length in the next section.

4.4 Empirical approach

The objective of this study is to evaluate the effect of membership in FO and access to FO services (as a measure of farmer adaptive capacity) on CSA adoption. In other words, we estimate the average treatment effect on the treated (ATT), this is the average difference in the adoption of CSA practices for the treated and control groups of farmers (Rosenbaum and Rubin, 1983). Given the observational nature of our data, we may directly compare farmers in the treated group against those in the control group. While this seems to be a straightforward analysis in an observational study, we cannot establish how the outcome (in our case CSA adoption) would have been without treatment (membership and access to FO services), consequently, we are faced with a missing data problem on the counterfactual. As such, any attempt to directly compare the two groups of farmers could be misleading, due to non-random self-selection into the treated groups (Caliendo and Kopeinig, 2008).

We, therefore, need to account for the self-selection bias in the analysis. Two potential sources of bias can be identified in the analysis: the bias arising from the difference in the treated group and control group with respect to observed and unobserved characteristics. We apply the propensity score matching (PSM) technique to construct counterfactuals with the same characteristics as the treated groups, thus controlling for observed characteristics (Caliendo and Kopeinig, 2008). The propensity score is the probability of assignment of treatments conditional on observed characteristics, this has the advantage of reducing the confounding effects in observational data through a quasi-experimental approach (Rosenbaum and Rubin, 1983). The covariates balancing of the propensity scores ensure that the distribution of the observed characteristics are similar for both the treated and the control group, and thus no systematic variations exist between the two groups.

The analysis is implemented in the following three steps. First, we explore the factors associated with membership in FOs to understand the probability of FO membership. Second, constructing the counterfactuals using the propensity scores and checking the covariates' balance. Third, we estimate the causal effects (ATT) of (a) membership and (b) access to FO services on CSA adoption.

After constructing the counterfactuals through the PSM technique, we estimate the doubly robust inverse probability weighted regression adjustment (IPWRA) as our primary estimator.

The procedure for estimating IPWRA proceeds as follows. First, we estimate the average treatment effect on the treated (ATT) as shown in equation 1:

$$\begin{aligned} ATT &= E\{Y_{1i} - Y_{0i} | T_i = 1\}, \\ &= E(Y_{1i} | T_i = 1) - E(Y_{0i} | T_i = 1) \end{aligned} \quad (1)$$

where $E(.)$ denotes the expectation term, Y_{1i} is the outcome for the treated group while Y_{0i} is the outcome for the control group and T_i is the treatment indicator equal to 1 if a household was in the treated group and 0 otherwise. The central problem in equation 1 is that we cannot observe the outcome of the treated group of farmers had they not been in the treated group, i.e. $E(Y_{0i}|T_i = 1)$. Replacing the unobserved counterfactuals with the outcomes of the control groups ($E(Y_{1i}|T_i = 0)$) may result in biased ATT estimates (Manda *et al.*, 2018; Takahashi and Barrett, 2013).

To solve this statistical pitfall, Wooldridge (2010) proposes the use of the IPWRA estimation strategy. IPWRA makes use of the inverse of the estimated probability weights to estimate the missing data-corrected regression coefficients which are used to calculate robust ATT estimates. The inverse probability weights are constructed by weighting the observations based on the inverse probability of being in the treated group. Generally, Rosenbaum and Rubin (1983) defined the probability of being in the treated group (propensity score) as:

$$p(X) = Pr(T_i = 1|X) = F\{h(X)\} = E(T_i|X) \quad (2)$$

where X is a vector of pre-treatment observed covariates that includes the farm and farmer characteristics, institutional and location characteristics associated with treatment. $F\{.\}$ is the cumulative distribution faction. The propensity scores from equation 2 are used to generate a sample in which the distribution of measured covariates is independent of treatment assignment. For the treated group, the inverse weight is equal to 1 while that of the control group is given by $\frac{\hat{p}(X)}{1-\hat{p}(X)}$. To combine the weights for both treated and control groups we follow the procedure suggested by Hirano and Imbens (2001) given as:

$$w_i = T_i + (1 - T_i)\frac{\hat{p}(X)}{1-\hat{p}(X)} \quad (3)$$

where $\hat{p}$ are the estimated propensity scores and w_i are the calculated inverse probability weights.

The regression adjustment (RA) on the other hand makes use of a linear regression model for both the treated and untreated units and finds averages of the predicted outcomes to obtain the treatment effects. Given this, it is evident that RA focuses more on the outcome, while IPW focuses more on treatment in calculating treatment effects, as such, there is value in combining the two estimators – IPWRA.

The ATT for the RA estimator is expressed following Wooldridge (2010) as:

$$ATT_{RA} = n_1^{-1} \sum_{i=1}^{n} T_i[r_1(X, \delta_1) - r_0(X, \delta_0)] \quad (4)$$

where n_1 is the total number of treatment units, $r_i(X)$ is the hypothesized regression model for both treated (1) and control group (0) based on the observed covariates X and parameters $\delta_i = (\propto_i, \beta_i)$.

Combining IPW (Equation 3) and RA (Equation 4) yields IPWRA. Since the combination may complicate the calculations, Wooldridge (2010) points out that it is sufficient to correctly specify either IPW or the RA equation to obtain reliable estimates of the treatment effects. The ATT for the IPWRA estimator can be expressed as:

$$ATT_{IPWRA} = n_1^{-1} \sum_{i=1}^{n} T_i[r_1^*(X, \delta_1^*) - r_0^*(X, \delta_0^*)] \quad (5)$$

the value parameter $\delta_1^* = (\alpha_1^*, \beta_1^*)$ is obtained from a weighted regression procedure given by:

$$\min_{\alpha_1^*, \beta_1^*} \sum_{i=i}^{N} T_i(y_i - \alpha_1^* - X\beta_1^*)^2 \,/\, \hat{p}(X, \hat{\gamma}\,) \quad (6)$$

the value of the parameter $\delta_0^* = (\alpha_0^*, \beta_0^*)$ is obtained from a weighted regression procedure given by:

$$\min_{\alpha_0^*, \beta_0^*} \sum_{i=i}^{N} (1 - T_i)(y_i - \alpha_0^* - X\beta_0^*)^2 \,/\, \big(1 - \hat{p}(X, \hat{\gamma})\big) \quad (7)$$

Like other treatment effect estimators, IPWRA relies on the assumption of conditional independence or confoundedness—implying that once we condition our analysis on a sufficient number of covariates, we approximate random treatment assignment. This is a strong assumption, since self-selection due to the unobservables may still be present. We mitigate this by conditioning our analysis on a rich set of covariates.

While we are aware that the outcome (CSA adoption) can be influenced by unobservable characteristics of the farmer and that IPWRA cannot fully account for this bias, it is recommended that the bias can be mitigated by checking the robustness of the IPWRA results using additional treatment effects approaches (Imbens and Wooldridge, 2009). Three estimation strategies are employed for the robustness check, PSM through the `teffects psmatch` Stata command which has the advantage of producing consistent standard errors of the ATT by accounting for the estimated propensity scores rather than taking them as known (Abadie and Imbens, 2016), and has the option of adjusting for biases that may arise when matching is based on more than one covariate (Abadie and Imbens, 2011), and independent inverse probability weighting (IPW) and regression adjustment (RA).

4.5 Results and Discussion

4.5.1 Descriptive statistics

The descriptive results of the variables used are presented in Table 1. The outcome variables (CSA practices adopted) show that on average less than 50% of the sampled farmers adopted the selected CSA practices, with the highest being the adoption of crop rotation at 44% and least being soil testing at 22%. This is consistent with previous studies that have indicated that the adoption of CSA remains low in sub-Saharan Africa given the low adaptive capacity resulting from limited resource endowment (Amadu *et al.*, 2020; Arslan *et al.*, 2014; Teklewold *et al.*, 2013). The CSA index shows that on average farmers adopted at least two CSA practices. Concerning the treatment variables, 63% of the sampled households were members of FOs, out of which 28% accessed credit, 80% accessed extension and 24% accessed the market for the potatoes through or from the FOs. The average age of the sampled farmers was 50 years, with an average of 17 years of experience in growing potato. This suggests that potato farmers are in the relatively older category of the population in Kenya. The average household size is five members and about 47% of the sampled farmers were female, indicating that potato is grown almost equally by both male and female farmers in Kenya.

Table 1: Variable description, measurement and summary statistics

Variable	Variable description	Mean	Std. dev
Outcome variables			
Irrigation (IR)	Applied the practice (*1= Yes; 0= No*)	0.31	0.46
Change in cultivation calendar (CCC)	Applied the practice (*1= Yes; 0= No*)	0.42	0.49
Use of certified seed (CS)	Applied the practice (*1= Yes; 0= No*)	0.30	0.46
Crop rotation (CR)	Applied the practice (*1= Yes; 0= No*)	0.44	0.50
Soil testing (ST)	Applied the practice (*1= Yes; 0= No*)	0.22	0.41
Intercropping (IC)	Applied the practice (*1= Yes; 0= No*)	0.36	0.48
CSA index	Number of CSA practices adopted by a farmer	2.05	1.27
Explanatory variables			
Sex	Sex of the farmer (*1= Male; 0= Female*)	0.53	0.50
Age	Age of the farmer in years (*Years*)	49.55	12.67
Age squared	Age squared	2615.80	1306.05
Household size	Number of household members (*Number*)	4.63	1.93
Education	Years of formal education of the farmer (*Years*)	9.14	3.36
Years growing potato	Number of years growing potato (*Years*)	17.91	12.23
Total land size owned	Total land owned by the farmer (Ha)	1.21	1.61
Land ownership	Land ownership status (*1= Owned; 0= Otherwise*)	0.78	0.41
Off-farm income	The farmer has off-farm income (*1= Yes; 0= No*)	0.31	0.46
Access climate info	Did the farmer access climate information (*1= Yes; 0= No*)	0.31	0.46
Motorized transport equipment	Ownership of motorized transport equipment	0.26	0.44
Distance to the source of farm inputs	Distance to the main source of farm inputs (Kilometres)	3.44	3.43
County	Location of the farmer (*1=Meru; 0= Nakuru*)	0.59	0.49
Treatment variables (membership and FO services access and use) n = 500			
Membership in FO	A member of potato FO (*1= Yes; 0= No*)	0.63	0.48
Access to credit	Accessed credit through/from the FO (*1= Yes; 0= No*)	0.28	0.45
Access to extension	Accessed extension through/from the FO (*1= Yes; 0= No*)	0.80	0.40
Access to market	Accessed market through/from the FO (*1= Yes; 0= No*)	0.24	0.43

4.5.2 Empirical model results

As a first step, we estimate the propensity to join a potato FO using a logit estimator, with a binary dependent variable being equal to 1 if the farmer is a member and 0 otherwise. The estimation results are presented in Appendix Table A1. Second, to construct the counterfactuals for comparison, it is essential that the covariates' balancing proprieties are satisfied. A satisfaction of balancing properties imply that there are no systematic variations in the observed characteristics between the treated and control groups. According to Rosenbaum and Rubin (1983), one may ignore the endogeneity of the treatment assignment if two conditions are met: (i) the conditional independence assumption (CIA), which suggests that a set of observable covariates exists and which, after controlling for, the potential outcomes are independent of the treatment status; and (ii) the common support assumption, which states that for each value of an identified observable covariate, there is a positive probability of being treated or untreated.

We rely on the standardised bias (SB) to test the covariate balance; variables with |SB|≥ 20 are considered imbalanced (Rosenbaum and Rubin, 2012). As shown by the results (Appendix Table A2), some variables are significantly different between control and treated groups before matching. However, after matching no variable is statistically different and all variables have SB less than 20. The visual inspection of the distribution of the propensity scores in Appendix Figure A1 shows that we achieved a good match. The matching procedure successfully generated control groups, and the treated groups are independent of the potential outcomes (Apel and Sweeten, 2010).

IPWRA results and robustness checks

After achieving balanced samples, we estimate the IPWRA for the impact of membership on the adoption of individual CSA practices and the CSA index (Table 2).

Table 2. IPWRA ATT estimates for the effect of membership on CSA adoption

	Outcome variables						
Treatment variable	IR	CCC	CS	CR	ST	IC	CSA index
Membership in FOs	0.094*** (0.033)	0.195*** (0.035)	0.212*** (0.031)	0.182*** (0.035)	0.185*** (0.027)	-0.323*** (0.035)	0.545*** (0.088)
Number of observations	792	792	792	792	792	792	792

Note: * p<0.10, ** p<0.05, *** p<0.001; Robust S.E. in parentheses.
IR = Irrigation; CCC = Change Cultivation Calendar; CS = Certified Seed; CR = Crop Rotation; ST = Soil Testing; IC = Intercropping.

The results show that membership on average increases the probability of adopting irrigation by 9.4%, changing the cultivation calendar by 19.5%, using certified potato seed by 21.2%, crop rotation by 18.2% and testing the soil by 18.5%. However, membership reduces the probability of intercropping by 32.3%. Overall, membership increases the number of CSA practices by 0.55 compared to non-membership. In sum, after controlling for observed heterogeneity FO membership increases the adoption of CSA practices on average. Different estimation strategies show that IPWRA results are robust (Table 3).

The negative effect of membership on intercropping highlights the trade-offs that farmers have to make in adopting some types of CSA practices and market-oriented production. For potato, which is largely grown as a mono-crop, market-oriented farmers are less likely to intercrop since they target high yields from the small land sizes. However, intercropping may be practised by farmers who are more concerned about diversifying their own production to achieve household food and nutrition security.

These results show the impact of FO membership on CSA adoption. In other words, this is a simple comparison of members to non-members which assumes that all member-farmers access the services offered by the FO. In reality, not all member farmers have access to FO services (Bizikova *et al.*, 2020). An analysis taking into account only membership does not reveal how, or the mechanism through which membership impacts CSA adoption.

Table 3. Robustness of ATT estimates for the impact of membership on CSA adoption

Outcome variables	Treatment variable: Membership in FOs		
	PSM	IPW	RA
Irrigation	0.064	0.091**	0.082**
	(0.054)	(0.038)	(0.034)
Change in cultivation calendar	0.156***	0.154***	0.155***
	(0.044)	(0.049)	(0.039)
Use of certified seed	0.186***	0.164***	0.147***
	(0.046)	(0.041)	(0.038)
Crop rotation	0.134***	0.161***	0.149***
	(0.046)	(0.049)	(0.040)
Soil test	0.150***	0.099*	0.142***
	(0.040)	(0.052)	(0.032)
Intercropping	-0.286***	-0.284***	-0.268***
	(0.047)	(0.047)	(0.042)
CSA index	0.408***	0.385***	0.408***
	(0.117)	(0.141)	(0.100)
Number of observations	792	792	792

Note: * p<0.10, ** p<0.05, *** p<0.001; Robust S.E. in parentheses
PSM estimated through the `teffects psmatch` Stata command

In the next sections of the results, the analysis proceeds with the CSA index as the outcome variable. We identify three services that a member of a FO may access; credit, extension and output market. We want to explore the effect of each of these services on CSA adoption (using the CSA index as the outcome variable). To do this, we estimate the ATT of membership with access to each of the services separately (Table 4). In this case, we compare members who accessed credit, extension and market services to non-member farmers (comparison of members with non-members).

Table 4. IPWRA ATT estimates for the effect of access to FO services on CSA adoption

	Outcome variable: CSA index	
Treatment variable	ATT estimates	No. of obs.
Membership with access to **credit** vs non-members	0.848***	431
	(0.128)	
Membership with access to **extension** vs non-members	0.618***	694
	(0.093)	
Membership with **market** access vs non-members	1.213***	414
	(0.132)	

Note: * p<0.10, ** p<0.05, *** p<0.001; Robust S.E. in parentheses

Table 4 shows that each of the three services provided by FOs has a positive and significant effect on CSA adoption. On average, members with market access adopted 1.21 more practices compared to the non-members. Access to credit and extension from FOs increased CSA adoption by 0.85 and 0.62 more practices, respectively, as compared to the non-members. The results are robust to a range of other specifications as shown in Table 5.

Our findings suggest that access to market, credit and extension improve farmers' adaptive capacity and thus the ability to invest in CSA adoption. Our results are consistent with previous studies that showed that market access increased the willingness of farmers to adopt climate change adaptation strategies (Alemayehu and Bewket, 2017; Chandra *et al.*, 2017; Thulstrup, 2015). Furthermore, Makate *et al.* (2019) found that access to credit and extension increase CSA adoption. Access to credit relaxes investment constraints while extension services provide information on new farming practices (Di Falco *et al.*, 2011; Lambrecht *et al.*, 2014). While our results corroborate with previous studies, the studies do not consider services provided by FOs.

Table 5. Robustness of ATT for the effect of access to FO services on the adoption of CSA practices

	Outcome variable: CSA index			
Treatment variable	PSM	IPW	RA	No. of obs.
Membership with access to **credit** vs non-members	0.503** (0.195)	0.613*** (0.171)	0.671*** (0.136)	431
Membership with access to **extension** vs non-members	0.565*** (0.117)	0.386** (0.166)	0.453*** (0.107)	694
Membership with **market** access vs non-members	0.844*** (0.155)	0.715*** (0.228)	0.821*** (0.142)	414

Note: * p<0.10, ** p<0.05, *** p<0.001; Robust S.E. in parentheses
PSM estimated through the `teffects psmatch` Stata command

In Table 4 we presented the results of the comparison between member-farmers with access to the three identified services and non-member farmers. While the results show the importance of access to market, credit and extension for CSA adoption, the estimated effects of access to services may be blurred by the fact that we compared FO members to non-members. The simple comparison between members and non-members does not disentangle the effect of access to the different FO services on CSA adoption. To extract the effects of access to FO services, we focus on the FO member-only subsample and compare member-farmers that accessed the specific services from FOs to the member-farmers that did not access the service under consideration.

Table 6 presents the results of the comparison between members that accessed the three services: market, credit and extension, with members that did not access the specific services (within-membership comparison). The results show that access to market, credit and extension services had a positive effect on CSA adoption with access to market having the largest effect, followed by credit and extension, respectively. Compared to members that did not access market services, members that accessed market adopted 0.88 more practices on average. Access to credit and extension on average increased the CSA adoption by 0.42 and 0.37 more practices, respectively, as compared to members that did not access the services.

Table 6. IPWRA ATT estimates for the effect of access to FO services on CSA adoption

	Outcome variable: CSA index	
Treatment variable	ATT estimates	No. of obs.
Membership with access to **credit** vs membership without access to credit	0.421*** (0.129)	500
Membership with access to **extension** vs membership without access to extension	0.374** (0.146)	500
Membership with **market** access vs membership without market access	0.884*** (0.131)	500

Note: * p<0.10, ** p<0.05, *** p<0.001; Robust S.E. in parentheses

As expected, the magnitudes of the effects are much lower when only members are considered (Table 6). This is a sign that our within-membership comparison does help to eliminate some of the remaining biases not addressed in Table 4. Once again, in Table 7 we show that our IPWRA ATT estimates are robust to other estimation strategies.

Table 7. Robustness of ATT for the effect of access to FO services on the CSA adoption

Treatment variable	Outcome variable: CSA index			
	PSM	IPW	RA	No. of obs.
Membership with access to **credit** vs membership without access to credit	0.338** (0.148)	0.350*** (0.116)	0.352*** (0.116)	500
Membership with access to **extension** vs membership without access to extension	0.306* (0.162)	0.285** (0.141)	0.227* (0131)	500
Membership with **market** access vs membership without market access	0.607** (0.162)	0.638*** (0.127)	0.605*** (0.129)	500

Note: * p<0.10, ** p<0.05, *** p<0.001; Robust S.E. in parentheses
PSM estimated through the `teffects psmatch` Stata command

IPWRA results with conditional analysis

In Table 6 we presented the effect of access to market, credit and extension services from FOs on CSA adoption comparing members only. We know, however, that farmers may access a combination of the services in varying constellations. For instance, a farmer may access both credit and extension, while another farmer may access credit but not extension. In this case, access to credit can be modelled conditional on access extension. Since we found that extension is accessed by about 80% of the member-farmers, we explore the effect of access to credit and market independently and conditional on access to extension.

Table 8 presents the IPWRA ATT estimates of access to credit conditional on access to extension (with access to extension and without). The results show that when credit is accessed together with extension, 0.52 more practices are adopted on average compared to access to credit without extension. Comparing the results as shown in Table 6 and Table 8, we find that the effect of access to credit together with extension is higher than access to credit only.

Table 8. IPWRA estimates for the effect of access to credit conditional on access to extension on CSA adoption

Treatment variable	Outcome variable: CSA index		
	ATT estimates	No. of obs.	Test for equality in coefficients of the two equations (*a* and *b*)
a) Membership with simultaneous access to **credit** and extension (credit =1; extension =1)	0.521*** (0.140)	402	z = 1.96 and probability 0.05 indicating that there is a *statistically significant difference*. *We reject the null hypothesis that* $\beta_1 = \beta_2$
b) Membership with access to **credit** but without access to extension (credit =1; extension =0)	-0.098 (0.284)	98	

Note: * p<0.10, ** p<0.05, *** p<0.001; Robust S.E. in parentheses

To further demonstrate the effect of access to credit conditional on access to extension, we test the equality of coefficients of the two equations (*a* and *b*), following the procedure described in Clogg *et al.* (1995). In the test of equality in coefficients, we reject the null hypothesis that the two coefficients are equal (Table 8). This indicates that the effect of access to credit simultaneously with extension is significantly different from access to credit without extension. This demonstrates the role of extension as a catalyst that enables the credit to bring out additional effects.

In another constellation, some member-farmers may access market simultaneously with extension services while others may have market access without extension. In this scenario, market access can be modelled conditional on access to extension. The results in Table 9 show the effect of market access conditional on access to extension. Members with simultaneous access to market and extension adopted 0.90 more practices on average compared to members with access to market without extension. While the findings emphasise the role of extension as a catalyst in CSA adoption, in the test for equality in coefficients of the two equations (*c* and *d*) we fail to reject the null hypothesis that the two coefficients are equal. We caution, however, that such a test is highly dependent on the sample size, and as such the findings should be interpreted with care. In our analysis, we lost statistical power since the number of observations was significantly reduced (Table 9).

Table 9. IPWRA ATT estimates for the effect of market access conditional on access to extension on CSA adoption

Treatment variable	Outcome variable: CSA index		
	ATT estimates	No. of obs.	Test for equality in coefficients of the two equations (*c* and *d*)
c) Membership with simultaneous access to **market** and extension (market =1; extension =1)	0.900*** (0.139)	402	z = 0.80 and probability 0.42 indicating that the difference is not statistically significant. *We fail to reject the null hypothesis that* $\beta_1 = \beta_2$
d) Membership with access to **market** access but without extension (market =1; extension =0)	0.560 (0.399)	98	

Note: * p<0.10, ** p<0.05, *** p<0.001; Robust S.E. in parentheses

In yet another constellation, some member-farmers may access both credit and market simultaneously with extension, while other member-farmers may access both credit and market simultaneously without extension. Table 10 presents the results of the effect of access to both credit and market simultaneously conditional on access to extension. When both credit and market are accessed simultaneously with extension, 0.92 more practices are adopted compared to simultaneous access to market and credit without extension. This further demonstrates that extension catalyses simultaneous access to credit and market to bring out additional effects. The test for equality in coefficients of the two equations (*e* and *f*) fails to reject the null hypothesis that the two coefficients are equal, probably because of the lost statistical power given the small sample size.

Table 10. IPWRA ATT effects of simultaneous access to credit and market conditional on access to extension on CSA adoption

Treatment variable	Outcome variable: CSA index		
	ATT estimates	No. of obs.	Test for equality in coefficients of the two equations (*e* and *f*)
e) Membership with simultaneous access to **credit** and **market** with extension (credit & market =1; extension =1)	0.915*** (0.162)	402	z = 0.87 and probability 0.38 indicating that the difference is not statistically significant. *We fail to reject the null hypothesis that* $\beta_1 = \beta_2$
f) Membership with simultaneous access to **credit** and **market** but without extension (credit & market =1; extension =0)	0.363 (0.611)	98	

Note: * p<0.10, ** p<0.05, *** p<0.001; Robust S.E. in parentheses

4.6 Conclusions

This paper connects two important yet often parallel academic debates on international development: one on farmers' adaptation to climate change (Di Falco *et al.*, 2011; Quiroga *et al.*, 2020) and another on the role of FOs in technology adoption (Abebaw and Haile, 2013; Wossen *et al.*, 2017). Specifically, our paper deepens the debate on farmers' adaptation to climate change by identifying how farmers' adaptive capacity can be enhanced. While it has been shown that adaptive capacity is dependent on access to production resources (Smit and Pilifosova, 2003; Williams *et al.*, 2019; Yaro *et al.*, 2014), this paper presents access to credit, market and extension from FOs as one of the mechanisms through which farmers' adaptive capacity can be enhanced in resource-constrained contexts such as in sub-Saharan Africa. A focus on farmers' adaptive capacity in climate change adaptation research minimizes the assumption that the more adaptation options available to farmers the higher the probability of adoption (Vanschoenwinkel *et al.*, 2020). Many studies assume that a higher number of adaptation options increases the likelihood of farmers adopting, yet this ignores the role of farmers' adaptive capacity. Understanding the factors that strengthen farmers' adaptive capacity is important for both policy and development community. This is because developing policies or development interventions that contribute to strengthening the adaptive capacity could potentially improve climate change adaptation.

We used a unique dataset from smallholder potato farmers in Kenya which allow for data disaggregation based on FO membership and access to credit, extension and market services. Our findings show that FOs play an important role in climate change adaptation by strengthening the capacity of smallholders to adopt CSA practices. FOs provide access to credit, extension and markets which increase the members' adaptive capacity and thus enable CSA adoption (Chandra *et al.*, 2017).

We estimate the IPWRA given its doubly robust property to reveal the impact of membership in FOs and access to different FO services on CSA adoption. Overall, the results show that membership increases CSA adoption. However, studying the effect of the simple membership dichotomy (being a member or not) is not very informative, as members differ in their access to services from the FO. To disentangle the effect of membership and the diverse access to services, there is a need for disaggregated analysis. To fill this knowledge gap, we first identified the services that FOs provide to their members to strengthen their adaptive capacity. Second, we estimated the impact of access to the identified services on CSA adoption, considering (a) members versus non-members and (b) members with access to specific services versus members without access to the specific services (within-membership comparison).

Our results show that market access had the highest impact on CSA adoption, followed by credit and extension, respectively. In other words, improving access to market farm produce, providing accessible and affordable credit and offering extension services are promising strategies that foster CSA adoption in resource-constrained contexts. Specifically, market access provides an incentive for farmers to invest in CSA adoption (Chandra *et al.*, 2017). Access to credit relaxes the liquidity constraints, while access to extension increases farmers' knowledge of the CSA practices (Di Falco *et al.*, 2011; Wossen *et al.*, 2017).

The conditional analysis highlights important results. First, when estimating the effect of access to credit conditional on access to extension, the results indicate a higher impact compared to the access to credit without extension. A test of equality of coefficients for the two ATT estimates ((a) access to credit with extension and (b) access to credit without extension) rejects the null hypothesis that the two coefficients are equal. This reveals the role of extension as a service that catalyses credit to generate additional effects. This finding corroborates with Makate *et al.* (2019) who found that access to credit simultaneously with extension has a synergistic impact on CSA adoption. Second, we also find that extension is a catalyst that induces market access to provide additional effects.

This paper makes three important contributions to the literature. First, we demonstrate that FOs contribute to the improvement of smallholder ability to adopt CSA practices through membership and service provision; however, we do not present the FO as the silver bullet for climate change challenges. Second, we show that membership is necessary but not sufficient in explaining the impact of FOs on adoption outcomes. Instead, access to services and their complementarities need to be accounted for; ignoring the role of services may provide an incorrect impact of FOs. Our study, therefore, extends the existing literature on the importance of FOs for smallholder welfare (Bachke, 2019; Fischer and Qaim, 2012b) and technology adoption (Abebaw and Haile, 2013) by considering the role of access to services from FOs.

Third, the results suggest that apart from gender differences which have been widely studied as a source of inequality in climate change adaptation (Azong and Kelso, 2021; Bhattarai, 2020), access to production resources and services is another source of inequality in climate change adaptation. From this study, the diversity in access to extension, market and credit may explain why some farmers better adapt to climate change than others, *ceteris paribus*. This implies that there are multiple sources of inequalities in climate change adaptation given the complexity of climate change and the diversity of farmers and communities. Therefore, attempts to close the inequality gap in climate change adaptation should take an intersectionality perspective rather than a focus on specific sources of inequality (Erwin *et al.*, 2021; Kaijser and Kronsell, 2013).

4.7 Policy and managerial implications

Our findings have important policy implications, specifically at the nexus of climate change adaptation, agricultural development and food policies. We show that CSA cannot be assumed to always deliver the triple-win benefits of maximising synergies between mitigation, adaptation and development (Ellis and Tschakert, 2019). Without policies that support smallholders to adopt a variety of CSA practices with synergistic benefits, any random adoption would not necessarily deliver climate-smart benefits.

Enhancing smallholder adaptive capacity requires designing and implementing policies that address both (a) structural deficits in access to production resources, and (b) organisational structure weaknesses. For effective climate change adaptation strategies, policymakers should not only focus on policies that support the formation of FOs but also on establishing an enabling environment for FOs to provide the necessary resources to members. For instance, the Kenya Climate-smart Agriculture Strategy 2017-2026 acknowledges the low adaptive capacity of local communities (MALF, 2017), yet the strategy does not identify specific policies that enhance smallholder adaptive capacity. Moreover, discrepancies exist between Kenya Climate-smart Agriculture Strategy 2017-2026 and sectoral policies (Faling, 2020). This points to the need for policy alignment to meet the CSA objectives to make significant strides in climate change adaptation.

For the development community, it is necessary to support FOs through partnerships with international, national or private-sector development partners to provide complementary services (i.e., credit, extension and market access) to increase the farmers' adaptive capacity. The leadership of FOs need to come up with viable approaches for providing complementary resources to the farmers. The provision of a wide variety of services by FOs has a managerial implication. That is, how does the leadership balance the different needs of members while at the same time remaining effective and efficient? A viable approach might be to coordinate the provision of services with complementary partners such as public and private extension agencies, input suppliers and NGOs (Abebe *et al.*, 2013).

Finally, although our findings have demonstrated the importance of FOs in shaping smallholder adaptive capacity, questions remain about how the development community can support the formation of FOs, and how FOs can be supported to efficiently provide services to their members. Future research could study community structures and dynamics to identify the factors that should be taken into account in forming new FOs and strengthening existing ones. A study on the organisational structures and the business models of FOs is also necessary for designing and identifying the entry point for support interventions to improve service provision to farmers.

Appendix

Table A1: Logit estimation for the propensity for membership in farmer organization

Variable	Coefficient	Robust Std. Err.	Marginal effects
Sex	-0.060	0.160	-0.013
Age	-0.034	0.045	-0.007
Age squared	0.001	0.001	0.000
Household size	0.195	0.049	0.041***
Education	0.075	0.026	0.016***
Years growing potato	-0.000	0.010	0.000
Total land size	0.246	0.090	0.052
Land ownership	-0.114	0.196	-0.024
Off-farm income	-0.286	0.169	-0.060*
Access climate info	0.485	0.175	0.102***
Motorized transport equipment	0.375	0.189	0.079**
Distance to source of farm inputs	0.014	0.087	0.003
County	0.071	0.172	0.015
Constant	-1.289	1.094	
Number of observations	792		
Prob > chi^2	0.000		

Table A2: Balancing Test on Covariates (Kernel-based Matching)

Variable	**Balance diagnostics: Standardized Bias (SB)**							
	Matching FO members *vs* non-members		Matching members with credit access *vs* members without		Matching members with extension access *vs* members without		Matching members with market access *vs* members without	
	Before matching	**After matching**	Before matching	**After matching**	Before matching	**After matching**	Before matching	**After matching**
Sex	9.2	-1.0	2.2	-0.8	-3.8	2.0	14.0	-5.9
Age	27.6	-6.3	-5.5	-1.3	-10.8	-1.6	-14.8	-8.4
Age squared	27.7	-6.5	-7.7	-1.7	-10.8	-0.1	-15.2	-7.8
Household size	34.9	1.7	7.9	1.3	0.4	-3.9	3.9	3.1
Education	16.9	3.0	6.7	1.3	1.7	4.0	19.8	7.0
Years growing potato	15.2	-7.4	6.8	1.5	-14.7	-3.5	10.4	-10.3
Total land size	33.8	12.5	-4.7	-1.9	9.2	7.1	7.4	1.6
Land ownership	2.1	3.4	-7.8	-0.6	9.2	5.0	11.1	-1.5
Off-farm income	-10.4	3.4	4.6	2.5	-11.5	-1.7	5.0	6.4
Access climate info	28.0	0.8	27.0	0.5	41.0	1.4	57.1	-1.4
Motorized transport equipment	20.1	2.4	7.4	0.7	-14.7	1.9	0.9	1.9
Distance to the main source of farm inputs	4.7	5.0	7.5	-0.3	19.5	8.9	14.7	6.4
County	-4.9	-2.4	-5.8	-0.5	-7.6	-0.3	41.2	4.2

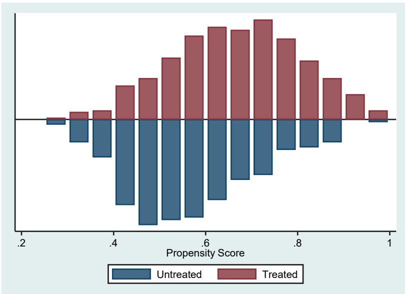

Fig 1a. Propensity score distribution and area of common support for FO members vs non-members

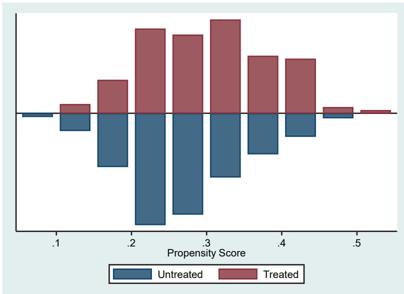

Fig 1b. Propensity score distribution and area of common support for members with credit access vs members without

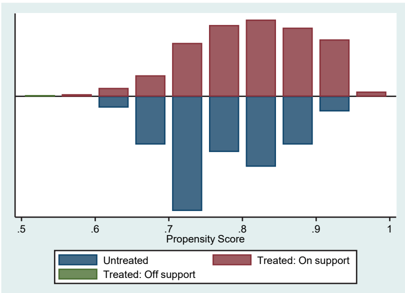

Fig 1c. Propensity score distribution and area of common support for membership with extension access vs members without

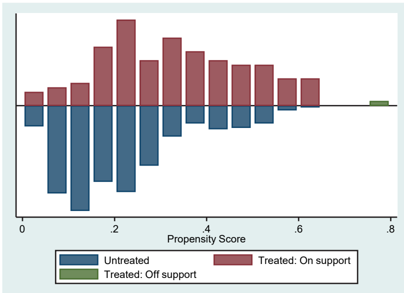

Fig 1d. Propensity score distribution and area of common support for membership with market access vs members without

Figure A1. Distribution of estimated propensity scores

Chapter 5

Farmer-buyer relationship, entrepreneurial orientation and climate change adaptation: the farmers' perspective within the Kenyan potato supply chain

Abstract

Climate change is one of the biggest environmental challenges facing humanity. Within the agri-food industry, climate change is already adversely affecting food production and supply chains and thus farm businesses need to adapt by strengthening their adaptive capacity. This study draws on social exchange theory and entrepreneurship literature to develop a theoretical model that proposes that farmer entrepreneurial orientation (EO) is the mechanism through which the farmer-buyer relationship affects the farmer's adaptive capacity. The proposed theoretical model was tested through a second-order confirmatory factor analysis and a structural equation modelling (SEM) approach using data from 792 smallholder potato farmers in Kenya. We found that farmer EO mediates the association between the farmer-buyer relationship and the farmer's adaptive capacity. This finding suggests that the farmer-buyer relationship can strengthen the farmer's adaptive capacity if the farmer develops its entrepreneurial orientation. We conclude that there is scope for governments and development practitioners to support the development of farmer EO as it is the pathway through which the farmer-buyer relationship affects the farmer's adaptive capacity.

Keywords: Farmer-buyer relationship; Entrepreneurial orientation; Adaptive capacity; Smallholders; Agri-food industry; Kenya

Unpublished chapter:
Kangogo, D., Dentoni, D., Bijman, J. & Parker M. L. Farmer-buyer relationship, entrepreneurial orientation and climate change adaptation: the farmers' perspective within the Kenyan potato supply chain

5.1 Introduction

The 2021 report of the Intergovernmental Panel on Climate Change (IPCC) identifies climate change as one of the biggest environmental challenges facing humanity (IPCC, 2021). Specifically, in the agri-food industry, climate change has adverse impacts on food production and supply chains. Given this turbulent business environment, a critical question in the supply chain management and marketing fields is how businesses adapt? A growing body of literature presents the business-to-business relationship as an important mechanism for climate change adaptation, particularly through improving the adaptive capacity of the business (Finke *et al.*, 2016; Mora Cortez and Johnston, 2020; Najafi-Tavani *et al.*, 2018). Business-to-business relationships improve business adaptive capacity by facilitating resource sharing, facilitating learning processes and managerial support (Wang *et al.*, 2008). The importance of business relationships stem from the fact that individual businesses have limited resources and capabilities to adapt to unprecedented business challenges (Canevari-Luzardo, 2020; Finke *et al.*, 2016; Veal *et al.*, 2010).

Research on business adaptation to change has been undertaken from different viewpoints. One dominant viewpoint is leveraging on buyer-seller relationships to support adaptation to business risks (Beverland, 2005). Other viewpoints focus on knowledge and product innovation (Chang, 2017; Inemek and Matthyssens, 2013); improving business performance (Gorton *et al.*, 2015; Mutonyi *et al.*, 2018); and support of learning processes (Cui *et al.*, 2013). Even with these opportunities, the role of the buyer-seller relationship within the agri-food industry has received little attention (Mutonyi *et al.*, 2018), especially with respect to adapting to climate change (Canevari-Luzardo *et al.*, 2019).

For the agri-food industry, understanding the effect of business relations on adaptation to climate change is particularly important and urgent for developing countries where the farmers' adaptive capacity remains low (Asfaw *et al.*, 2016; Canevari-Luzardo *et al.*, 2019). At the farm level, adaptive capacity refers to the farmer's potential to convert existing resources into successful climate change adaptation strategies (Marshall *et al.*, 2013). Adaptive capacity is important because it affects the ability of farmers to invest their limited resources into climate adaptation strategies (Gallopín, 2006; Pérez *et al.*, 2016).

In this paper, we examine the effect of the farmer-buyer relationship – a specific form of buyer-seller relationship within the agri-food industry – on the farmers adaptive capacity. This responds to recent calls for research that take a relational view of climate change adaptation (Bodin, 2017; Canevari-Luzardo *et al.*, 2019; González-Mon *et al.*, 2019). The relational view of climate change adaptation acknowledges that businesses do not operate or adapt in isolation, rather they interact and are interdependent. Taking the relational perspective, the relationships that farmers and buyers develop and maintain contribute to improving the adaptive capacity of both the farmers and buyers (Canevari-Luzardo *et al.*, 2019; Marshall, 2010), particularly through sharing of resources and risks (Finke *et al.*, 2016; González-Mon *et al.*, 2019; Wang *et al.*, 2008).

In business relationships such as farmer-buyer relationships, the degree to which a relationship affects behaviour is largely influenced by the nature of the relationship (Centola, 2010). If there is mutual satisfaction, commitment and balanced power distribution between the farmers and the buyers, opportunistic behaviour and conflict are minimized. This, in turn, facilitates risk-sharing, knowledge exchange, and access to complementary resources (Claycomb and Frankwick, 2010; Lu *et al.*, 2008). A satisfactory relationship has also been shown to reduce transaction costs and thus enhance efficiency (Mutonyi *et al.*, 2018).

A growing body of literature on relationship marketing suggests that building and maintaining collaborative relationships between sellers and buyers benefit all parties involved. For instance, Mutonyi *et al.* (2018) found that the farmer-buyer relationship benefits both farmer and buyer by reducing post-harvest losses. Gorton *et al.* (2015) found farmer-buyer relationships to improve the quality and quantity of dairy products, to the benefit of both farmers and buyers. Castaño *et al.* (2005) showed that good relationships between farmers and buyers incentivised the uptake of sustainable agricultural practices. González-Mon *et al.* (2019) found that the nature of the business relationship between fishermen and fish buyers improved the adaptive capacity of both parties.

While there are opportunities for leveraging farmer-buyer relationships in improving climate change adaptation, the fundamental question of *how* these relationships influence adaptation remains underexplored (Linnenluecke *et al.*, 2013). This question is relevant for the design of development interventions that seek to support climate change adaptation. We contribute to filling the knowledge gap in two ways. First, by drawing on social exchange theory (SET) the paper tests the hypothesis that the farmer-buyer relationship is positively associated with the farmer's adaptive capacity.

Second, the paper attempts to answer the question of *how* farmer-buyer relationships improve climate change adaptation. Our study focuses on one managerial characteristic that reflects the farmer's cognitive traits and decision-making style (Boling *et al.*, 2016), namely entrepreneurial orientation (EO) (Lumpkin and Dess, 1996). EO reflects the extent to which the farmer as the farm decision-maker identifies opportunities even when faced with climate change; EO is an expression of innovativeness, risk-taking, and proactiveness traits (Lumpkin and Dess, 1996; Morgan *et al.*, 2016). Against this backdrop, this paper tests the hypothesis that farmer EO mediates the relationship between the farmer-buyer relationship and the farmer's adaptive capacity. In other words, we conjecture that the nature of the farmer-buyer relationship encourages the farmer to be innovative, proactive and take calculated risks in the face of climate change, in turn, contributing to the farmer's adaptive capacity as exhibited by the adoption of climate-smart agriculture.

We make use of household survey data collected from 792 smallholder farms within the Kenyan potato supply chain. Potato is the second most important crop in Kenya after maize contributing to household food security, livelihoods and economic development (Okello *et al.*, 2017). Like other crops, potato is adversely affected by climate change, yet, limited research efforts have been directed to understand the mechanisms through which potato farmers adapt.

This paper makes three contributions to the literature. First, it contributes to the scholarly work on the supply chain management and relationship marketing literature by applying SET to understand the effect of the farmer-buyer relationship on the farmer's adaptive capacity. Secondly, a large body of literature presents market access as an opportunity for enhancing adaptation to climate change (Bryan *et al.*, 2009; Eakin *et al.*, 2011). We posit that it is not only market access that matters for climate change adaptation, but also the business relationships that farmers and buyers develop and maintain. Third, by studying the effect of the farmer-buyer relationship on climate change adaptation, we contribute to the recent calls to take a relational view in research on adaptation to business challenges (Canevari-Luzardo *et al.*, 2019; Kamalaldin *et al.*, 2020).

The paper is structured as follows. Section 2 presents a brief theoretical background leading to the formulation of hypotheses regarding the association among the main constructs. Section 3 explains the research methodology used to collect and analyze the data. This is followed by the presentation of the results in section 4. In the final sections, we discuss the implications, study limitations and recommendations for future research.

5.2 Theoretical background and hypotheses

5.2.1 Adaptive capacity

Adaptive capacity refers to the potential of actors to convert existing resources into successful adaptation strategies (Marshall *et al.*, 2013). A stream of literature exists that examine the role of business relationships in shaping adaptive capacity (Canevari-Luzardo *et al.*, 2019; González-Mon *et al.*, 2019; Guercini *et al.*, 2014; Gulati *et al.*, 2005). Business relationships are important for accessing and sharing resources, and for aligning activities of the two businesses involved. Collaborative business relationships improve coordination among businesses and this not only impacts positively to the business performance but also the ability to adapt to business risks and shocks (Gulati *et al.*, 2005).

There are at least three aspects that signify a higher level of adaptive capacity (Marshall *et al.*, 2013; Marshall *et al.*, 2012) these include; the extent of management of risks and uncertainties; the skills in planning and organising; and the interest in adapting to change. For farmers, the ability to manage climate risks and uncertainties reflect the options and opportunities available for adaptation. These include the resources, relationships and skills that the farmer can take advantage of to adapt to climate change (Marshall *et al.*, 2014). A key component of risk management ability is risk perception which is related to individual experience, knowledge, and access to resources and the support available (Taylor, 2003). As such, risk-taking behaviour – one of the dimensions of EO – may explain the difference in the ability to manage climate risks and uncertainties among farmers. Farmer-buyer relationship presents opportunities through which the risk-taking behaviour can be shaped and hence the ability to manage climate risks is determined. This is because the farmer-buyer relationship provides opportunities to access resources and knowledge that would otherwise be inaccessible to the farmers (Canevari-Luzardo *et al.*, 2019) and provide incentives for the investment of own or borrowed resources into uncertain climate adaptation practices (Canevari-Luzardo, 2020).

The level of skills in farm planning and organising denotes the capacity to anticipate, prepare and respond to current and future climate challenges. It is a function of the ability to innovate and respond proactively to make the most of the available resources and opportunities. Without the skills to plan and learn from previous occurrences, any response to change will be reactive (Marshall *et al.*, 2014).

The interest in adapting to change is an aspect of adaptive capacity that reflects the readiness and dedication to learn about how to respond to change (Marshall *et al.*, 2014). The interest to adapt to change enables farmers to identify the sources and consequences of change, and the potential response strategies (Howden *et al.*, 2007). The farmer-buyer relationship may influence the interest in adapting to climate change by providing incentives and confidence to invest in learning, new knowledge and skills (Marshall *et al.*, 2011).

Overall, the farmer's adaptive capacity represents the ability to manage climate risks and uncertainties; the skills in planning and organising; and the level of interest in adapting to climate change.

5.2.2 Social exchange theory underpinning the farmer-buyer relationship

Social exchange theory (SET) was originally proposed by Homans (1958) and it grew at the intersection of economics, sociology and psychology. It was developed to understand the social behaviour between actors' in economic exchanges. In SET, relationships are viewed as a series of repeated exchanges that rely on reciprocity such that favourable actions are rewarded while the unfavourable ones are punished (Blau, 1964; Griffith *et al.*, 2006). In principle, the comparison between the rewards and punishment lead to a decision to continue or terminate the exchange relationships. It is worth noting, however, that rewards and punishments can be economic or social, are highly subjective, dynamic and how they are governed vary from relationship to relationship (Lambe *et al.*, 2001).

Generally, the governance of transactions in exchange relationships can be formal and/or informal (Williamson, 1979). On the one hand, for formal governance, contractual arrangements are used to govern the transactions between exchange parties (Jia *et al.*, 2020). On the other hand, informal governance uses norms and social mechanisms to govern the transactions (Villena *et al.*, 2011). Distinguishing between the two forms of governing transaction in exchange relationship helps in understanding the nature and the role that farmer-buyer relationship plays in strengthening the farmer's adaptive capacity. This is because how transactions in exchange relationships are governed influence the behaviour of the exchange parties (Bodin and Crona, 2009; Villena *et al.*, 2011).

While formal governance through contractual arrangements is well established in the agri-food industry, research on informal governance remains scant (Boniface, 2012), particularly in SSA (Mutonyi *et al.*, 2018). In China, considerable strides have been made to understand informal exchange through the study of *guanxi* relationships (Dong *et al.*, 2017; Lu *et al.*, 2008; Niu *et al.*, 2020).

The informal governance of exchange relationships, especially between farmers and buyers, is relevant for SSA where market-supporting institutions and formal structures are absent or underdeveloped (Sydow *et al.*, 2020). There is, therefore, a need for a deeper understanding of how informal governance of transactions can be leveraged to support climate change adaptation (Canevari-Luzardo *et al.*, 2019).

From a SET perspective, informal mechanisms play crucial roles in governing transactions, such that, the outcomes of the exchange relationship depend on the relational commitment, satisfaction, power-dependency among others (Anderson and Weitz, 1992; Anderson and Narus, 1984; Lambe *et al.*, 2001). Relational commitment refers to the willingness of an actor to invest financial, physical or social resources in a relationship (Morgan and Hunt, 1994). These resources may be invested in adapting to challenges facing the business. According to Krause *et al.* (2007) relational commitment improve the business performance of both the selling and buying parties by encouraging the parties to invest their limited resources.

Relational satisfaction refers to the overall evaluation of an exchange relationship based on relationship outcomes both economic and social (Geyskens *et al.*, 1999). In this paper, relational satisfaction is the cumulative effect developed throughout repeated exchange transactions and not only an outcome of one specific transaction (Anderson *et al.*, 1997). In this perspective, satisfied actors are less likely to exit the relationship through switching to other buyers, instead, they are more likely to nurture the relationship by investing in their businesses (Brown *et al.*, 2020; Murphy and Sashi, 2018). Accordingly, Brown *et al.* (2020) showed that relational satisfaction is an important element of SET which acts as an incentive for transaction-specific investments.

Power-dependency is the ability of an actor to influence another actor's behaviour (Cox *et al.*, 2002; Hunt and Nevin, 1974) implying that the less powerful actor relies on the powerful actor (Anderson and Narus, 1990). Power-dependency is central in exchange relationships as it is a means through which an actor can modify or influence the behaviour of another actor in a relationship (Caniëls and Gelderman, 2007; Zhao *et al.*, 2008). In times of business shocks, power-dependency shapes access to and control over resources necessary to generate innovative activities for adaptation (Jean *et al.*, 2012). It also influences the sharing of risks and value generated between exchange partners (Touboulic *et al.*, 2014). Two sources of power-dependency can be identified: (i) structural power-dependency which is the power exerted by one actor on another because of the resources they possess and control, and (ii) behavioural power-dependency is the power exerted by one actor on another through behavioural manipulation (Caniëls and Roeleveld, 2009). For instance, on the one hand, if one actor can provide financial support to another actor in an exchange relationship, the actor with financial resources may dictate where and how the finance is to be invested. On the other hand, actors with market information may use the information to manipulate the other actors in the exchange (i.e. by creating an artificial glut). Regardless of the source of power, Molm (1991) has shown that power-dependency has diverse outcomes, for instance, they found that the use of power by one party to the disadvantage of the other party to the exchange creates dissatisfaction. In other words, even when the opportunities for short term gains from exercising power may be accrued, the long term continuation of the exchange relationship is negatively affected. Exercising absolute power by one actor may have negative impacts on long range planning and organising for the other actor in the relationship. Structural power-dependency, for instance, has been shown to create lock-in situations where one party to the exchange is heavily dependent upon another party (Narasimhan *et al.*, 2009; Schmitz *et al.*, 2016). In addition, Nyaga *et al.* (2013) and Wang *et al.* (2008) have found that asymmetric power-dependency negatively affects the behaviour of actors and business outcomes, and this may create dissatisfaction and conflict leading to relationship collapse and a diminished ability of businesses to adapt to changes.

Taken together, the relationship between farmers and buyers consist of three elements: relational commitment, relational satisfaction and power-dependency. From a farmers perspective, we postulate that the nature of the relationships that emerge between farmers and buyers are associated with climate change adaptation through improving the farmer's adaptive capacity. Hence, we test the following hypothesis:

H1: The farmer-buyer relationship is positively associated with farmer's adaptive capacity

5.2.3 The mediating role of farmer EO

Whereas we have hypothesized an association between the farmer-buyer relationship and farmer's adaptive capacity, certain conditions may augment or constrain this association. Cognitive characteristics of the farmers and buyers as the main decision-makers of their respective businesses are examples of such conditions. One such cognitive characteristic important in this context is the entrepreneurial orientation (EO) (Boling *et al.*, 2016). EO plays a key role as it determines the ability to access and organise resources to take advantage of emerging opportunities and overcome business challenges (Jiang *et al.*, 2016). For this study, we hypothesize that EO mediates the relationship between farmer-buyer relationship and adaptive capacity. As a mediator, EO represents the decision-making style that is influenced by the nature of farmer-buyer relationship and in turn, it influences entrepreneurial behaviour towards climate change adaptation (Morgan *et al.*, 2016).

EO has gained significant attention as a key construct in the entrepreneurship literature at both the firm and individual levels (Ferreira *et al.*, 2015; Jocic *et al.*, 2021). EO reflects the ability to continuously exhibit innovative, risk-taking and proactive behaviour (Lumpkin and Dess, 1996). EO enable business managers to adapt by reorganising resources and enabling access to necessary for adaptation (Giunipero *et al.*, 2005; Rosenbusch *et al.*, 2011).

Innovativeness is the propensity to experiment adopt and use new practices, products and technologies. Risk-taking depicts the willingness to commit scarce resources to activities and projects in uncertain environments (Lumpkin and Dess, 1996). Proactiveness is an opportunity-seeking behaviour reflecting the ability to try and adopt new practices before others in response to emerging needs and opportunities, and to adapt to changes (Lumpkin and Dess, 1996). Faced with climate change, farmers may exhibit risk-taking behaviour by investing in finance-intensive adaptation strategies, experimenting with new practices and technologies before other farmers.

The level of innovativeness, proactiveness and risk-taking is largely influenced by the businesses relationships that exchange parties are embedded in (Day *et al.*, 1998; Kusa *et al.*, 2018). We posit that when the farmer-buyer relationship is believed to be reliable and effective, then the EO of both the farmers and buyers flourishes. Thus, from the farmer's perspective, we postulated that farmer-buyer relationship facilitates the growth and development of farmer EO which in turn improves the farmer's adaptive capacity. Therefore, we test the hypotheses that;

H2: The farmer-buyer relationship is positively associated with farmer EO

H3: Farmer EO is positively associated with farmer's adaptive capacity

From the foregoing, the study hypothesizes that farmer EO is the mechanism through which the farmer-buyer relationship influence the farmer's adaptive capacity. In other words, rather than testing the direct effect of farmer-buyer relationship on the farmer's adaptive capacity, we posit that farmer EO (consisting of the three dimensions; innovativeness, proactiveness and risk-taking) mediate the association between the farmer-buyer relationship and farmer's adaptive capacity. This hypothesis is consistent with that of Rosenbusch *et al.* (2011) and Khedhaouria *et al.* (2014) who found that overall, the external environment influence EO, in turn, EO transforms the advantages provided by the environment into business opportunities. Thus, the following hypothesis is tested;

H4: Farmer EO mediates the association between the farmer-buyer relationship and the farmer's adaptive capacity.

The theoretical model guiding this research is illustrated in Figure 1.

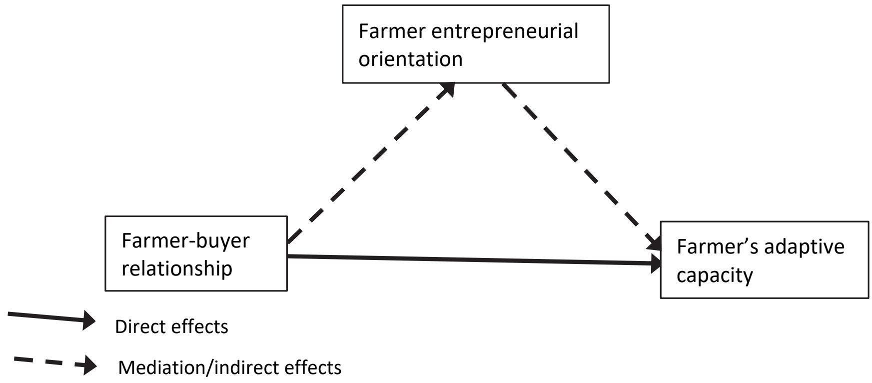

Figure 1. Theoretical model

5.3 Research design

5.3.1 Sample and data collection

To test the hypotheses advanced in this paper, we collected data from smallholders within the potato supply chain in Kenya. We first developed a questionnaire based on previous empirical and conceptual studies. Second, we pretested the questionnaire to check the wording and ease of understanding of the questions. Based on feedback from the pretesting exercise, some of the questions were reworded for easy understanding. Third, a random sample of 792 potato farmers was interviewed by a team of trained enumerators. The survey was conducted between June to August 2019 in Meru and Nakuru counties, which represent two of the main potato producing counties of Kenya.

5.3.2 Variables and measurements

The variables and measurements used are based on previously validated measures which we adapted to our context to improve content reliability and validity. From the proposed theoretical model, the dependent variable is the farmer's adaptive capacity measured in terms of three aspects of farmer's ability to manage climate risks and uncertainties; the level of skills in planning and organising; and the level of interest in adapting to climate change. These measures were adapted from previous studies (Marshall *et al.*, 2016; Marshall *et al.*, 2013).

The independent variable is the farmer-buyer relationships measured as a latent construct comprising of three elements identified in the SET: relational commitment, power-dependency and relational satisfaction. These measures have been used previously to understand farmer-buyer relationships (Batt, 2003; Dlamini-Mazibuko *et al.*, 2019; Morgan and Hunt, 1994). The mediator variable is the farmer EO which is measured as a multidimensional construct comprising of three dimensions namely innovativeness, proactiveness and risk-taking. These measures of EO have been used previously (Ciampi *et al.*, 2021; Kreiser *et al.*, 2012; Lumpkin and Dess, 1996). All the items used were measured on a 7-point Likert scale, with 7 representing strongly agree, and 1 representing strongly disagree.

We also included a set of control variables to account for other factors that may influence the farmer's adaptive capacity. Specifically, the control variables included are the farmer's age, gender, education, land size and membership in farmer organizations. Previous studies have shown that these farmer and farm characteristics may influence the farmer's ability to adapt to climate change (Asfaw *et al.*, 2016).

5.3.3 Common method bias

Given that the data was collected through a household survey, a common method bias (CMB) may be a concern. CMB is a situation where the survey tool and the measurement method cause the observed effects rather than the actual association between the various indicators under study. This may cause the indicators to share some proportion of variation (Podsakoff *et al.*, 2003). To minimize this concern, we applied some procedural remedies. First, the respondents were informed at the beginning of the interview that their identities will be kept private and confidential and therefore it would not be possible to trace the responses back. Second, the respondents were informed that no answer was right or wrong, that it only represented their situation. Third, we adapted the question items to fit our context and pretested the tool to ensure a common understanding among participants. Fourth, we divided the questionnaire into three sections; farmer-buyer relationship, farmer EO and adaptive capacity. Each of these sections was followed by unrelated questions to minimize the possibility of the participants making a systematic connection between sections.

In addition to the above remedies, we conducted Harman's single-factor test which tests the extent to which CMB is a concern (Chang *et al.*, 2010; Podsakoff *et al.*, 2003). Harman's single-factor test requires that all items are loaded in one factor and an unrotated solution should not account for the majority of the variance (over 50%) (Podsakoff *et al.*, 2003). Our results show that a single and an unrotated factor accounts for about 18% of the variance. This indicates that CMB is not a concern in this study.

5.4 Data analysis and results

Following Anderson and Gerbing (1988) two-step structural equation modelling approach, we first test the measurement model through confirmatory factor analysis (CFA). Second, once a satisfactory measurement model is identified, we test the hypothesized relationships through the structural model.

5.4.1 Measurement model

As a first step, we checked the multicollinearity in the data, results show that the variance inflation factor (VIF) is less than 2 suggesting no multicollinearity issue. Second, using AMOS version 25.0, we test the reliability and validity of the indicators used. To proceed with the measurement model the following criteria need to be met, factor loadings > 0.70, AVE >0.50, Cronbach's alpha (∝) and CR > 0.70 (Hair *et al.*, 2016). Table 1 presents the measurement results which include the items factor loadings, Cronbach's alpha (∝) values, the average variance extracted (AVE) and the construct reliability (CR).

From the results in Table 1, two items were deleted to improve the construct validity; one for proactiveness and one for risk-taking. The Cronbach alpha values, CR and AVE of the remaining items are all within the acceptable limits indicating that the data achieved satisfactory convergence and discriminant validity.

Table 1. Construct reliability and validity

Farmer-Buyer relationship	**Loadings**
Relational satisfaction *(∝= 0.850; CR= 0.846; AVE= 0.525)*	
Trading with my major buyer involves low market risk	0.705
There is good cooperation between me and my major buyer	0.813
My major buyer meets my expectations	0.767
My major buyer treats me fairly	0.620
My major buyer is honest	0.704
Power-dependency *(∝= 0.868; CR= 0.870; AVE= 0.627)*	
I am free to choose another buyer at anytime	0.727
My major buyer has better offers than other buyers	0.902
If my relationship with my major buyer was terminated, I would find it difficult to find an alternative buyer of my produce [R]	0.764
My major buyer controls all the information regarding our trading relationship [R]	0.763
Relational Commitment *(∝= 0.951; CR= 0.951; AVE= 0.866)*	
I expect the relationship with my major buyer to continue for a long time	0.922
I am committed to the relationship with my major buyer	0.949
I have invested considerable effort and resources to build a relationship with my major buyer	0.921
Farmers' adaptive capacity	
Management of climate risks *(∝= 0.916; CR=0.917; AVE= 0.786)*	
If the climate changes, there is much I can do to respond	0.915
Climate change brings many opportunities	0.854
Given the changing climate, I feel I have the ability to adapt	0.890
Level of skills in planning and organizing *(∝= 0.897; CR= 0.748; AVE= 0.899)*	
If climate changes, I just hope for the best [R]	0.886
Current approaches for dealing with climate change are sufficient	0.885
I do not believe in long term planning, things are too uncertain [R]	0.821
Level of interest in adapting to climate change *(∝= 0.708 CR= 0.726; AVE= 0.575)*	
I am interested in learning about the effects of climate change on my farm	0.635
I am interested in learning new farming skills	0.864
Farmer Entrepreneurial Orientation	
Risk-taking *(∝= 0.917; CR= 0.918; AVE= 0.848)*	
I prefer to stick with my current farming practices rather than trying new ones [R]	0.945
With the current challenging farming environment, I prefer to avoid further investment in my farm [R]	0.895
I am always ready to try new farming practices	
Innovativeness *(∝= 0.865; CR= 0.871; AVE= 0.693)*	
I like to use new farming practices	0.897
I often improve my farming practices	0.840
I like to have the latest information on farming practices	0.754
Proactiveness *(∝= 0.882; CR= 0.891; AVE= 0.805)*	
I respond more quickly to changes in the farming environment compared to other farmers	0.983
I am among the first farmers to adopt new farming practices in my village	0.802
I am constantly looking out for new ways to improve my farm	

Notes: ∝ Crombach alpha; CR = construct reliability; AVE = average variance extracted
[R] reversed items; items in italics were dropped because of low factor loadings <0.6

Next, we assessed the measurement models (CFA). Both first-order and second-order CFA models were estimated. A combination of fit indices is recommended to provide evidence of a satisfactory model fit. Hu and Bentler (1999) recommend fit indices and their cut-off criteria, these include chi-square/df, comparative fit index (CFI), root mean square error of approximation (RMSEA), standardized root mean squared residual (SRMR) and pclose.

Both the first-order and second-order CFA models exhibit good model fit by all criteria mentioned above. We adopt the second-order CFA for our analysis. Table 2 presents the results of the second-order CFA model. (See Appendix Table A1 for the details of the first-order CFA model).

Table 2. Second-order confirmatory factor model

Measure	**Estimate**	**Threshold**	**Interpretation**
Chi-square	766.84	--	--
DF	309	--	--
CMIN/DF	2.482	Between 1 and 3	Excellent
CFI	0.965	>0.95	Excellent
TLI	0.960	>0.95	Excellent
RMSEA	0.043	<0.06	Excellent
SRMR	0.064	<0.06	Excellent
PClose	0.998	>0.05	Excellent

Note: TLI = Tucker-Lewis index; CFI = comparative fit index; RMSEA = root mean square error of approximation; SRMR = standardized root mean squared residual; DF = degrees of freedom

The summary statistics of the control variables used in the study are presented in Table 3.

Table 3. Farmer and farm characteristics

Variable	**Description**	**Mean**	**Std. Dev.**	**Min**	**Max**
Age	Age of the farmer in years (Years)	49.55	12.67	20	89.00
Gender	Gender of the farmer (1= Male; 0= Female)	0.53	0.50	0	1.00
Education	Years of formal education of the farmer (Years)	9.14	3.36	0	20.00
Total land size owned	Total land owned by the farmer (Ha)	1.21	1.61	0	20.24
Years growing potato	Number of years growing potato (Years)	17.91	12.23	1	60.00
Membership in FO	A member of potato farmer organisation (1= Yes; 0= No)	0.63	0.48	0	1.00
Observations	Number of observations	792			

5.4.2 Structural model and hypotheses testing

To estimate the structural model including the mediation effects James and Brett (1984) recommends the use of the structural equations approach adopting a maximum likelihood approach. To do this, we follow MacKinnon *et al.* (2002) and Collier (2020) procedure of simultaneously estimating the path from the farmer-buyer relationship to the farmer's adaptive capacity through the farmer EO (the mediator) as illustrated in Figure 1. Given the lack of solid theory linking the association between the nature of farmer-buyer relationship and the farmer's adaptive capacity, it is advisable to constrain the direct effects to 0 when testing mediation (James *et al.*, 2006).

The control variables were included in the structural model and regressed on the dependent variable (farmer's adaptive capacity). All the control variables and the independent variable (farmer-buyer relationship) were allowed to covary. The results of the structural model indicate that a good model fit was achieved as shown by the fit indices of chi-square/df = 2.833; CFI = 0.940; RMSEA =0.048; SRMR = 0.069 and pclose = 0.838.

To test the mediation hypothesis, we conducted bootstrapping with 2000 samples and bias-corrected confidence intervals of 95% level to get accurate standard errors as recommended in Shrout and Bolger (2002).

Table 4 presents the results of the direct effects. The results provide support for two hypotheses H2 and H3 but fail to support one H1.

Table 4. Direct effects

Causal path	Path coefficient	S.E	Decision
H1: Farmer-buyer relationship ---> Farmers' adaptive capacity	0.095	0.121	Not supported
H2: Farmer-buyer relationship ---> Farmer EO	0.151***	0.048	Supported
H3: Farmer EO ---> Farmers' adaptive capacity	0.810***	0.619	Supported
Control variables			
Age	-0.004	0.006	
Gender	0.115	0.096	
Education	0.042***	0.018	
Land size	0.029	0.028	
Years of experience growing potato	0.008*	0.005	
Membership in potato farmer organization	0.291***	0.126	

Note: * p<0.10, ** p<0.05, *** p<0.001;
S.E = Standard Errors;

Second, we perform mediation analysis (indirect effects) while accounting for the control variables. The mediation analysis captures the association between farmer-buyer relationship and the farmer's adaptive capacity via the farmer EO.

To test the hypothesis that farmer EO mediates the association between farmer-buyer relationship and farmer's adaptive capacity, we rely on the parameter estimates for the path from farmer-buyer relationship to farmer's adaptive capacity via the farmer EO while setting the direct path from farmer-buyer relationship to farmer's adaptive capacity to zero. A mediation hypothesis is supported if the causal path from the independent variable (farmer-buyer relationship) to the mediator (farmer EO) and from the mediator to the outcome variable (farmer's adaptive capacity) are jointly not equal to zero (MacKinnon *et al.*, 2002).

Table 5 presents the results of the mediation analysis. The results show that the hypothesis is supported suggesting that farmer EO fully mediates the association between farmer-buyer relationship and farmer's adaptive capacity.

Table 5. Mediation effects

Causal path	**Path coefficient**	**S.E**	**Decision**	**Mediation type**
H4: Farmer-buyer relationship ---> Farmer EO ---> Farmer's adaptive capacity	0.123***	0.116	Supported	Full mediation

Note: Mediation effects using the bootstrap method with 2000 iterations, with two-tailed BC 95% CI
* p<0.10, ** p<0.05, *** p<0.001; S.E- Bootstrap Standard Errors

5.5 Discussion

This study contributes to the climate change adaptation literature by examining the role played by the farmer-buyer relationship. Existing literature has paid limited attention to whether and how the farmer-buyer relationship and broadly the value chain relationships are associated with the farmer's adaptive capacity (Canevari-Luzardo, 2019). We attempt to understand the role of farmer-buyer relationship through the social exchange theory (SET). Like previous studies that have applied the SET (Lambe *et al.*, 2001; Luo and Donthu, 2007; Mora Cortez and Johnston, 2020), we identified three elements of SET that collectively define the nature of farmer-buyer relationship and posit that the farmer-buyer relationship is associated directly or indirectly to farmer's adaptive capacity. This study tests the theoretical model using the case of smallholder potato farming in Kenya.

Generally, the results provide evidence that the farmer-buyer relationship is not directly associated with the farmer's adaptive capacity (as shown by the insignificant direct path coefficient in Table 4). However, the association between farmer-buyer relationship and the farmer's adaptive capacity is fully mediated by farmer EO (as shown by the significant indirect path coefficient in Table 5). This implies that for the farmer-buyer relationship to affect the farmer's adaptive capacity, the relationships need to undergo some transformation and be used strategically. The findings indicate that one way of transforming farmer-buyer relationship to improve the farmer's adaptive capacity is by a farmer exploiting her entrepreneurial orientation (Ciampi *et al.*, 2021; Rosenbusch *et al.*, 2011).

From the farmer's perspective, the findings suggest that when farmers perceive the relationships with the buyers to be characterised by relational satisfaction, relational commitment and symmetrical power-dependency, then the farmers are motivated to take calculated risks, act innovatively and proactively in running the farm business. This, in turn, improves climate risk management, improves farm planning and organisation and stimulates the interest in climate change adaptation.

Our findings support the idea that when facing economic and environmental risks, the ability to adapt is a function of the business relationships that business partners develop and maintain (Canevari-Luzardo *et al.*, 2019). Our study provides evidence that farmer-buyer relationship improves the farmer's adaptive capacity by supporting the development of farmer EO.

5.6 Implications

5.6.1 Theoretical and managerial implications

Despite increased scholarly work examining the buyer-seller relationship, the specific form of farmer-buyer relationship remains underexplored (Gorton *et al.*, 2015; Mutonyi *et al.*, 2018). The effect of farmer-buyer relationship is worth examining because the ability of businesses to overcome challenges and improve performance depend on the nature of relationships that business partners develop and maintain (Canevari-Luzardo, 2020). This paper contributes to the wider buyer-seller relationship literature by theorizing and empirically testing the association between the farmer-buyer relationship and farmer's adaptive capacity using a case of smallholder potato farming in Kenya. It is worth noting that in emerging markets, such as Kenya, the agriculture sector is dominated by smallholders who face diverse and dynamic market relationships compared to farmers in developed economies. Particularly, the market environment in emerging markets is characterized by limited or absent market support infrastructure and a weak functioning regulatory system that create institutional voids. With such institutional voids, informal mechanisms are increasingly being used to govern business relationships.

Our findings show that the association between the farmer-buyer relationship and farmer's adaptive capacity is significant only in the presence of farmer EO. We thus contribute to the literature at the intersection of buyer-seller relationship, entrepreneurial orientation and climate change adaptation. First, for the entrepreneurship literature, our study advances to the work of Covin and Lumpkin (2011) who present EO as a "needed construct" in times of change. This study shows that farmer EO is the mechanism through which the farmer-buyer relationship improve climate change adaptation. Consistent with Lumpkin and Dess (1996) farmer EO is presented as the farmer traits and managerial styles that are used to leverage on the relationships with buyers and thus enhancing the ability to adapt to climate change. Second, we show that the farmer-buyer relationship may be viewed as an antecedent of farmer EO. This corroborates with the findings of Xhoxhi *et al.* (2021) who found that farmer EO is shaped by the relationship that they build and maintain with their buyers. Furthermore, our finding strengthens the argument by Rwehumbiza and Marinov (2019) that informal institutions in Kenya and Tanzania shape entrepreneurial orientation. Third, relating to contribution to the buyer-seller relationship literature, this study is one of the first to apply social exchange theory to understand the effect of the farmer-buyer relationship on climate change adaptation in Sub-Saharan Africa.

From a managerial perspective, the findings offer valuable insights for farmers, supply chain managers, policy and development community. The findings suggest that farmer-buyer relationship need to be developed, maintained and nurtured as they enhance farmer EO which in turn improve farmer's adaptive capacity. There is thus scope for governments and development practitioners to provide an enabling environment that supports the formation and nurturing of business relationships between smallholders and buyers. One potential avenue for improving the relationship between farmers and buyers is through farmers leveraging on membership in farmer organizations to increase their bargaining power, minimize power asymmetry and opportunistic behaviour (Hulke and Revilla Diez, 2020). For the development practitioners and supply chain managers, there is a need for a shift from focusing not only on improving market access but also on building and nurturing the business relationships as we have shown that farmer-buyer relationship matters for climate change adaptation.

5.7 Limitations and suggestions for future research

Our empirical findings need to be considered in light of the research limitations this study faced. First, the findings of this study are context-specific, that is, the case of smallholder potato farming in Kenya. Since smallholder farmers in Africa are heterogeneous and embedded in multiple types of relationships with multiple buyers, the findings need to be taken with caution when generalizing. We suggest that since smallholders perform mixed farming, there is a need for future studies to examine the whole farm as opposed to a specific farming component as we did.

Second, given that farmer-buyer relationships specifically, those governed by relational norms are shaped, grow and mature over time, the cross-sectional study design adopted in this study makes it challenging to account for relationship dynamics and associations over time. Future studies could benefit from testing the proposed theoretical model by applying a longitudinal study design that better captures the relationship dynamics and associations over time. Related to this, an important question for future research is how to develop and maintain farmer-buyer relationships that are flexible and adaptable to changes over time while they remain stable to facilitate the development of entrepreneurial orientation.

Third, this study takes only the farmers' perspective, thus the implications drawn are limited to the farmers' views of the farmer-buyer relationship. Studying the proposed theoretical model from both the farmer and the buyer side of the dyad may provide a more nuanced explanation of the proposed theoretical relationships, we leave this for the future.

Appendix

Table A1. First-order confirmatory factor model

Measure	Estimate	Threshold	Interpretation
Chi-square	603.806	--	--
DF	285	--	--
CMIN/DF	2.119	Between 1 and 3	Excellent
CFI	0.975	>0.95	Excellent
TLI	0.97	>0.95	Excellent
RMSEA	0.038	<0.06	Excellent
SRMR	0.042	<0.08	Excellent
PClose	1	>0.05	Excellent

Chapter 6
Discussion and conclusions

6.1 Introduction

Climate change is one of the main threats to agricultural productivity, food security and economic development in Sub-Saharan Africa (SSA). In this part of the world, the majority of the farmers are smallholders facing multiple challenges such as dependence on rain-fed agriculture coupled with increasing frequency and severity of harsh weather conditions, missing markets, low technology adoption and limited access to production resources (Di Falco, 2014). These challenges make the smallholders highly vulnerable to the changes in the farm. Given that food and nutrition security, and livelihoods of the farmers in SSA depend directly or indirectly on agriculture, the need for smallholders to adapt is high in the agenda of research, development practitioners and policy-makers.

There are opportunities for smallholders to cope with and adapt to the effects of climate change, this includes the adoption of climate adaptation strategies such as climate-smart agriculture (CSA) – a strategy which is being increasingly promoted by both governmental and non-governmental organizations as a means to meet the “triple-win” benefits of simultaneously enhancing production and food security, adapting agriculture to climate change while improving mitigation (Campbell *et al.*, 2014; FAO, 2010). Even with the promising benefits of CSA, the ability of smallholder farmers to take advantage of the opportunities is hampered by the farmers’ limited adaptive capacity (Asfaw *et al.*, 2016; Mortreux and Barnett, 2017).

Coupled with the low adaptive capacity, the future of farmers is uncertain given that the climate predictions models indicate that adverse climate events are expected to increase in frequency and severity in the coming years (Girvetz *et al.*, 2019; IPCC, 2021). What the predictions models have not been able to predict with certainty is the type of adverse climate events likely to happen in the future. This uncertainty adds another layer of uncertainty to the future of farmers. For the researchers, developments practitioners supporting farmers to adapt to climate change is still a work-in-progress. What is apparent is that tackling climate change from a risk management standpoint – identifying climate risks and designing interventions to respond – is no longer feasible, given the uncertain future (Darnhofer, 2014; Slijper *et al.*, 2020).

Recently, the concept of resilience has gained traction as an approach to support farmers adapt to the uncertain future (Darnhofer, 2014; Slijper *et al.*, 2020). Resilience refers to the ability to ensure the provision of farm functions while facing multiple shocks and risks through strengthening the absorptive, adaptive and transformative capacities (Meuwissen *et al.*, 2019; Walker *et al.*, 2004). The focus of this thesis is on adaptive capacity one of the building blocks of resilience. Specifically, farmers' adaptive capacity has been identified as one of the reasons for the low adoption of climate adaptation strategies in SSA (Arslan *et al.*, 2017; Asfaw *et al.*, 2016). Marshall *et al.* (2013) describe adaptive capacity as the human potential to plan and organize the farm, experiment and learn from previous experience, seize opportunities and convert existing resources into effective adaptation strategies. Looked at this way, farmers' adaptive capacity relates to the factors that assist to manage and adjust to changes in the farm. In this thesis, we have identified three pathways through which farmers' adaptive capacity can be improved, these are tapping into farmer entrepreneurial orientation, membership and access to FO services, and leveraging on farmer-buyer relationships.

Research such as this conducted to understand the opportunities for improving farmers' adaptive capacity provide a basis for proposing policies, designing effective interventions and investment priorities that support climate change adaptation.

This thesis provides a detailed analysis of the opportunities for improving the adaptive capacity of smallholders in Kenya to increase adaptation to climate change. It does so by addressing four specific albeit interrelated research questions that were raised in Chapter 1 and comprehensively dealt with in Chapters 2 to 5.

This chapter reflects and summarizes the findings of the thesis. The next sections of this chapter are organized as follows. In section 6.2 brief findings to the research questions are provided. Section 6.3 provides a synthesis of the findings in a broader perspective. Section 6.4 discusses the contribution to the literature, followed by the practical implications of the findings in section 6.5. Finally, section 6.6 provides the concluding remarks and implications for future research.

6.2 Brief findings to the research questions

The main focus of Chapter 2 of this thesis was to understand the determinants of farm resilience to climate change. The review specifically answered the following research question:

RQ1: *What are the determinants of farm resilience to climate change and how can farm resilience be improved?*

This research question has been answered through a literature review. From the review, it is evident that smallholders in SSA face multiple and complex challenges in agricultural production. One such complexity relates to climate change, where the future climatic events cannot be predicted with certainty to enable farmers to plan their response strategies. Therefore, the concept of resilience is relevant from policy and development viewpoints as it focuses on building the farmers' capacity to cope with and adapt to the uncertain future (Bennett *et al.*, 2014). Emerging from a wide range of disciplines, resilience has been defined as the ability of a system to absorb, adapt or transform in the face of change to still retain the same functions, structure and identity (Walker *et al.*, 2004). At the farm level, resilience is defined as the ability to ensure the provision of farm functions while facing multiple shocks and risks through strengthening the absorptive, adaptive and transformative capacities (Meuwissen *et al.*, 2019). From the review, we identified farmers' adaptive capacity as a fundamental building block for farm resilience. Further, in terms of how the farmers' adaptive capacity can be strengthened to improve farm resilience, the review identified three pathways; (i) tapping into the farmer cognitive traits, specifically the farmer entrepreneurial orientation (EO) as proposed in Manyise and Dentoni (2021); (ii) membership and access to farmer organization services as proposed in Dapilah *et al.* (2019) and Hulke and Revilla Diez (2020); and (iii) leveraging on the relationships that farmers and buyers of farm produce build and maintain (Canevari-Luzardo *et al.*, 2019).

Following the largely explorative literature review in Chapter 2, Chapters 3 to 5 have empirically tested the propositions relating to the role of farmer EO, membership and access to FO services and farmer-buyer relationship in influencing farmers' adaptive capacity as advanced the literature review.

Regarding the role of farmers EO, the study assessed in Chapter 3 whether or not the farmer EO influence the farmers' adaptive capacity as manifested by farmers adoption of climate-smart agriculture (CSA). The premise is that farmer EO strengthens the farmers' adaptive capacity, this, in turn, improve the adoption of CSA practices. The objective in Chapter 3 is achieved by answering the following research question:

RQ2: *Does farmer entrepreneurial orientation matter for smallholders' adaptation to climate change?*

The main aim of this research question was to understand whether farmer EO matter for CSA adoption among smallholder potato farmers in Kenya. Six CSA practices were considered, these are; irrigation, changing cultivation calendar, use of certified seed, crop rotation, soil testing and intercropping. The study included in the estimation model the three dimensions constituting the farmer EO, these are; risk-taking, innovativeness and proactiveness in addition to the farm and farmer characteristics and institutional factors that have been identified as hindering the adoption of farm technologies (Kassie *et al.*, 2013; Kpadonou *et al.*, 2017). First, the results indicate that the three dimensions of farmer EO influence the adoption of CSA differently. Specifically, risk-taking is positively associated with the adoption of all the CSA practices except intercropping. Innovativeness is negatively associated with the adoption of potato certified seed with no effect on other CSA practices. Proactiveness is positively associated with the application of irrigation, changing of the cultivation calendar and application of potato certified seed but negatively associated with practising intercropping.

Second, when the intensity of resources required for the adoption is considered, the results indicate that risk-taking is positively associated with the adoption of CSA practices that require skilled labour and finance-intensive resources. Innovativeness is negatively associated with the adoption of CSA practices that require the adoption of finance-intensive resources. Proactiveness on the other hand displayed mixed findings, on the one hand, proactiveness is positively associated with the adoption of CSA practices that require finance-intensive resources. On the other hand, proactiveness is negatively associated with the adoption of CSA practices that require unskilled labour-intensive resources. Overall, the findings are evidence that farmer EO matter for climate change adaptation.

In addition to the farmer EO, we also examined the role of farmer organizations (FOs) in strengthening the farmers' adaptive capacity. Chapter 4 evaluated the role of membership ad access to FO services on the adoption of CSA practices. The following research question was answered:

RQ3: *How do membership and access to FO services impact on smallholders' adaptation to climate change?*

Research question 3 evaluates the impact of membership and access to FO services on the smallholders' adoption of CSA practices. this research question is answered in three stages using a quasi-experimental research design. In the first stage, FO member-farmers were compared to non-member farmers on the adoption of CSA practices. Overall, the results show that membership (regardless of whether the member-farmers accessed FO services or not) increased CSA adoption.

While this finding is useful both for the policy and development perspectives, studying only the impacts of the simple membership dichotomy (i.e. being a member or not) is not very informative considering that members differ in access to services from the FO. We, therefore, considered three services that may be provided by FOs to strengthen farmers' adaptive capacity, and thus increase the adoption of CSA. These services are; access to credit, extension and market. In the second stage, we estimated the impact of access to the three services on CSA adoption, considering (a) members versus non-members and (b) members with access to specific services versus members without access to the specific services (within-membership comparison). The results show that market access had the highest impact on CSA adoption, followed by credit and extension, respectively.

In the third stage, we conducted conditional analysis where one service is considered conditional on access to another service. The results show that the impact of access to credit conditional on access to extension is higher compared to the access to credit without extension. Similarly, when access to market conditional to access to extension is considered, the impacts as higher than when access to market without extension. These findings highlight the role of extension as a service that catalyses credit and market to generate additional effects.

Chapter 4 has analysed the impact of FOs – a form of horizontal collaboration among farmers – on the adoption of CSA practices. In chapter 5 the analysis turns to the vertical collaboration in the form of the relationship between farmers and buyers of farm produce. The aim is to understand whether and how the farmer-buyer relationship is associated with farmers' adaptive capacity. The following research question was answered:

RQ4: *How do farmer-buyer relationship influence smallholder adaptation to climate change?*

In Chapter 5, research question 4 which sought to understand the association between the farmer-buyer relationship and farmers' adaptive capacity was answered. Taking the farmers' perspective and estimating a structural equation model the results show that the relationships between farmers and buyers are not directly associated with the farmers' adaptive capacity. However, when mediated by farmer EO, farmer-buyer relationship are positively associated with farmers' adaptive capacity. From the farmers' perspective, this implies that even when the relationships between farmers and buyers are collaborative but farmers do not take advantage by acting entrepreneurially, the relationships may not support climate change adaptation.

6.3 Research findings from a broader perspective

This section provides a synthesis of the findings of the empirical studies from a broader perspective. The findings are discussed in relation to two broad scientific debates. First, is the debate on farmer agency which is the ability of the farmers to make choices whether individually or collectively in response to risks (Bandura, 2001). Specifically, by studying the role of farmer EO in climate change adaptation, we contribute to the calls to understand the role of farmers' agency in strengthening or weakening farm resilience to climate change (Brown and Westaway, 2011; Dwiartama and Rosin, 2014). Second, we contribute to the emerging debate on the relational approach to farm resilience (Canevari-Luzardo *et al.*, 2019; Darnhofer *et al.*, 2016). At the farm level, the relational approach allows for identification and leveraging on relationships and collaborations that are made and maintained in the value chain. In contributing to the relational view, two forms of value chain collaborations were studied, (a) horizontal collaboration represented by the relationships among farmers through membership in farmer organizations, and (b) vertical collaboration represented by the relationships between farmers and buyers (farmer-buyer relationship). The main findings as summarized in section 6.2 are synthesized in light of these three debates.

6.3.1 Research findings from a broader perspective

Farmer agency has been considered as a key determinant for adaptation climate change (Brown and Westaway, 2011). Emphasis on agency helps to underscore the view that farmers are not just passive actors in the face of climate change, instead, farmers are farm managers who through their cognitive characteristics influence farm adaptation to climate change (McLaughlin and Dietz, 2008). Broadly, farmers' agency is related to the farmers' adaptive capacity which is the central focus of climate adaptation literature and is affected by among others the cognitive abilities of the farmer (Brown and Westaway, 2011; Grothmann and Patt, 2005). According to Darnhofer *et al.* (2016) and Tanner *et al.* (2014), farm resilience depends on the ability of the farmer to make sense of available options, and to navigate uncertainty by experimenting, learning, engaging in networks and collaborating. Within this framing, this thesis contributed to the understanding of the role of farmer agency on farm resilience by studying farmer EO. To date, studies linking entrepreneurship and resilience exist at a conceptual level where the basic question is, which one comes first between entrepreneurship or resilience (McInnis-Bowers *et al.*, 2017) and have not been contextualized (Vlasov *et al.*, 2018). Our findings suggest that at the farm level, farmer entrepreneurship, specifically farmer EO is essential for strengthening farm resilience. In this regard, this thesis advocate for the consideration of farmers' agency such as farmer EO in efforts to gain a clearer picture of the factors that strengthen or diminish farm resilience to climate change. The premise is that farmer EO improve farmers' adaptive capacity by enabling farmers to pursue entrepreneurial activities.

6.3.2 Farmer organizations and farm resilience

Farmer organizations (FOs) have been studied widely in SSA as institutional innovations that support smallholders in their agricultural production. The general agreement is that FOs fill the gap left by weak government institutions such as the departments of extension, credit and those tasked with governing markets. FOs fill these gaps by facilitating access to production resources and markets, increasing economies of scale and bargaining power (Fischer and Qaim, 2012b; Hellin *et al.*, 2009; Markelova *et al.*, 2009). This thesis examined the role of FOs in climate change adaptation, a topic that has received little attention despite the smallholders' limited access to resources necessary for climate change adaptation (Hulke and Revilla Diez, 2020; Washington-Ottombre and Pijanowski, 2012). The findings of this thesis contribute to the debate on the role of FOs in enhancing farm resilience. The contribution is two-fold, first, it responds to the question of whether FOs support farm resilience. Overall, our findings show that membership of FOs support smallholders to adapt to climate change. Second, it provides empirical evidence to the question of how does FO support farm resilience. The findings show that it is not only membership but also the access to production resources from FOs that farm resilience. Overall, our findings imply that when studying the impacts of FOs membership is necessary but not sufficient, access to services provided by the FOs needs to be considered.

6.3.3 Farmer-buyer relationship and farm resilience

Relational view emphasizes that there are opportunities for building farm resilience through taking advantage of relationships that the farms make and maintain, for instance, the relationship between the farmers and the wider social and ecological context (Darnhofer *et al.*, 2016) and value chain collaboration (Canevari-Luzardo *et al.*, 2019). In this thesis, the value chain collaboration specifically the vertical collaboration in the form of relationships between the farmers and buyers of farm produce were examined in light of farm resilience. Empirical results point out that farmer-buyer relationship improves farm resilience through strengthening farmer EO. This finding contributes to the emerging debate on the relational view of farm resilience. It does this by extending the work of Canevari-Luzardo *et al.* (2019) who show that how the exchange relations are governed (formal or informal), the level of resource-dependency and the diversification strategies shape the adaptive capacity of the exchange parties. In contributing to this debate, we have shown that farmer-buyer relationship and farmers' adaptive capacity are positively associated only when the association is mediated by farmer EO. Broadly, this implies that exchange relationships should not be viewed in isolation, rather, the characteristics of the exchange parties, such as, the entrepreneurial characteristics need to be considered since they enable the parties to make the most out of the relationships that they are embedded in (Darnhofer, 2021). In sum, our insights on the relational view contribute to shifting the understanding of resilience from being conceptualized as a static characteristic of the farm to a dynamic process that can be influenced by the farmer characteristics and the diverse relations developed within and outside of the farm.

6.4 Contribution to the literature

This thesis contributes to the climate change adaptation literature, specifically it identifies farmers' adaptive capacity as an essential building block for farm resilience to climate change. The specific contribution to the literature relates the three pathways for improving farmers' adaptive capacity, namely; farmer EO, farmer organizations (FOs) and farmer-buyer relationship.

6.4.1 Farmer entrepreneurial orientation

This thesis contributes to the technology adoption literature particularly relating to the adoption of climate change adaptation strategies. Over the last decades since the works of Feder *et al.* (1985), researchers have increasingly studied the factors that influence the adoption of farm technologies and innovations (Gebremariam and Tesfaye, 2018; Kassie *et al.*, 2013; Kpadonou *et al.*, 2017; Kumar *et al.*, 2020). These studies largely examine the role of farmer and farm characteristics and institutional factors in the adoption decisions. However, while the farmer and farm characteristics, and institutional factors play important roles in the adoption decisions, the role of farmer cognitive and behavioural characteristics have remained underexplored (Dessart *et al.*, 2019; Grothmann and Patt, 2005). A handful of studies have attempted to incorporate some cognitive traits such as farmers' risk attitudes (Ali *et al.*, 2019; Barham *et al.*, 2014; van Winsen *et al.*, 2014), farmers' aspirations (Mausch *et al.*, 2018; Mojo *et al.*, 2016) and preferences (Jaeck and Lifran, 2014; Martey *et al.*, 2021). Consistent with the recent work of Morris *et al.* (2017) and Barzola Iza and Dentoni (2020) we argue in this thesis that adoption decisions are not only influenced by farmers' risk, preferences and aspirations, but other cognitive traits also need to be considered, these include among others farmer innovativeness and proactiveness. We contribute to the technology adoption literature by incorporating farmers' risk-taking, innovative and proactive behaviour which altogether constitute the farmer entrepreneurial orientation (Lumpkin and Dess, 1996). Relating to climate change adaptation, the basis is that farmer EO enhance farmers' adaptive capacity and this increase the ability of farmers to adopt climate adaptation strategies. The insights gained from incorporating farmer EO into adoption literature in our view provide a wider overview of the factors that may promote or hinder the adoption of farm innovations.

6.4.2 Farmer Organizations

Although examining the role of farmer organizations (FOs) in supporting smallholders is not a new phenomenon (Bizikova *et al.*, 2020; Grashuis and Su, 2019), little research has been conducted to unravel the mechanism through which FOs support their members. Often, there is a strong assumption that once farmers join FOs they are guaranteed the benefits. In practice, this is not always the case, for instance, Pascucci *et al.* (2011) showed that membership varies depending on access to the benefits provided by FOs to members, as such two membership categories were identified; (i) membership with product delivery – *strong membership* and (ii) membership without product delivery – *soft membership*. Besides, Bernard and Spielman (2009) and Mwambi *et al.* (2020) have provided evidence that some FO members based on their gender, poverty levels and farm location are excluded in the governance of FOs. Arguably, this exclusion may equally have implications for the member access to FO services. In this thesis, we argue that membership does not sufficiently explain the impact of FOs, instead, there is a need to disentangle whether indeed the members used the services provided by the FO. In an attempt to fill this knowledge gap, Chapter 4 of this thesis examined the role of membership and access to FOs services on the adoption of climate adaptation strategies. Our study contributes to the FO literature in two ways, first, it responds to the recent call by Grashuis and Su (2019) for an improvement in the empirical methodologies to allow for robust analysis of the impacts of FOs. Second, we contribute to the limited understanding of the role of FOs in climate change adaptation. Consistent with the findings of Hulke and Revilla Diez (2020) we show that the services provided by FOs improve the member farmers' adaptive capacity.

6.4.3 Farmer-buyer relationship

While buyer-seller relationship has been extensively studied, at least two issues remain. Firstly, the majority of the studies view the exchange relationships from the transaction cost economics (TCE) perspective (Brown *et al.*, 2020; Kim *et al.*, 2010; Wong *et al.*, 2021) and often take the buyers' perspective of the relationships (Claycomb and Frankwick, 2010; González-Mon *et al.*, 2019). Secondly, the majority of the studies focus on buyer-seller relationship in other sectors of the economy other than the agriculture sector (Mutonyi *et al.*, 2018). This thesis contributes to filling these knowledge gaps by, first drawing on the social exchange theory (SET) to explain the exchange relationship between farmers and buyers. SET is particularly relevant in a context such as that of farmers and buyers in Kenya where exchange relationships are governed by informal mechanisms such as trust, satisfaction and the principle of reciprocity (Macchiavello and Morjaria, 2015; Mutonyi *et al.*, 2018). Specifically, relations mechanisms govern exchange relationships presence of weak contract monitoring and enforcement that arise from institutional voids (Macchiavello and Morjaria, 2015). Second, we study the role of the farmer-buyer relationship on smallholders adaptation to climate change which is a specific form of buyer-seller relationship within the potato value chains in Kenya. By studying the role of farmer-buyer relationship on climate change adaptation we contribute to the recent call by Canevari-Luzardo *et al.* (2019) for the need to study value chain relationships as opportunities that shape the perception of climate change and adaptive capacity.

6.5 Practical implications

This thesis has important implications, mainly policy and managerial.

6.5.1 Policy implications

This thesis explored the pathways through which farmers' adaptive capacity can be improved to achieve farmer resilience to climate change. The findings that farmer EO, membership and access to FO services, and leveraging on farmer-buyer relationship improve the farmers' adaptive capacity have several policy implications. In Chapter 3 the finding that farmer EO increase the adoption of climate adaptation strategies by enabling farmers to act entrepreneurially suggest two policy directions. First, that there is a need for policies that enable agricultural extension departments and development agencies to complement agronomic training programs with entrepreneurship training in their extension approaches and the development interventions respectively. Secondly, we have shown that the specific dimensions of farmer EO risk-taking, innovativeness and proactiveness influence the adoption of CSA differently. From a policy perspective, this suggests that there is no one-size-fits-all training program on entrepreneurship, training programs should target the needs of the farmers in relation to the deficiency in the EO dimensions. The above policy directions present opportunities for considering behavioural characteristics when designing development interventions as suggested in Dessart *et al.* (2019).

The findings in Chapter 4 that membership and access to FO services are important in strengthening farm resilience suggest that policies need to focus on the formation and joining FOs in tandem with the provision of an enabling environment for FOs to provide the necessary resources to members. This may be achieved through providing financial and organisational support to FOs to provide services to members or through FOs partnering with international, national or private-sector development partners to provide complementary services.

Finally, in Chapter 5 we showed that farmer-buyer relationship through improving farmer EO strengthens farmers' adaptive capacity. This suggests that there is a need for policies that help in developing, maintaining and nurturing farmer-buyer relationship.

6.5.3 Managerial implications

This thesis provides practical implications for managers and agribusiness firms working or wishing to work with smallholders in SSA. Principally, in Chapter 3 empirical findings suggest that capacity building activities need to focus on the development of farmers' proactive, innovative and risk-taking mindsets and attitudes. This may be achieved through workshops and peer learning initiatives. In the efforts to build farmers' EO capacities, FOs and farmer-buyer relationship represent useful organisational spaces for engaging in entrepreneurship training through supporting the development of entrepreneurial ecosystems (Dentoni and Klerkx, 2015). In Chapter 4, empirical findings point to the need for FO leaders to ensure – through their management decisions – that FOs are inclusive and that members access the FO services equitably. FO leaders need also to ensure that FO access the necessary support needed to provide services to members. In Chapter 5, empirical findings suggest value chain managers need to help structure relationships and collaboration within the value chain, as we have shown that farmer-buyer relationship is positively associated with farmers' adaptive capacity particularly through strengthening the farmer EO.

6.5.4 Implications for the development practitioners

The findings from this thesis inform development practitioners about the development interventions and funding priorities that support climate resilience. Overall, in terms of development interventions, this thesis provide evidence which suggest that development practitioners need to focus their efforts and resources on interventions that build farmers EO; that not only encourage the joining of FOs but also support the FOs to provide production resources to members; and that encourage the development, nurturing and maintaining of farmer-buyer relationship. This is important as we have demonstrated that farmer EO, membership in a farmer organization and access to services, and farmer-buyer relationship improve farmers' adaptive capacity which in turn contribute to farm resilience (Darnhofer, 2021; Meuwissen *et al.*, 2019).

6.6 Concluding remarks and implications for future research

Climate change is one of the threats to humanity (IPCC, 2021). For farmers, climate change threatens agricultural production and their livelihoods, as such, understanding how they can be supported to adapt is indispensable. While this thesis provides evidence on the role of farmer EO, membership and access to FO services and farmer-buyer relationship on climate change adaptation, a number of issues remain. Firstly, this thesis relied on data collected using a cross-sectional design which poses some limitations to the estimation strategies. Future research needs to consider longitudinal research design which allows for a more rigorous analysis of the relationships and casual claims made in this thesis. Secondly, reflecting on the external validity of the findings, this thesis focused on one farm enterprise, that is, potato farming, not the entire portfolio of possible farm enterprises and only in Kenya. This being the case, the findings of our study may raise the question of generalizability, concerning the extent to which our findings apply to other farm enterprises and for different countries. To respond to this question, we note that the problem of limited access to production resources is not unique to a particular farm enterprise or Kenya – all farm enterprises need the same production resources and most countries in SSA are faced with similar challenges. We, therefore, believe that the insights from this research are relevant and applicable to countries with similar contexts to Kenya. Perhaps, our findings may benefit from further research that takes into account all the portfolios of farm enterprises and from other countries.

Finally, the foundation of this thesis hinges on the role of farmers' adaptive capacity as one of the building blocks of farm resilience (Dapilah *et al.*, 2019; Meuwissen *et al.*, 2019). Due to data limitations, we have not been able to ascertain the relationship between farmers' adaptive capacity and farm resilience. In addition, we only analyzed the farmers' perspective of the farmer-buyer relationship in Chapter 5 due to data limitations. Availability of data from both the buyers' and farmers perspectives of the farmer-buyer relationship would have enriched this thesis, we leave these for the future.

References

Abadie, A., & Imbens, G. W. (2011). Bias-Corrected Matching Estimators for Average Treatment Effects. *Journal of Business & Economic Statistics, 29*(1), 1-11. doi:10.1198/jbes.2009.07333

Abadie, A., & Imbens, G. W. (2016). Matching on the Estimated Propensity Score. *Econometrica, 84*(2), 781-807. doi:10.3982/ecta11293

Abate, G. T. (2018). Drivers of agricultural cooperative formation and farmers' membership and patronage decisions in Ethiopia. *Journal of Co-operative Organization and Management, 6*(2), 53-63. doi:10.1016/j.jcom.2018.06.002

Abebaw, D., & Haile, M. G. (2013). The impact of cooperatives on agricultural technology adoption: Empirical evidence from Ethiopia. *Food Policy, 38*, 82-91. doi:10.1016/j.foodpol.2012.10.003

Abebe, G. K., Bijman, J., Pascucci, S., & Omta, O. (2013). Adoption of improved potato varieties in Ethiopia: The role of agricultural knowledge and innovation system and smallholder farmers' quality assessment. *Agricultural Systems, 122*, 22-32. doi:10.1016/j.agsy.2013.07.008

Adger, W. N., Brooks, N., Bentham, G., Agnew, M., & Eriksen, S. (2004). *New indicators of vulnerability and adaptive capacity*. Technical Report 7. Tyndall Centre for Climate Change Research. University of East Anglia, Norwich.

Adomako, S., Narteh, B., Danquah, J. K., & Analoui, F. (2016). Entrepreneurial orientation in dynamic environments. *International Journal of Entrepreneurial Behavior & Research, 22*(5), 616-642. doi:10.1108/ijebr-12-2015-0320

Agrawal, A. (2008). *The role of local institutions in adaptation to climate change*. Paper presented at the Social Dimensions of Climate Change, Social Development Department, The World Bank

Agrawal, A. (2010). Local institutions and adaptation to climate change. In *Social dimensions of climate change: Equity and vulnerability in a warming world* (Vol. 2, pp. 173-178). Washington, DC: The World Bank.

Ainembabazi, J. H., van Asten, P., Vanlauwe, B., Ouma, E., Blomme, G., Birachi, E. A., . . . Manyong, V. M. (2017). Improving the speed of adoption of agricultural technologies and farm performance through farmer groups: evidence from the Great Lakes region of Africa. *Agricultural Economics, 48*(2), 241-259. doi:10.1111/agec.12329

Ajzen, I. (1991). The theory of planned behavior. *Organizational behavior and human decision processes, 50*, 179-211.

Aker, J. C. (2011). Dial "A" for agriculture: a review of information and communication technologies for agricultural extension in developing countries. *Agricultural Economics, 42*(6), 631-647. doi:10.1111/j.1574-0862.2011.00545.x

Akinbami, C. A. O., Olawoye, J. E., Adesina, F. A., & Nelson, V. (2019). Exploring potential climate-related entrepreneurship opportunities and challenges for rural Nigerian women. *Journal of Global Entrepreneurship Research, 9*(1). doi:10.1186/s40497-018-0141-3

Alemayehu, A., & Bewket, W. (2017). Determinants of smallholder farmers' choice of coping and adaptation strategies to climate change and variability in the central highlands of Ethiopia. *Environmental Development, 24*, 77-85. doi:10.1016/j.envdev.2017.06.006

Ali, D. A., Bowen, D., & Deininger, K. (2019). Personality Traits, Technology Adoption, and Technical Efficiency: Evidence from Smallholder Rice Farms in Ghana. *The Journal of Development Studies, 56*(7), 1330-1348. doi:10.1080/00220388.2019.1666978

Amadu, F. O., McNamara, P. E., & Miller, D. C. (2020). Understanding the adoption of climate-smart agriculture: A farm-level typology with empirical evidence from southern Malawi. *World Development, 126*. doi:10.1016/j.worlddev.2019.104692

Amadu, F. O., Miller, D. C., & McNamara, E. (2020b). Agroforestry as a pathway to agricultural yield impacts in climate-smart agriculture investments: Evidence from southern Malawi. *Ecological Economics, 167*. doi:10.1016/j.ecolecon.2019.106443

Amankwah-Amoah, J., Danso, A., & Adomako, S. (2019). Entrepreneurial orientation, environmental sustainability and new venture performance: Does stakeholder integration matter? *Business Strategy and the Environment, 28*(1), 79-87. doi:10.1002/bse.2191

Anderson, E., & Weitz, B. (1992). The Use of Pledges to Build and Sustain Commitment in Distribution Channels. *Journal of Marketing Research, 29*(1), 18-34. doi:10.1177/002224379202900103

Anderson, E. W., Fornell, C., & Rust, R. T. (1997). Customer Satisfaction, Productivity, and Profitability: Differences Between Goods and Services. *Marketing science, 16*(2), 129-145. doi:10.1287/mksc.16.2.129

Anderson, J. C., & Gerbing, D. W. (1988). Structural equation modeling in practice: A review and recommended two-step approach. *Psychological bulletin, 103*(3), 411-423. doi:10.1037/0033-2909.103.3.411

Anderson, J. C., & Narus, J. A. (1984). A Model of the Distributor's Perspective of Distributor-Manufacturer Working Relationships. *Journal of Marketing, 48*(4), 62-74. doi:10.1177/002224298404800407

Anderson, J. C., & Narus, J. A. (1990). A model of distributor firm and manufacturer firm working partnerships. *Journal of Marketing, 54*(1), 42-58. doi:10.1177/002224299005400103

Angeler, D. G., Fried-Petersen, H., Allen, C. R., Garmestani, A., Twidwell, D., Birge, H. E., . . . Wonkka, C. L. (2019). Adaptive capacity in ecosystems. *Adv Ecol Res, 60*, 1-24. doi:10.1016/bs.aecr.2019.02.001

Ansah, I. G. K., Gardebroek, C., & Ihle, R. (2019). Resilience and household food security: a review of concepts, methodological approaches and empirical evidence. *Food Security, 11*(6), 1187-1203. doi:10.1007/s12571-019-00968-1

Apel, R. J., & Sweeten, G. (2010). Propensity ScoreMatching in Criminology and Criminal Justice. In A. R. Piquero & D. Weisburd (Eds.), *Handbook of Quantitative Criminology*. New York: Springer

Araral, E. (2013). A transaction cost approach to climate adaptation: Insights from Coase, Ostrom and Williamson and evidence from the 400-year old zangjeras. *Environmental Science & Policy, 25*, 147-156. doi:10.1016/j.envsci.2012.08.005

Armitage, D. (2005). Adaptive capacity and community-based natural resource management. *Environmental management, 35*(6), 703-715. doi:10.1007/s00267-004-0076-z

Armitage, D. (2007). Building resilient livelihoods through adaptive co-management: the role of adaptive capacity. In *Adaptive co-management: collaboration, learning and multi-level governance. UBC Press, Vancouver, British Columbia, Canada* (pp. 62-82).

Armitage, D., & Plummer, R. (2010). Adapting and transforming: governance for navigating change. In *Adaptive capacity and environmental governance* (pp. 287-302): Springer.

Arslan, A., Belotti, F., & Lipper, L. (2017). Smallholder productivity and weather shocks: Adoption and impact of widely promoted agricultural practices in Tanzania. *Food Policy, 69*, 68-81. doi:10.1016/j.foodpol.2017.03.005

Arslan, A., McCarthy, N., Lipper, L., Asfaw, S., & Cattaneo, A. (2014). Adoption and intensity of adoption of conservation farming practices in Zambia. *Agriculture, Ecosystems & Environment, 187*, 72-86. doi:10.1016/j.agee.2013.08.017

Arslan, A., McCarthy, N., Lipper, L., Asfaw, S., Cattaneo, A., & Kokwe, M. (2015). Climate Smart Agriculture? Assessing the Adaptation Implications in Zambia. *Journal of Agricultural Economics, 66*(3), 753-780. doi:10.1111/1477-9552.12107

Arunrat, N., Wang, C., Pumijumnong, N., Sereenonchai, S., & Cai, W. (2017). Farmers' intention and decision to adapt to climate change: A case study in the Yom and Nan basins, Phichit province of Thailand. *Journal of Cleaner Production, 143*, 672-685. doi:10.1016/j.jclepro.2016.12.058

Aryal, J. P., Jat, M. L., Sapkota, T. B., Khatri-Chhetri, A., Kassie, M., Rahut, D. B., & Maharjan, S. (2018). Adoption of multiple climate-smart agricultural practices in the Gangetic plains of Bihar, India. *International Journal of Climate Change Strategies and Management, 10*(3), 407-427. doi:10.1108/ijccsm-02-2017-0025

Aryal, J. P., Rahut, D. B., Maharjan, S., & Erenstein, O. (2018). Factors affecting the adoption of multiple climate-smart agricultural practices in the Indo-Gangetic Plains of India. *Natural Resources Forum, 42*(3), 141-158. doi:10.1111/1477-8947.12152

Asfaw, S., McCarthy, N., Lipper, L., Arslan, A., & Cattaneo, A. (2016). What determines farmers' adaptive capacity? Empirical evidence from Malawi. *Food Security, 8*(3), 643-664. doi:10.1007/s12571-016-0571-0

Azong, M. N., & Kelso, C. J. (2021). Gender, ethnicity and vulnerability to climate change: The case of matrilineal and patrilineal societies in Bamenda Highlands Region, Cameroon. *Global Environmental Change, 67*. doi:10.1016/j.gloenvcha.2021.102241

Azumah, S. B., Donkoh, S. A., & Ansah, I. G. K. (2017). Contract farming and the adoption of climate change coping and adaptation strategies in the northern region of Ghana. *Environment, Development and Sustainability, 19*(6), 2275-2295. doi:10.1007/s10668-016-9854-z

Bachke, M. E. (2019). Do farmers' organizations enhance the welfare of smallholders? Findings from the Mozambican national agricultural survey. *Food Policy, 89*. doi:10.1016/j.foodpol.2019.101792

Bandura, A. (2001). Social cognitive theory: an agentic perspective. *Annual review of psychology, 52*(1), 1-26. doi:10.1146/annurev.psych.52.1.1

Bardsley, D. K., & Bardsley, A. M. (2014). Organising for socio-ecological resilience: The roles of the mountain farmer cooperative Genossenschaft Gran Alpin in Graubünden, Switzerland. *Ecological Economics, 98*, 11-21. doi:10.1016/j.ecolecon.2013.12.004

Barham, B. L., Chavas, J.-P., Fitz, D., Salas, V. R., & Schechter, L. (2014). The roles of risk and ambiguity in technology adoption. *Journal of Economic Behavior & Organization, 97*, 204-218. doi:10.1016/j.jebo.2013.06.014

Barnes, A. P., Soto, I., Eory, V., Beck, B., Balafoutis, A., Sánchez, B., . . . Gómez-Barbero, M. (2019). Exploring the adoption of precision agricultural technologies: A cross regional study of EU farmers. *Land Use Policy, 80*, 163-174. doi:10.1016/j.landusepol.2018.10.004

Barrett, C. B., Christiaensen, L., Sheahan, M., & Shimeles, A. (2017). On the Structural Transformation of Rural Africa. *Journal of African Economies, 26*(suppl_1), i11-i35. doi:10.1093/jae/ejx009

Barzman, M., Bàrberi, P., Birch, A. N. E., Boonekamp, P., Dachbrodt-Saaydeh, S., Graf, B., . . . Sattin, M. (2015). Eight principles of integrated pest management. *Agronomy for Sustainable Development, 35*(4), 1199-1215. doi:10.1007/s13593-015-0327-9

Barzola Iza, C. L., & Dentoni, D. (2020). How entrepreneurial orientation drives farmers' innovation differential in Ugandan coffee multi-stakeholder platforms. *Journal of Agribusiness in Developing and Emerging Economies, 10*(5), 629-650. doi:10.1108/jadee-01-2020-0007

Barzola Iza, C. L., Dentoni, D., Mordini, M., Isubikalu, P., Oduol, J. B. A., & Omta, O. (2019). The role of farmers' entrepreneurial orientation on agricultural innovations in Ugandan multi-stakeholder platform. In *The Climate-Smart Agriculture Papers* (pp. 201-213): Springer, Cham.

Batt, P. J. (2003). Examining the performance of the supply chain for potatoes in the Red River Delta using a pluralistic approach. *Supply Chain Management: An International Journal, 8*(5), 442-454. doi:10.1108/13598540310500277

Bechtold, K.-B., & Abdulai, A. (2014). Combining attitudinal statements with choice experiments to analyze preference heterogeneity for functional dairy products. *Food Policy, 47*, 97-106. doi:10.1016/j.foodpol.2014.05.007

Behzadi, G., O'Sullivan, M. J., Olsen, T. L., Scrimgeour, F., & Zhang, A. (2017). Robust and resilient strategies for managing supply disruptions in an agribusiness supply chain. *International Journal of Production Economics, 191*, 207-220. doi:10.1016/j.ijpe.2017.06.018

Belderbos, R., Carree, M., Diederen, B., Lokshin, B., & Veugelers, R. (2004). Heterogeneity in R&D cooperation strategies. *International Journal of Industrial Organization, 22*(8-9), 1237-1263. doi:10.1016/j.ijindorg.2004.08.001

Bell, P., Namoi, N., Lamanna, C., Corner-Dolloff, C., Girvetz, E. H., Thierfelder, C., & Rosenstock, T. S. (2018). *A Practical Guide to Climate-Smart Agriculture Technologies in Africa*. CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS), (Working Paper No. 224).

Below, T. B., Mutabazi, K. D., Kirschke, D., Franke, C., Sieber, S., Siebert, R., & Tscherning, K. (2012). Can farmers' adaptation to climate change be explained by socio-economic household-level variables? *Global Environmental Change, 22*(1), 223-235. doi:10.1016/j.gloenvcha.2011.11.012

Béné, C., Newsham, A., Davies, M., Ulrichs, M., & Godfrey-Wood, R. (2014). Review Article: Resilience, Poverty and Development. *Journal of International Development, 26*(5), 598-623. doi:10.1002/jid.2992

Bennett, E., Carpenter, S., Gordon, L., Ramakutty, N., Balvanera, P., Campbell, B., & Spierenburg, M. (2014). Resilient thinking for a more sustainable agriculture. *The Solutions Journal, 5*(5), 65-75.

Bentley, J. W. (2006). Folk experiments. *Agriculture and Human Values, 23*(4), 451-462. doi:10.1007/s10460-006-9017-1

Benton, W. C., & Maloni, M. (2005). The influence of power driven buyer/seller relationships on supply chain satisfaction. *Journal of Operations Management, 23*(1), 1-22. doi:10.1016/j.jom.2004.09.002

Bernard, T., & Spielman, D. J. (2009). Reaching the rural poor through rural producer organizations? A study of agricultural marketing cooperatives in Ethiopia. *Food Policy, 34*(1), 60-69. doi:10.1016/j.foodpol.2008.08.001

Bernier, Q., Meinzen-Dick, R. S., Kristjanson, P. M., Haglund, E., Kovarik, C., Bryan, E., . . . Silvestri, S. (2015). *Gender and institutional aspects of climate-smart agricultural practices: evidence from Kenya*. CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS), (Working Paper No. 79).

Beverland, M. (2005). Adapting within relationships to adapt to market-led change: Does relationship success lead to marketplace inertia? *Industrial Marketing Management, 34*(6), 577-589. doi:10.1016/j.indmarman.2004.09.023

Bhattarai, B. (2020). How do gender relations shape a community's ability to adapt to climate change? Insights from Nepal's community forestry. *Climate and Development, 12*(10), 876-887. doi:10.1080/17565529.2019.1701971

Bijman, J. (2008). *Contract farming in developing countries: an overview*. Retrieved from

Bijman, J., Muradian, R., & Schuurman, J. (2016). *Cooperatives, economic democratization and rural development*. Cheltenham, UK: Edward Elgar Publishing.

Bijman, J., Omta, S., Trienekens, J., Wijnands, J., & Wubben, E. (2006). Management and organization in international agri-food chains and networks. *International Agri-Food Chains and Networks: Management and Organization, Wageningen Academic Publishers, Wageningen*, 15-30.

Bizikova, L., Nkonya, E., Minah, M., Hanisch, M., Turaga, R. M. R., Speranza, C. I., . . . Timmers, B. (2020). A scoping review of the contributions of farmers' organizations to smallholder agriculture. *Nature Food, 1*(10), 620-630. doi:10.1038/s43016-020-00164-x

Blau, P. M. (1964). *Exchange and Power in Social Life*. New York: Wiley.

Bodin, Ö. (2017). Collaborative environmental governance: achieving collective action in social-ecological systems. *Science, 357*(6352). doi:10.1126/science.aan1114

Bodin, Ö., & Crona, B. I. (2009). The role of social networks in natural resource governance: What relational patterns make a difference? *Global Environmental Change, 19*(3), 366-374. doi:10.1016/j.gloenvcha.2009.05.002

Boling, J. R., Pieper, T. M., & Covin, J. G. (2016). CEO Tenure and Entrepreneurial Orientation within Family and Nonfamily Firms. *Entrepreneurship Theory and Practice, 40*(4), 891-913. doi:10.1111/etap.12150

Boniface, B. (2012). Producer relationships segmentation in Malaysia's milk supply chains. *British Food Journal, 114*(10), 1501-1516. doi:10.1108/00070701211263046

Borda-Rodriguez, A., & Vicari, S. (2015). Coffee Co-Operatives in Malawi: Building Resilience through Innovation. *Annals of Public and Cooperative Economics, 86*(2), 317-338. doi:10.1111/apce.12075

Borges, J. A. R., Tauer, L. W., & Lansink, A. G. J. M. O. (2016). Using the theory of planned behavior to identify key beliefs underlying Brazilian cattle farmers' intention to use improved natural grassland: A MIMIC modelling approach. *Land Use Policy, 55*, 193-203. doi:10.1016/j.landusepol.2016.04.004

Borsky, S., & Spata, M. (2018). The Impact of Fair Trade on Smallholders' Capacity to Adapt to Climate Change. *Sustainable Development, 26*(4), 379-398. doi:10.1002/sd.1712

Boudreaux, C. J., Nikolaev, B. N., & Klein, P. (2019). Socio-cognitive traits and entrepreneurship: The moderating role of economic institutions. *Journal of Business Venturing, 34*(1), 178-196. doi:10.1016/j.jbusvent.2018.08.003

Bowman, M. S., & Zilberman, D. (2013). Economic Factors Affecting Diversified Farming Systems. *Ecology and Society, 18*(1). doi:10.5751/es-05574-180133

Boyabatlı, O., Nasiry, J., & Zhou, Y. (2019). Crop Planning in Sustainable Agriculture: Dynamic Farmland Allocation in the Presence of Crop Rotation Benefits. *Management Science*. doi:10.1287/mnsc.2018.3044

Boyd, E., Osbahr, H., Ericksen, P. J., Tompkins, E. L., Lemos, M. C., & Miller, F. (2008). Resilience and 'Climatizing' Development: Examples and policy implications. *Development, 51*(3), 390-396. doi:10.1057/dev.2008.32

Brown, J. R., Crosno, J. L., Liu, Y., & Dev, C. S. (2020). Relationship satisfaction: An overlooked marketing channel safeguard. *Industrial Marketing Management, 87*, 171-180. doi:10.1016/j.indmarman.2020.01.011

Brown, K., & Westaway, E. (2011). Agency, Capacity, and Resilience to Environmental Change: Lessons from Human Development, Well-Being, and Disasters. *Annual Review of Environment and Resources, 36*(1), 321-342. doi:10.1146/annurev-environ-052610-092905

Bryan, E., Deressa, T. T., Gbetibouo, G. A., & Ringler, C. (2009). Adaptation to climate change in Ethiopia and South Africa: options and constraints. *Environmental Science & Policy, 12*(4), 413-426. doi:10.1016/j.envsci.2008.11.002

Brzozowski, J., & Cucculelli, M. (2016). Proactive and Reactive Attitude to Crisis: Evidence from European Firms. *Entrepreneurial Business and Economics Review, 4*(1), 181-191. doi:10.15678/eber.2016.040111

Buli, B. M. (2017). Entrepreneurial orientation, market orientation and performance of SMEs in the manufacturing industry. *Management Research Review, 40*(3), 292-309. doi:10.1108/mrr-07-2016-0173

Burke, M., & Emerick, K. (2016). Adaptation to Climate Change: Evidence from US Agriculture. *American Economic Journal: Economic Policy, 8*(3), 106-140. doi:10.1257/pol.20130025

Caliendo, M., & Kopeinig, S. (2008). Some Practical Guidance for the Implementation of Propensity Score Matching. *Journal of Economic Surveys, 22*(1), 31-72. doi:10.1111/j.1467-6419.2007.00527.x

Campbell, B. M., Thornton, P., Zougmoré, R., van Asten, P., & Lipper, L. (2014). Sustainable intensification: What is its role in climate smart agriculture? *Current Opinion in Environmental Sustainability, 8*, 39-43. doi:10.1016/j.cosust.2014.07.002

Canevari-Luzardo, L. (2020). Climate change adaptation in the private sector: application of a relational view of the firm. *Climate and Development, 12*(3), 216-227. doi:10.1080/17565529.2019.1613214

Canevari-Luzardo, L. M. (2019). Value chain climate resilience and adaptive capacity in micro, small and medium agribusiness in Jamaica: a network approach. *Regional Environmental Change, 19*(8), 2535-2550. doi:10.1007/s10113-019-01561-0

Canevari-Luzardo, L. M., Berkhout, F., & Pelling, M. (2019). A relational view of climate adaptation in the private sector: How do value chain interactions shape business perceptions of climate risk and adaptive behaviours? *Business Strategy and the Environment, 29*(2), 432-444. doi:10.1002/bse.2375

Caniëls, M. C. J., & Gelderman, C. J. (2007). Power and interdependence in buyer supplier relationships: A purchasing portfolio approach. *Industrial Marketing Management, 36*(2), 219-229. doi:10.1016/j.indmarman.2005.08.012

Caniëls, M. C. J., & Roeleveld, A. (2009). Power and dependence perspectives on outsourcing decisions. *European Management Journal, 27*(6), 402-417. doi:10.1016/j.emj.2009.01.001

Carpenter, S., Arrow, K., Barrett, S., Biggs, R., Brock, W., Crépin, A.-S., . . . Zeeuw, A. (2012). General Resilience to Cope with Extreme Events. *Sustainability, 4*(12), 3248-3259. doi:10.3390/su4123248

Carpenter, S., Walker, B., Anderies, J. M., & Abel, N. (2001). From Metaphor to Measurement: Resilience of What to What? *Ecosystems, 4*(8), 765-781. doi:10.1007/s10021-001-0045-9

Castaing, P. (2020). Joint liability and adaptation to climate change: evidence from Burkinabe cooperatives. *European Review of Agricultural Economics*. doi:10.1093/eurrag/jbaa020

Castaño, J., Meulenberg, M., & Van Tilburg, A. (2005). The impact of marketing systems on soil sustainability of agriculture in developing countries: a method and an application. *Agricultural Economics, 33*(1), 51-66. doi:10.1111/j.1574-0862.2005.00230.x

Centola, D. (2010). The spread of behavior in an online social network experiment. *Science, 329*(5996), 1194-1197. doi:10.1126/science.1185231

Chandra, A., Dargusch, P., McNamara, K. E., Caspe, A. M., & Dalabajan, D. (2017). A Study of Climate-Smart Farming Practices and Climate-resiliency Field Schools in Mindanao, the Philippines. *World Development, 98*, 214-230. doi:10.1016/j.worlddev.2017.04.028

Chang, J. (2017). The effects of buyer-supplier's collaboration on knowledge and product innovation. *Industrial Marketing Management, 65*, 129-143. doi:10.1016/j.indmarman.2017.04.003

Chang, S.-J., van Witteloostuijn, A., & Eden, L. (2010). From the Editors: Common method variance in international business research. *Journal of International Business Studies, 41*(2), 178-184. doi:10.1057/jibs.2009.88

Chavas, J. P., Chambers, R. G., & Pope, R. D. (2010). Production Economics and Farm Management: a Century of Contributions. *American Journal of Agricultural Economics, 92*(2), 356-375. doi:10.1093/ajae/aaq004

Chen, C., Pan, J., & Lam, S. K. (2013). A review of precision fertilization research. *Environmental Earth Sciences, 71*(9), 4073-4080. doi:10.1007/s12665-013-2792-2

Chen, Z., Huang, Y., & Sternquist, B. (2011). Guanxi practice and Chinese buyer–supplier relationships: The buyer's perspective. *Industrial Marketing Management, 40*(4), 569-580. doi:10.1016/j.indmarman.2010.12.013

Cherry, T. L., Howe, E. L., & Murphy, J. J. (2015). Sharing as risk pooling in a social dilemma experiment. *Ecology and Society, 20*(1). doi:10.5751/es-07390-200168

Ciampi, F., Demi, S., Magrini, A., Marzi, G., & Papa, A. (2021). Exploring the impact of big data analytics capabilities on business model innovation: The mediating role of entrepreneurial orientation. *Journal of Business Research, 123*, 1-13. doi:10.1016/j.jbusres.2020.09.023

Cinner, J. E., Adger, W. N., Allison, E. H., Barnes, M. L., Brown, K., Cohen, P. J., . . . Morrison, T. H. (2018). Building adaptive capacity to climate change in tropical coastal communities. *Nature Climate Change, 8*(2), 117-123. doi:10.1038/s41558-017-0065-x

CIP. (2017). *USAID Kenya Accelerated Value Chain Development Program (AVCD) Potato Value Chain*. International Potato Center.

Clay, N., & King, B. (2019). Smallholders' uneven capacities to adapt to climate change amid Africa's 'green revolution': Case study of Rwanda's crop intensification program. *World Development, 116*, 1-14. doi:10.1016/j.worlddev.2018.11.022

Claycomb, C., & Frankwick, G. L. (2010). Buyers' perspectives of buyer–seller relationship development. *Industrial Marketing Management, 39*(2), 252-263. doi:10.1016/j.indmarman.2008.08.004

Clements, R., Haggar, J., Quezada, A., & Torres, J. (2011). *Technologies for climate change adaptation: agricultural sector*. Roskilde, Denmark: UNEP Risø Centre.

Clogg, C. C., Petkova, E., & Haritou, A. (1995). Statistical Methods for Comparing Regression Coefficients Between Models. *American Journal of Sociology, 100*(5), 1261-1293. doi:10.1086/230638

Cohen, P. J., Lawless, S., Dyer, M., Morgan, M., Saeni, E., Teioli, H., & Kantor, P. (2016). Understanding adaptive capacity and capacity to innovate in social-ecological systems: Applying a gender lens. *Ambio, 45*(Suppl 3), 309-321. doi:10.1007/s13280-016-0831-4

Collier, D., LaPorte, J., & Seawright, J. (2012). Putting Typologies to Work. *Political Research Quarterly, 65*(1), 217-232. doi:10.1177/1065912912437162

Collier, J. E. (2020). *Applied structural equation modeling using AMOS: Basic to advanced techniques*. New York: Routledge.

Córdova, A. (2009). Methodological note: Measuring relative wealth using household asset indicators. *AmericasBarometer Insights, 6*, 1-9.

Covin, J. G., & Lumpkin, G. T. (2011). Entrepreneurial Orientation Theory and Research: Reflections on a Needed Construct. *Entrepreneurship Theory and Practice, 35*(5), 855-872. doi:10.1111/j.1540-6520.2011.00482.x

Covin, J. G., & Wales, W. J. (2012). The Measurement of Entrepreneurial Orientation. *Entrepreneurship Theory and Practice, 36*(4), 677-702. doi:10.1111/j.1540-6520.2010.00432.x

Cox, A., Ireland, P., Lonsdale, C., Sanderson, J., & Watson, G. (2002). *Supply chains, markets and power - Mapping buyer and supplier power regimes*. London: Routledge.

Cropanzano, R., & Mitchell, M. S. (2005). Social Exchange Theory: An Interdisciplinary Review. *Journal of Management, 31*(6), 874-900. doi:10.1177/0149206305279602

Cui, N., Wen, N., Xu, L., & Qin, Y. (2013). Contingent effects of managerial guanxi on new product development success. *Journal of Business Research, 66*(12), 2522-2528. doi:10.1016/j.jbusres.2013.05.044

Czekaj, M., Adamsone-Fiskovica, A., Tyran, E., & Kilis, E. (2020). Small farms’ resilience strategies to face economic, social, and environmental disturbances in selected regions in Poland and Latvia. *Global Food Security, 26*. doi:10.1016/j.gfs.2020.100416

Dapilah, F., Nielsen, J. Ø., & Friis, C. (2019). The role of social networks in building adaptive capacity and resilience to climate change: a case study from northern Ghana. *Climate and Development, 12*(1), 42-56. doi:10.1080/17565529.2019.1596063

Darnhofer, I. (2010). Strategies of family farms to strengthen their resilience. *Environmental Policy and Governance, 20*(4), 212-222. doi:10.1002/eet.547

Darnhofer, I. (2014). Resilience and why it matters for farm management. *European Review of Agricultural Economics, 41*(3), 461-484. doi:10.1093/erae/jbu012

Darnhofer, I. (2021). Resilience or how do we enable agricultural systems to ride the waves of unexpected change? *Agricultural Systems, 187*. doi:10.1016/j.agsy.2020.102997

Darnhofer, I., Bellon, S., Dedieu, B., & Milestad, R. (2010). Adaptiveness to enhance the sustainability of farming systems. A review. *Agronomy for Sustainable Development, 30*(3), 545-555. doi:10.1051/agro/2009053

Darnhofer, I., Fairweather, J., & Moller, H. (2011). Assessing a farm's sustainability: insights from resilience thinking. *International Journal of Agricultural Sustainability, 8*(3), 186-198. doi:10.3763/ijas.2010.0480

Darnhofer, I., Lamine, C., Strauss, A., & Navarrete, M. (2016). The resilience of family farms: Towards a relational approach. *Journal of Rural Studies, 44*, 111-122. doi:10.1016/j.jrurstud.2016.01.013

Day, J., Dean, A. A., & Reynolds, P. L. (1998). Relationship marketing: its key role in entrepreneurship. *Long Range Planning, 31*(6), 828-837. doi:10.1016/S0024-6301(98)80019-8

De Rosa, M., McElwee, G., & Smith, R. (2019). Farm diversification strategies in response to rural policy: a case from rural Italy. *Land Use Policy, 81*, 291-301. doi:10.1016/j.landusepol.2018.11.006

Dentoni, D., & Klerkx, L. (2015). Co-managing public research in Australian fisheries through convergence–divergence processes. *Marine Policy, 60*, 259-271. doi:10.1016/j.marpol.2015.07.001

Dentoni, D., Pinkse, J., & Lubberink, R. (2019). *A complex adaptive system view on business model partnerships for sustainability.* Paper presented at the 6th Cross-Sector Social Interactions conference, Copenhagen, Denmark, 10 June 2018.

Dessart, F. J., Barreiro-Hurlé, J., & van Bavel, R. (2019). Behavioural factors affecting the adoption of sustainable farming practices: a policy-oriented review. *European Review of Agricultural Economics, 46*(3), 417-471. doi:10.1093/erae/jbz019

Devaux, A., Horton, D., Velasco, C., Thiele, G., López, G., Bernet, T., . . . Ordinola, M. (2009). Collective action for market chain innovation in the Andes. *Food Policy, 34*(1), 31-38. doi:10.1016/j.foodpol.2008.10.007

Di Falco, S. (2014). Adaptation to climate change in Sub-Saharan agriculture: assessing the evidence and rethinking the drivers. *European Review of Agricultural Economics, 41*(3), 405-430. doi:10.1093/erae/jbu014

Di Falco, S., & Bulte, E. (2013). The Impact of Kinship Networks on the Adoption of Risk-Mitigating Strategies in Ethiopia. *World Development, 43*, 100-110. doi:10.1016/j.worlddev.2012.10.011

Di Falco, S., Doku, A., & Mahajan, A. (2019). Peer effects and the choice of adaptation strategies. *Agricultural Economics, 51*(1), 17-30. doi:10.1111/agec.12538

Di Falco, S., Veronesi, M., & Yesuf, M. (2011). Does Adaptation to Climate Change Provide Food Security? A Micro-Perspective from Ethiopia. *American Journal of Agricultural Economics, 93*(3), 829-846. doi:10.1093/ajae/aar006

Dias, C. S. L., Rodrigues, R. G., & Ferreira, J. J. (2019). What's new in the research on agricultural entrepreneurship? *Journal of Rural Studies, 65*, 99-115. doi:10.1016/j.jrurstud.2018.11.003

Dirks, K. T., & Ferrin, D. L. (2001). The Role of Trust in Organizational Settings. *Organization Science, 12*(4), 450-467. doi:10.1287/orsc.12.4.450.10640

Dlamini-Mazibuko, B. P., Ferrer, S., & Ortmann, G. (2019). Examining the farmer-buyer relationships in vegetable marketing channels in Eswatini. *Agrekon, 58*(3), 369-386. doi:10.1080/03031853.2019.1596824

Dong, W., Ma, Z., & Zhou, X. (2017). Relational governance in supplier-buyer relationships: The mediating effects of boundary spanners' interpersonal guanxi in China's B2B market. *Journal of Business Research, 78*, 332-340. doi:10.1016/j.jbusres.2016.12.029

Dorfman, J. H. (1996). Modeling Multiple Adoption Decisions in a Joint Framework. *American Journal of Agricultural Economics, 78*(3), 547-557. doi:10.2307/1243273

Doughty, C. A. (2015). Building climate change resilience through local cooperation: a Peruvian Andes case study. *Regional Environmental Change, 16*(8), 2187-2197. doi:10.1007/s10113-015-0882-2

Douglass-Gallagher, E., & Stuart, D. (2019). Crop Growers' Adaptive Capacity to Climate Change: A Situated Study of Agriculture in Arizona's Verde Valley. *Environ Manage, 63*(1), 94-109. doi:10.1007/s00267-018-1114-6

Dwiartama, A., & Rosin, C. (2014). Exploring agency beyond humans: the compatibility of Actor-Network Theory (ANT) and resilience thinking. *Ecology and Society, 19*(3). doi:10.5751/es-06805-190328

Dwyer, F. R., Schurr, P. H., & Oh, S. (1987). Developing Buyer-Seller Relationships. *Journal of Marketing, 51*(2), 11-27. doi:10.1177/002224298705100202

Eakin, H. (2005). Institutional change, climate risk, and rural vulnerability: Cases from Central Mexico. *World Development, 33*(11), 1923-1938. doi:10.1016/j.worlddev.2005.06.005

Eakin, H., Bojorquez-Tapia, L. A., Monterde Diaz, R., Castellanos, E., & Haggar, J. (2011). Adaptive capacity and social-environmental change: theoretical and operational modeling of smallholder coffee systems response in Mesoamerican Pacific Rim. *Environmental management, 47*(3), 352-367. doi:10.1007/s00267-010-9603-2

Eakin, H., & Lemos, M. C. (2006). Adaptation and the state: Latin America and the challenge of capacity-building under globalization. *Global Environmental Change, 16*(1), 7-18. doi:10.1016/j.gloenvcha.2005.10.004

Eakin, H., & Lemos, M. C. (2010). Institutions and change: The challenge of building adaptive capacity in Latin America. *Global Environmental Change, 20*(1), 1-3. doi:10.1016/j.gloenvcha.2009.08.002

Eakin, H., York, A., Aggarwal, R., Waters, S., Welch, J., Rubiños, C., . . . Anderies, J. M. (2015). Cognitive and institutional influences on farmers' adaptive capacity: insights into barriers and opportunities for transformative change in central Arizona. *Regional Environmental Change, 16*(3), 801-814. doi:10.1007/s10113-015-0789-y

Ellis, N. R., & Tschakert, P. (2019). Triple-wins as pathways to transformation? A critical review. *Geoforum, 103*, 167-170. doi:10.1016/j.geoforum.2018.12.006

Engelen, A., Kube, H., Schmidt, S., & Flatten, T. C. (2014). Entrepreneurial orientation in turbulent environments: The moderating role of absorptive capacity. *Research Policy, 43*(8), 1353-1369. doi:10.1016/j.respol.2014.03.002

Eriksen, S., Schipper, E. L. F., Scoville-Simonds, M., Vincent, K., Adam, H. N., Brooks, N., . . . West, J. J. (2021). Adaptation interventions and their effect on vulnerability in developing countries: Help, hindrance or irrelevance? *World Development, 141*. doi:10.1016/j.worlddev.2020.105383

Erwin, A., Ma, Z., Popovici, R., Salas O'Brien, E. P., Zanotti, L., Zeballos Zeballos, E., . . . Arce Larrea, G. R. (2021). Intersectionality shapes adaptation to social-ecological change. *World Development, 138*. doi:10.1016/j.worlddev.2020.105282

Eshima, Y., & Anderson, B. S. (2016). Firm growth, adaptive capability, and entrepreneurial orientation. *Strategic Management Journal, 38*(3), 770-779. doi:10.1002/smj.2532

Etriya, E., Scholten, V. E., Wubben, E. F. M., & Omta, S. W. F. (2019). The impact of networks on the innovative and financial performance of more entrepreneurial versus less entrepreneurial farmers in West Java, Indonesia. *NJAS - Wageningen Journal of Life Sciences, 89*. doi:10.1016/j.njas.2019.100308

Faling, M. (2020). Framing agriculture and climate in Kenyan policies: a longitudinal perspective. *Environmental Science & Policy, 106*, 228-239. doi:10.1016/j.envsci.2020.01.014

Falkowski, J. (2015). Resilience of farmer-processor relationships to adverse shocks: the case of dairy sector in Poland. *British Food Journal, 117*(10), 2465-2483. doi:10.1108/bfj-12-2014-0433

FAO. (2010). *Climate-Smart Agriculture: Policies, Practices and Financing for Food Security, Adaptation and Mitigation*. Rome, FAO.

FAO. (2013). *Resilient livelihoods: disaster risk reduction for food and nutrition security*: Food and Agriculture Organization of the United Nations.
FAOSTAT. (2019). *Food and Agriculture Organization of the United States, Crop and Livestock Products.* Retrieved 22 June 2021 http://www.fao.org/faostat/en/#data/QL.
Fazey, I., Fazey, J. A., Fischer, J., Sherren, K., Warren, J., Noss, R. F., & Dovers, S. R. (2007). Adaptive capacity and learning to learn as leverage for social–ecological resilience. *Frontiers in Ecology and the Environment, 5*(7), 375–380. doi:10.1890/1540-9295
Feder, G., Just, R. E., & Zilberman, D. (1985). Adoption of Agricultural Innovations in Developing Countries: A Survey. *Economic development and cultural change, 33*(2), 255-298. doi:10.1086/451461
Fernández-Giménez, M. E., Batkhishig, B., Batbuyan, B., & Ulambayar, T. (2015). Lessons from the Dzud: Community-Based Rangeland Management Increases the Adaptive Capacity of Mongolian Herders to Winter Disasters. *World Development, 68*, 48-65. doi:10.1016/j.worlddev.2014.11.015
Ferreira, F. A. F., Marques, C. S. E., Bento, P., Ferreira, J. J. M., & Jalali, M. S. (2015). Operationalizing and measuring individual entrepreneurial orientation using cognitive mapping and MCDA techniques. *Journal of Business Research, 68*(12), 2691-2702. doi:10.1016/j.jbusres.2015.04.002
Finke, T., Gilchrist, A., & Mouzas, S. (2016). Why companies fail to respond to climate change: Collective inaction as an outcome of barriers to interaction. *Industrial Marketing Management, 58*, 94-101. doi:10.1016/j.indmarman.2016.05.018
Fintrac. (2015). *USAID-KAVES Potato Value Chain Analysis*.
Fischer, C., & Hartmann, M. (2010). Collaborative advantage, relational risks and sustainable relationships: a literature review and definition. In *Agri-food chain relationships*. Oxfordshire, UK: CABI.
Fischer, E., & Qaim, M. (2012a). Gender, agricultural commercialization, and collective action in Kenya. *Food Security, 4*(3), 441-453. doi:10.1007/s12571-012-0199-7
Fischer, E., & Qaim, M. (2012b). Linking Smallholders to Markets: Determinants and Impacts of Farmer Collective Action in Kenya. *World Development, 40*(6), 1255-1268. doi:10.1016/j.worlddev.2011.11.018
Fitz-Koch, S., Nordqvist, M., Carter, S., & Hunter, E. (2017). Entrepreneurship in the Agricultural Sector: A Literature Review and Future Research Opportunities. *Entrepreneurship Theory and Practice, 42*(1), 129-166. doi:10.1177/1042258717732958
Fleming, A., Hobday, A. J., Farmery, A., van Putten, E. I., Pecl, G. T., Green, B. S., & Lim-Camacho, L. (2014). Climate change risks and adaptation options across Australian seafood supply chains – A preliminary assessment. *Climate Risk Management, 1*, 39-50. doi:10.1016/j.crm.2013.12.003
Folke, C., Carpenter, S. R., Walker, B., Scheffer, M., Chapin, T., & Rockström, J. (2010). Resilience thinking: integrating resilience, adaptability and transformability. *Ecology and Society, 15*(4), 20. doi:http://www.ecologyandsociety.org/vol15/iss4/art20/
Frank, J., & Penrose-Buckley, C. (2012). *Small-scale Farmers and Climate Change: How Can Farmer Organisations and Fairtrade Build the Adaptive Capacity of Smallholders?* : International Institute for Environment and Development.
Freduah, G., Fidelman, P., & Smith, T. F. (2019). A framework for assessing adaptive capacity to multiple climatic and non-climatic stressors in small-scale fisheries. *Environmental Science & Policy, 101*, 87-93. doi:10.1016/j.envsci.2019.07.016
Gallopín, G. C. (2006). Linkages between vulnerability, resilience, and adaptive capacity. *Global Environmental Change, 16*(3), 293-303. doi:10.1016/j.gloenvcha.2006.02.004

Ge, L., Anten, N. P. R., van Dixhoorn, I. D. E., Feindt, P. H., Kramer, K., Leemans, R., . . . Sukkel, W. (2016). Why we need resilience thinking to meet societal challenges in bio-based production systems. *Current Opinion in Environmental Sustainability, 23*, 17-27. doi:10.1016/j.cosust.2016.11.009

Gebrehiwot, T., & van der Veen, A. (2013). Farm level adaptation to climate change: the case of farmer's in the Ethiopian highlands. *Environ Manage, 52*(1), 29-44. doi:10.1007/s00267-013-0039-3

Gebremariam, G., & Tesfaye, W. (2018). The heterogeneous effect of shocks on agricultural innovations adoption: Microeconometric evidence from rural Ethiopia. *Food Policy, 74*, 154-161. doi:10.1016/j.foodpol.2017.12.010

Gellynck, X., Cárdenas, J., Pieniak, Z., & Verbeke, W. (2015). Association between Innovative Entrepreneurial Orientation, Absorptive Capacity, and Farm Business Performance. *Agribusiness, 31*(1), 91-106. doi:10.1002/agr.21394

Geyskens, I., & Steenkamp, J.-B. E. M. (2000). Economic and social satisfaction: measurement and relevance to marketing channel relationships. *Journal of Retailing, 76*(1), 11-32. doi:10.1016/s0022-4359(99)00021-4

Geyskens, I., Steenkamp, J.-B. E. M., & Kumar, N. (1999). A Meta-Analysis of Satisfaction in Marketing Channel Relationships. *Journal of Marketing Research, 36*(2), 223-238. doi:10.1177/002224379903600207

Gildemacher, P. R., Kaguongo, W., Ortiz, O., Tesfaye, A., Woldegiorgis, G., Wagoire, W. W., . . . Leeuwis, C. (2009b). Improving Potato Production in Kenya, Uganda and Ethiopia: A System Diagnosis. *Potato Research, 52*(2), 173-205. doi:10.1007/s11540-009-9127-4

Gildemacher, P. R., Leeuwis, C., Demo, P., Borus, D., Schulte-Geldermann, E., Mundia, P., . . . Struik, P. C. (2012). Positive selection in seed potato production in Kenya as a case of successful research-led innovation. *International Journal of Technology Management & Sustainable Development, 11*(1), 67-92. doi:10.1386/tmsd.11.1.67_1

Giller, K. E. (2013). Can We Define the Term ‘Farming Systems’? A Question of Scale. *Outlook on Agriculture, 42*(3), 149-153. doi:10.5367/oa.2013.0139

Girvetz, E., Ramirez-Villegas, J., Claessens, L., Lamanna, C., Navarro-Racines, C., Nowak, A., . . . Rosenstock, T. S. (2019). Future climate projections in Africa: where are we headed? In *The climate-smart agriculture papers* (pp. 15-27): Springer, Cham.

Gitz, V., & Meybeck, A. (2012). Risks, vulnerabilities and resilience in a context of climate change. In *Building resilience for adaptation to climate change in the agriculture sector* (Vol. 23, pp. 19).

Giunipero, L. C., Denslow, D., & Eltantawy, R. (2005). Purchasing/supply chain management flexibility: Moving to an entrepreneurial skill set. *Industrial Marketing Management, 34*(6), 602-613. doi:10.1016/j.indmarman.2004.11.004

González-Mon, B., Bodin, Ö., Crona, B., Nenadovic, M., & Basurto, X. (2019). Small-scale fish buyers' trade networks reveal diverse actor types and differential adaptive capacities. *Ecological Economics, 164*. doi:10.1016/j.ecolecon.2019.05.018

Gooch, M., & Warburton, J. (2009). Building and Managing Resilience in Community-Based NRM Groups: An Australian Case Study. *Society & Natural Resources, 22*(2), 158-171. doi:10.1080/08941920801967880

Gorton, M., Angell, R., Dries, L., Urutyan, V., Jackson, E., & White, J. (2015). Power, buyer trustworthiness and supplier performance: Evidence from the Armenian dairy sector. *Industrial Marketing Management, 50*, 69-77. doi:10.1016/j.indmarman.2015.05.024

Granovetter, M. (1985). Economic action and social structure: The problem of embeddedness. *American Journal of Sociology, 91*(3), 481-510. doi:10.1086/228311

Grashuis, J., & Su, Y. (2019). A Review of the Empirical Literature on Farmer Cooperatives: Performance, Ownership and Governance, Finance, and Member Attitude. *Annals of Public and Cooperative Economics, 90*(1), 77-102. doi:10.1111/apce.12205

Green, W. H. (2008). *Econometric Analysis.* New Jersey: Prentice Hall.

Greiner, R., & Gregg, D. (2011). Farmers' intrinsic motivations, barriers to the adoption of conservation practices and effectiveness of policy instruments: Empirical evidence from northern Australia. *Land Use Policy, 28*(1), 257-265. doi:10.1016/j.landusepol.2010.06.006

Griffith, D. A., Harvey, M. G., & Lusch, R. F. (2006). Social exchange in supply chain relationships: The resulting benefits of procedural and distributive justice. *Journal of Operations Management, 24*(2), 85-98. doi:10.1016/j.jom.2005.03.003

Groot, J., Cortez-Arriola, J., Rossing, W., Améndola Massiotti, R., & Tittonell, P. (2016). Capturing Agroecosystem Vulnerability and Resilience. *Sustainability, 8*(11). doi:10.3390/su8111206

Grothmann, T., & Patt, A. (2005). Adaptive capacity and human cognition: The process of individual adaptation to climate change. *Global Environmental Change, 15*(3), 199-213. doi:10.1016/j.gloenvcha.2005.01.002

Guercini, S., La Rocca, A., Runfola, A., & Snehota, I. (2014). Interaction behaviors in business relationships and heuristics: Issues for management and research agenda. *Industrial Marketing Management, 43*(6), 929-937. doi:10.1016/j.indmarman.2014.05.007

Guido, Z., Knudson, C., & Rhiney, K. (2020). Will COVID-19 be one shock too many for smallholder coffee livelihoods? *World Dev, 136*, 105172. doi:10.1016/j.worlddev.2020.105172

Gulati, R., Lawrence, P. R., & Puranam, P. (2005). Adaptation in vertical relationships: beyond incentive conflict. *Strategic Management Journal, 26*(5), 415-440. doi:10.1002/smj.458

Gunderson, L. H. (2000). Ecological Resilience—In Theory and Application. *Annual Review of Ecology and Systematics, 31*(1), 425-439. doi:10.1146/annurev.ecolsys.31.1.425

Gupta, J., Termeer, C., Klostermann, J., Meijerink, S., van den Brink, M., Jong, P., . . . Bergsma, E. (2010). The Adaptive Capacity Wheel: a method to assess the inherent characteristics of institutions to enable the adaptive capacity of society. *Environmental Science & Policy, 13*(6), 459-471. doi:10.1016/j.envsci.2010.05.006

Hair, J. F., Hult, G. T. M., Ringle, C., & Sarstedt, M. (2016). *A primer on partial least squares structural equation modeling (PLS-SEM)*: Sage publications.

Hansen, B. G. (2015). Robotic milking-farmer experiences and adoption rate in Jæren, Norway. *Journal of Rural Studies, 41*, 109-117. doi:10.1016/j.jrurstud.2015.08.004

Hansen, J., Hellin, J., Rosenstock, T., Fisher, E., Cairns, J., Stirling, C., . . . Campbell, B. (2019). Climate risk management and rural poverty reduction. *Agricultural Systems, 172*, 28-46. doi:10.1016/j.agsy.2018.01.019

Hao, J., Bijman, J., Gardebroek, C., Heerink, N., Heijman, W., & Huo, X. (2018). Cooperative membership and farmers' choice of marketing channels – Evidence from apple farmers in Shaanxi and Shandong Provinces, China. *Food Policy, 74*, 53-64. doi:10.1016/j.foodpol.2017.11.004

Hellin, J., Lundy, M., & Meijer, M. (2009). Farmer organization, collective action and market access in Meso-America. *Food Policy, 34*(1), 16-22. doi:10.1016/j.foodpol.2008.10.003

Hess, S., Daly, A., & Batley, R. (2018). Revisiting consistency with random utility maximisation: theory and implications for practical work. *Theory Decision, 84*(2), 181-204. doi:10.1007/s11238-017-9651-7

Hirano, K., & Imbens, G. W. (2001). Estimation of Causal Effects using Propensity Score Weighting: An Application to Data on Right Heart Catheterization. *Health Services and Outcomes Research Methodology, 2*(3/4), 259-278. doi:10.1023/a:1020371312283

Homans, G. C. (1958). Social Behavior as Exchange. *American Journal of Sociology, 63*(6), 597-606. doi:10.1086/222355

Howden, S. M., Soussana, J. F., Tubiello, F. N., Chhetri, N., Dunlop, M., & Meinke, H. (2007). Adapting agriculture to climate change. *Proc Natl Acad Sci U S A, 104*(50), 19691-19696. doi:10.1073/pnas.0701890104

Hu, L. t., & Bentler, P. M. (1999). Cutoff criteria for fit indexes in covariance structure analysis: Conventional criteria versus new alternatives. *Structural Equation Modeling: A Multidisciplinary Journal, 6*(1), 1-55. doi:10.1080/10705519909540118

Huang, M.-C., Yen, G.-F., & Liu, T.-C. (2014). Reexamining supply chain integration and the supplier's performance relationships under uncertainty. *Supply Chain Management: An International Journal, 19*(1), 64-78. doi:10.1108/scm-04-2013-0114

Hulke, C., & Revilla Diez, J. (2020). Building adaptive capacity to external risks through collective action – Social learning mechanisms of smallholders in rural Vietnam. *International Journal of Disaster Risk Reduction, 51*. doi:10.1016/j.ijdrr.2020.101829

Hunt, S. D., & Nevin, J. R. (1974). Power in a Channel of Distribution: Sources and Consequences. *Journal of Marketing Research, 11*(2), 186-193. doi:10.1177/002224377401100210

Hyland, J. J., Heanue, K., McKillop, J., & Micha, E. (2018). Factors influencing dairy farmers’ adoption of best management grazing practices. *Land Use Policy, 78*, 562-571. doi:10.1016/j.landusepol.2018.07.006

Imbens, G. W., & Wooldridge, J. M. (2009). Recent Developments in the Econometrics of Program Evaluation. *Journal of Economic Literature, 47*(1), 5-86. doi:10.1257/jel.47.1.5

Inemek, A., & Matthyssens, P. (2013). The impact of buyer–supplier relationships on supplier innovativeness: An empirical study in cross-border supply networks. *Industrial Marketing Management, 42*(4), 580-594. doi:10.1016/j.indmarman.2012.10.011

IPCC. (2021). *Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge University Press.

Irwin, B., & Campbell, R. (2015). *Market systems for resilience*. Leveraging Economic Opportunities, (LEO Report #6).

Isik, M., & Khanna, M. (2003). Stochastic Technology, Risk Preferences, and Adoption of Site-Specific Technologies. *American Journal of Agricultural Economics, 85*(2), 305-317. doi:10.1111/1467-8276.00121

Jacobi, J., Schneider, M., Bottazzi, P., Pillco, M., Calizaya, P., & Rist, S. (2013). Agroecosystem resilience and farmers’ perceptions of climate change impacts on cocoa farms in Alto Beni, Bolivia. *Renewable Agriculture and Food Systems, 30*(2), 170-183. doi:10.1017/s174217051300029x

Jacobi, J., Schneider, M., Pillco Mariscal, M., Huber, S., Weidmann, S., Bottazzi, P., & Rist, S. (2015). Farm Resilience in Organic and Nonorganic Cocoa Farming Systems in Alto Beni, Bolivia. *Agroecology and Sustainable Food Systems, 39*(7), 798-823. doi:10.1080/21683565.2015.1039158

Jaeck, M., & Lifran, R. (2014). Farmers’ Preferences for Production Practices: A Choice Experiment Study in the Rhone River Delta. *Journal of Agricultural Economics, 65*(1), 112-130. doi:10.1111/1477-9552.12018

Jajja, M. S. S., Asif, M., Montabon, F., & Chatha, K. A. (2019). Buyer-supplier relationships and organizational values in supplier social compliance. *Journal of Cleaner Production, 214*, 331-344. doi:10.1016/j.jclepro.2018.12.289

James, L. R., & Brett, J. M. (1984). Mediators, moderators, and tests for mediation. *Journal of applied psychology, 69*(2), 307-321. doi:10.1037/0021-9010.69.2.307

James, L. R., Mulaik, S. A., & Brett, J. M. (2006). A Tale of Two Methods. *Organizational Research Methods, 9*(2), 233-244. doi:10.1177/1094428105285144

Jean, R.-J. B., Kim, D., & Sinkovics, R. R. (2012). Drivers and Performance Outcomes of Supplier Innovation Generation in Customer-Supplier Relationships: The Role of Power-Dependence. *Decision Sciences, 43*(6), 1003-1038. doi:10.1111/j.1540-5915.2012.00380.x

Ji, C., Jin, S., Wang, H., & Ye, C. (2019). Estimating effects of cooperative membership on farmers' safe production behaviors: Evidence from pig sector in China. *Food Policy, 83*, 231-245. doi:10.1016/j.foodpol.2019.01.007

Jia, Y., Wang, T., Xiao, K., & Guo, C. (2020). How to reduce opportunism through contractual governance in the cross-cultural supply chain context: Evidence from Chinese exporters. *Industrial Marketing Management, 91*, 323-337. doi:10.1016/j.indmarman.2020.09.014

Jiang, X., Yang, Y., Pei, Y.-L., & Wang, G. (2016). Entrepreneurial Orientation, Strategic Alliances, and Firm Performance: Inside the Black Box. *Long Range Planning, 49*(1), 103-116. doi:10.1016/j.lrp.2014.09.003

Jianjun, J., Yiwei, G., Xiaomin, W., & Nam, P. K. (2015). Farmers' risk preferences and their climate change adaptation strategies in the Yongqiao District, China. *Land Use Policy, 47*, 365-372. doi:10.1016/j.landusepol.2015.04.028

Jocic, M. R., Morris, M. H., & Kuratko, D. F. (2021). Familiness and innovation outcomes in family firms: The mediating role of entrepreneurial orientation. *Journal of Small Business Management*, 1-33. doi:10.1080/00472778.2020.1861284

Johnston, D. A., McCutcheon, D. M., Stuart, F. I., & Kerwood, H. (2004). Effects of supplier trust on performance of cooperative supplier relationships. *Journal of Operations Management, 22*(1), 23-38. doi:10.1016/j.jom.2003.12.001

Joseph, J. (2018). *Varieties of resilience: Studies in governmentality*: Cambridge University Press.

Jung, K. (2017). Sources of Organizational Resilience for Sustainable Communities: An Institutional Collective Action Perspective. *Sustainability, 9*(7). doi:10.3390/su9071141

Kaguongo, W., Gildemacher, P., Demo, P., Wagoire, W., Kinyae, P., Andrade, J., . . . Thiele, G. (2008). *Farmer practices and adoption of improved potato varieties in Kenya and Uganda*. Social Sciences Working paper: Lima, Peru.

Kaguongo, W., Maingi, G., & Giencke, S. (2014). *Post-harvest losses in potato value chains in Kenya: analysis and recommendations for reduction strategies.* Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH.

Kaguongo, W., Nyangweso, A., Mutunga, J., Nderitu, J., Lunga'ho, C., Nganga, N., . . . Schulte-Geldermann, E. (2013). *A policymakers' guide to crop diversification: The case of the potato in Kenya*. Food and Agriculture Organization of the United Nations (FAO).

Kaijser, A., & Kronsell, A. (2013). Climate change through the lens of intersectionality. *Environmental politics, 23*(3), 417-433. doi:10.1080/09644016.2013.835203

Kaiser, H. F. (1958). The varimax criterion for analytic rotation in factor analysis. *Psychometrika, 23*(3), 187-200. doi:10.1007/bf02289233

Kamalaldin, A., Linde, L., Sjödin, D., & Parida, V. (2020). Transforming provider-customer relationships in digital servitization: A relational view on digitalization. *Industrial Marketing Management, 89*, 306-325. doi:10.1016/j.indmarman.2020.02.004

Kamanga, B. C. G., Waddington, S. R., Robertson, M. J., & Giller, K. E. (2009). Risk Analysis of Maize-Legume Crop Combinations with Smallholder Farmers Varying in Resource Endowment in Central Malawi. *Experimental Agriculture, 46*(1), 1-21. doi:10.1017/s0014479709990469

Kangogo, D., Dentoni, D., & Bijman, J. (2020). Determinants of Farm Resilience to Climate Change: The Role of Farmer Entrepreneurship and Value Chain Collaborations. *Sustainability, 12*(3). doi:10.3390/su12030868

Karadzic, V., Antunes, P., & Grin, J. (2014). Adapting to environmental and market change: Insights from Fish Producer Organizations in Portugal. *Ocean & Coastal Management, 102*, 364-374. doi:10.1016/j.ocecoaman.2014.10.010

Kassie, M., Jaleta, M., Shiferaw, B., Mmbando, F., & Mekuria, M. (2013). Adoption of interrelated sustainable agricultural practices in smallholder systems: Evidence from rural Tanzania.

Technological Forecasting and Social Change, 80(3), 525-540. doi:10.1016/j.techfore.2012.08.007

Kassie, M., Teklewold, H., Jaleta, M., Marenya, P., & Erenstein, O. (2015). Understanding the adoption of a portfolio of sustainable intensification practices in eastern and southern Africa. *Land Use Policy, 42*, 400-411. doi:10.1016/j.landusepol.2014.08.016

Kearney, J., & Berkes, F. (2007). *Communities of interdependence for adaptive co-management*. Vancouver, BC, Canada: UBC Press.

Khanal, U., Wilson, C., Hoang, V.-N., & Lee, B. (2017). Impact of community-based organizations on climate change adaptation in agriculture: empirical evidence from Nepal. *Environment, Development and Sustainability, 21*(2), 621-635. doi:10.1007/s10668-017-0050-6

Khanna, M. (2001). Sequential Adoption of Site-Specific Technologies and its Implications for Nitrogen Productivity: A Double Selectivity Model. *American Journal of Agricultural Economics, 83*(1), 35-51. doi:10.1111/0002-9092.00135

Khedhaouria, A., Gurău, C., & Torrès, O. (2014). Creativity, self-efficacy, and small-firm performance: the mediating role of entrepreneurial orientation. *Small Business Economics, 44*(3), 485-504. doi:10.1007/s11187-014-9608-y

Kidane, B. Z., Hailu, M. H., & Haile, H. T. (2017). Maize and Potato Intercropping: A Technology to Increase Productivity and Profitability in Tigray. *Open Agriculture, 2*(1). doi:10.1515/opag-2017-0044

Kihiu, E. N. (2016). Basic capability effect: Collective management of pastoral resources in southwestern Kenya. *Ecological Economics, 123*, 23-34. doi:10.1016/j.ecolecon.2016.01.003

Kim, K. (2000). On Interfirm Power, Channel Climate, and Solidarity in Industrial Distributor-Supplier Dyads. *Journal of the Academy of Marketing Science, 28*(3), 388-405. doi:10.1177/0092070300283007

Kim, K. K., Park, S.-H., Ryoo, S. Y., & Park, S. K. (2010). Inter-organizational cooperation in buyer–supplier relationships: Both perspectives. *Journal of Business Research, 63*(8), 863-869. doi:10.1016/j.jbusres.2009.04.028

Kirezieva, K., Bijman, J., Jacxsens, L., & Luning, P. A. (2016). The role of cooperatives in food safety management of fresh produce chains: Case studies in four strawberry cooperatives. *Food Control, 62*, 299-308. doi:10.1016/j.foodcont.2015.10.038

Klomp, J., & Bulte, E. (2013). Climate change, weather shocks, and violent conflict: a critical look at the evidence. *Agricultural Economics, 44*(s1), 63-78. doi:10.1111/agec.12051

Korber, S., & McNaughton, R. B. (2018). Resilience and entrepreneurship: a systematic literature review. *International Journal of Entrepreneurial Behavior & Research, 24*(7), 1129-1154. doi:10.1108/ijebr-10-2016-0356

Kpadonou, R. A. B., Owiyo, T., Barbier, B., Denton, F., Rutabingwa, F., & Kiema, A. (2017). Advancing climate-smart-agriculture in developing drylands: Joint analysis of the adoption of multiple on-farm soil and water conservation technologies in West African Sahel. *Land Use Policy, 61*, 196-207. doi:10.1016/j.landusepol.2016.10.050

Krause, D. R., Handfield, R. B., & Tyler, B. B. (2007). The relationships between supplier development, commitment, social capital accumulation and performance improvement. *Journal of Operations Management, 25*(2), 528-545. doi:10.1016/j.jom.2006.05.007

Kreiser, P. M., Marino, L. D., Kuratko, D. F., & Weaver, K. M. (2012). Disaggregating entrepreneurial orientation: the non-linear impact of innovativeness, proactiveness and risk-taking on SME performance. *Small Business Economics, 40*(2), 273-291. doi:10.1007/s11187-012-9460-x

Kruijssen, F., Keizer, M., & Giuliani, A. (2009). Collective action for small-scale producers of agricultural biodiversity products. *Food Policy, 34*(1), 46-52. doi:10.1016/j.foodpol.2008.10.008

Kuhl, L. (2018). Potential contributions of market-systems development initiatives for building climate resilience. *World Development, 108*, 131-144. doi:10.1016/j.worlddev.2018.02.036

Kumar, A., Takeshima, H., Thapa, G., Adhikari, N., Saroj, S., Karkee, M., & Joshi, P. K. (2020). Adoption and diffusion of improved technologies and production practices in agriculture: Insights from a donor-led intervention in Nepal. *Land Use Policy, 95*. doi:10.1016/j.landusepol.2020.104621

Kummer, S., Milestad, R., Leitgeb, F., & Vogl, C. R. (2012). Building Resilience through Farmers' Experiments in Organic Agriculture: Examples from Eastern Austria. *Sustainable Agriculture Research, 1*(2). doi:10.5539/sar.v1n2p308

Kusa, R., Marques, D. P., & Navarrete, B. R. (2018). External cooperation and entrepreneurial orientation in industrial clusters. *Entrepreneurship & Regional Development, 31*(1-2), 119-132. doi:10.1080/08985626.2018.1537151

Kyallo, G., James, P. K., Kipyegon, G., Ndabarua, J., Yatich, C., Mburu, J. G., & Patrick, N. (2017). *Horticulture validated report 2016-2017*. Retrieved from http://kilimodata.developlocal.org/dataset/3534b0b9-e49e-4c72-a90a-e423844a83a2/resource/c7758a80-9102-481e-a6c2-fa983081221d/download/horticulture-validated-data-2016-2017.pdf:

Lambe, C. J., Wittmann, C. M., & Spekman, R. E. (2001). Social Exchange Theory and Research on Business-to-Business Relational Exchange. *Journal of Business-to-Business Marketing, 8*(3), 1-36. doi:10.1300/J033v08n03_01

Lambrecht, I., Vanlauwe, B., Merckx, R., & Maertens, M. (2014). Understanding the Process of Agricultural Technology Adoption: Mineral Fertilizer in Eastern DR Congo. *World Development, 59*, 132-146. doi:10.1016/j.worlddev.2014.01.024

Leitgeb, F., Funes-Monzote, F. R., Kummer, S., & Vogl, C. R. (2011). Contribution of farmers' experiments and innovations to Cuba's agricultural innovation system. *Renewable Agriculture and Food Systems, 26*(4), 354-367. doi:10.1017/s1742170511000251

Lim-Camacho, L., Ariyawardana, A., Lewis, G. K., Crimp, S. J., Somogyi, S., Ridoutt, B., & Howden, S. M. (2016). Climate adaptation of food value chains: the implications of varying consumer acceptance. *Regional Environmental Change, 17*(1), 93-103. doi:10.1007/s10113-016-0976-5

Lim, K., Wichmann, B., & Luckert, M. (2021). Adaptation, spatial effects, and targeting: Evidence from Africa and Asia. *World Development, 139*. doi:10.1016/j.worlddev.2020.105230

Linnenluecke, M. K., Griffiths, A., & Winn, M. I. (2013). Firm and industry adaptation to climate change: a review of climate adaptation studies in the business and management field. *Wiley Interdisciplinary Reviews: Climate Change, 4*(5), 397-416. doi:10.1002/wcc.214

Lipper, L., Thornton, P., Campbell, B. M., Baedeker, T., Braimoh, A., Bwalya, M., . . . Torquebiau, E. F. (2014). Climate-smart agriculture for food security. *Nature Climate Change, 4*(12), 1068-1072. doi:10.1038/nclimate2437

Liu, Y., Luo, Y., & Liu, T. (2009). Governing buyer-supplier relationships through transactional and relational mechanisms: Evidence from China. *Journal of Operations Management, 27*(4), 294-309. doi:10.1016/j.jom.2008.09.004

Liu, Y., Ruiz-Menjivar, J., Zhang, L., Zhang, J., & Swisher, M. E. (2019). Technical training and rice farmers' adoption of low-carbon management practices: The case of soil testing and formulated fertilization technologies in Hubei, China. *Journal of Cleaner Production, 226*, 454-462. doi:10.1016/j.jclepro.2019.04.026

Lockwood, M., Raymond, C. M., Oczkowski, E., & Morrison, M. (2015). Measuring the dimensions of adaptive capacity: a psychometric approach. *Ecology and Society, 20*(1). doi:10.5751/es-07203-200137

Lu, H., Feng, S., Trienekens, J. H., & Omta, S. W. F. (2008). Performance in vegetable supply chains: the role of Guanxi networks and buyer–seller relationships. *Agribusiness, 24*(2), 253-274. doi:10.1002/agr.20158

Lumpkin, G. T., & Dess, G. G. (1996). Clarifying the Entrepreneurial Orientation Construct and Linking It To Performance. *Academy of Management Review, 21*(1), 135-172. doi:10.5465/amr.1996.9602161568

Lumpkin, G. T., & Dess, G. G. (2001). Linking two dimensions of entrepreneurial orientation to firm performance. *Journal of Business Venturing, 16*(5), 429-451. doi:10.1016/s0883-9026(00)00048-3

Luo, X., & Donthu, N. (2007). The role of cyber-intermediaries: a framework based on transaction cost analysis, agency, relationship marketing and social exchange theories. *Journal of Business & Industrial Marketing, 22*(7), 452-458. doi:10.1108/08858620710828836

Lynch, D. R., Foroud, N., Kozub, G. C., & Farries, B. C. (1995). The effect of moisture stress at three growth stages on the yield, components of yield and processing quality of eight potato varieties. *American Potato Journal volume, 72*, 375–385. doi:10.1007/BF02849334

Ma, W., & Abdulai, A. (2019). IPM adoption, cooperative membership and farm economic performance. *China Agricultural Economic Review, 11*(2), 218-236. doi:10.1108/caer-12-2017-0251

Macchiavello, R., & Morjaria, A. (2015). The Value of Relationships: Evidence from a Supply Shock to Kenyan Rose Exports. *American Economic Review, 105*(9), 2911-2945. doi:10.1257/aer.20120141

MacKinnon, D. P., Lockwood, C. M., Hoffman, J. M., West, S. G., & Sheets, V. (2002). A comparison of methods to test mediation and other intervening variable effects. *Psychological methods, 7*(1), 83-104. doi:10.1037/1082-989x.7.1.83

Maggio, G., & Sitko, N. (2019). Knowing is half the battle: Seasonal forecasts, adaptive cropping systems, and the mediating role of private markets in Zambia. *Food Policy, 89*. doi:10.1016/j.foodpol.2019.101781

Maidment, R. I., Allan, R. P., & Black, E. (2015). Recent observed and simulated changes in precipitation over Africa. *Geophysical Research Letters, 42*(19), 8155-8164. doi:10.1002/2015gl065765

Makate, C., Makate, M., Mutenje, M., Mango, N., & Siziba, S. (2019). Synergistic impacts of agricultural credit and extension on adoption of climate-smart agricultural technologies in southern Africa. *Environmental Development, 32*. doi:10.1016/j.envdev.2019.100458

Malakar, Y. (2012). Increasing Adaptive Capacity: What Is the Role of Local Institutions? *Risk, Hazards & Crisis in Public Policy, 3*(4), 60-76. doi:10.1002/rhc3.18

Maleksaeidi, H., Karami, E., Zamani, G. H., Rezaei-Moghaddam, K., Hayati, D., & Masoudi, M. (2016). Discovering and characterizing farm households' resilience under water scarcity. *Environment, Development and Sustainability, 18*(2), 499-525. doi:10.1007/s10668-015-9661-y

MALF. (2017). *Kenya Climate Smart Agriculture Strategy 2017-2026*. Retrieved from Kenya Ministry of Agriculture, Livestock and Fisheries https://www.tralac.org/documents/resources/by-country/kenya/665-kenya-climate-smart-agriculture-strategy-2017-2026/file.html:

Mancini, M. C. (2019). Motivations, Drivers, and Barriers to the Development of Sustainable Agri-Food Systems and Consumption Patterns. *Sustainability, Sustainable Agriculture Special issue*.

Manda, J., Gardebroek, C., Kuntashula, E., & Alene, A. D. (2018). Impact of improved maize varieties on food security in Eastern Zambia: A doubly robust analysis. *Review of Development Economics, 22*(4), 1709-1728. doi:10.1111/rode.12516

Mandal, S., & Sarathy, R. (2018). The Effect of Supply Chain Relationships on Resilience: Empirical Evidence from India. *Global Business Review, 19*(3_suppl), S196-S217. doi:10.1177/0972150918758094

Manyise, T., & Dentoni, D. (2021). Value chain partnerships and farmer entrepreneurship as balancing ecosystem services: Implications for agri-food systems resilience. *Ecosystem Services, 49*. doi:10.1016/j.ecoser.2021.101279

Marcos, J., & Prior, D. D. (2017). Buyer-supplier relationship decline: A norms-based perspective. *Journal of Business Research, 76*, 14-23. doi:10.1016/j.jbusres.2017.03.005

Markelova, H., Meinzen-Dick, R., Hellin, J., & Dohrn, S. (2009). Collective action for smallholder market access. *Food Policy, 34*(1), 1-7. doi:10.1016/j.foodpol.2008.10.001

Markelova, H., & Mwangi, E. (2010). Collective Action for Smallholder Market Access: Evidence and Implications for Africa. *Review of Policy Research, 27*(5), 621-640. doi:10.1111/j.1541-1338.2010.00462.x

Marshall, N. A. (2010). Understanding social resilience to climate variability in primary enterprises and industries. *Global Environmental Change, 20*(1), 36-43. doi:10.1016/j.gloenvcha.2009.10.003

Marshall, N. A., Crimp, S., Curnock, M., Greenhill, M., Kuehne, G., Leviston, Z., & Ouzman, J. (2016). Some primary producers are more likely to transform their agricultural practices in response to climate change than others. *Agriculture, Ecosystems & Environment, 222*, 38-47. doi:10.1016/j.agee.2016.02.004

Marshall, N. A., Gordon, I. J., & Ash, A. J. (2011). The reluctance of resource-users to adopt seasonal climate forecasts to enhance resilience to climate variability on the rangelands. *Climatic Change, 107*(3-4), 511-529. doi:10.1007/s10584-010-9962-y

Marshall, N. A., Park, S., Howden, S. M., Dowd, A. B., & Jakku, E. S. (2013). Climate change awareness is associated with enhanced adaptive capacity. *Agricultural Systems, 117*, 30-34. doi:10.1016/j.agsy.2013.01.003

Marshall, N. A., Park, S. E., Adger, W. N., Brown, K., & Howden, S. M. (2012). Transformational capacity and the influence of place and identity. *Environmental Research Letters, 7*(3). doi:10.1088/1748-9326/7/3/034022

Marshall, N. A., Stokes, C. J., Webb, N. P., Marshall, P. A., & Lankester, A. J. (2014). Social vulnerability to climate change in primary producers: A typology approach. *Agriculture, Ecosystems & Environment, 186*, 86-93. doi:10.1016/j.agee.2014.01.004

Martey, E., Etwire, P. M., Adogoba, D. S., & Tengey, T. K. (2021). Farmers' preferences for climate-smart cowpea varieties: implications for crop breeding programmes. *Climate and Development*, 1-16. doi:10.1080/17565529.2021.1889949

Martínez-García, C. G., Arriaga-Jordán, C. M., Dorward, P., Rehman, T., & Rayas-Amor, A. A. (2016). Using a Socio-Psychological Model to Identify and Understand Factors Influencing the Use and Adoption of a Successful Innovation by Small-Scale Dairy Farmers of Central Mexico. *Experimental Agriculture, 54*(1), 142-159. doi:10.1017/s0014479716000703

Mashizha, T. M. (2019). Building adaptive capacity: Reducing the climate vulnerability of smallholder farmers in Zimbabwe. *Business Strategy & Development, 2*(3), 166-172. doi:10.1002/bsd2.50

Masuku, M. B., Kirsten, J. F., Van Rooyen, C. J., & Perret, S. (2003). Contractual Relationships between Small-Holder Sugarcane Growers and Millers in the Sugar Industry Supply Chain in Swaziland. *Agrekon, 42*(3), 183-199. doi:10.1080/03031853.2003.9523619

Matewos, T. (2020). The state of local adaptive capacity to climate change in drought-prone districts of rural Sidama, southern Ethiopia. *Climate Risk Management, 27*. doi:10.1016/j.crm.2019.100209

Mausch, K., Harris, D., Heather, E., Jones, E., Yim, J., & Hauser, M. (2018). Households' aspirations for rural development through agriculture. *Outlook on Agriculture, 47*(2), 108-115. doi:10.1177/0030727018766940

McCarthy, N., Lipper, L., & Zilberman, D. (2018). Economics of climate smart agriculture: An overview. In *Climate Smart Agriculture* (pp. 31-47).

McCord, P. F., Cox, M., Schmitt-Harsh, M., & Evans, T. (2015). Crop diversification as a smallholder livelihood strategy within semi-arid agricultural systems near Mount Kenya. *Land Use Policy, 42*, 738-750. doi:10.1016/j.landusepol.2014.10.012

McElwee, G. (2011). Farmers as Entrepreneurs: Developing Competitive Skills. *Journal of Developmental Entrepreneurship, 11*(03), 187-206. doi:10.1142/s1084946706000398

McElwee, G., & Smith, R. (2012). Classifying the strategic capability of farmers: a segmentation framework. *International Journal of Entrepreneurial Venturing, 4*(2), 111-131. doi:10.1504/ijev.2012.046517

McInnis-Bowers, C., Parris, D. L., & Galperin, B. L. (2017). Which came first, the chicken or the egg? Exploring the relationship between entrepreneurship and resilience among the Boruca Indians of Costa Rica. *Journal of Enterprising Communities: People and Places in the Global Economy, 11*(1), 39-60. doi:10.1108/jec-01-2015-0014

McLaughlin, P., & Dietz, T. (2008). Structure, agency and environment: Toward an integrated perspective on vulnerability. *Global Environmental Change, 18*(1), 99-111. doi:10.1016/j.gloenvcha.2007.05.003

Meinzen-Dick, R., DiGregorio, M., & McCarthy, N. (2004). Methods for studying collective action in rural development. *Agricultural Systems, 82*(3), 197-214. doi:10.1016/j.agsy.2004.07.006

Mesquita, L. F., & Lazzarini, S. G. (2008). Horizontal and Vertical Relationships in Developing Economies: Implications for SMEs'Access to Global Markets. *Academy of Management Journal, 51*(2), 359-380. doi:10.1007/978-1-4419-0058-6_3

Meuwissen, M. P. M., Feindt, P. H., Spiegel, A., Termeer, C. J. A. M., Mathijs, E., Mey, Y. d., . . . Reidsma, P. (2019). A framework to assess the resilience of farming systems. *Agricultural Systems, 176*. doi:10.1016/j.agsy.2019.102656

Mikko Vesala, K., Peura, J., & McElwee, G. (2007). The split entrepreneurial identity of the farmer. *Journal of Small Business and Enterprise Development, 14*(1), 48-63. doi:10.1108/14626000710727881

Minah, M., & Malvido Pérez Carletti, A. (2019). Mechanisms of Inclusion: Evidence from Zambia’s Farmer Organisations. *The European Journal of Development Research, 31*(5), 1318-1340. doi:10.1057/s41287-019-00212-8

MoALF. (2018). *(Ministry of Agriculture, Livestock and Fisheries) Kenya Climate Smart Agriculture Implementation Framework 2018–2027.* https://www.ke.undp.org/content/dam/kenya/docs/energy_and_environment/2018/The%20Kenya%20CSA%20Implementation%20Framework%202018-2027.pdf (accessed on 15 January 2010).

Mojo, D., Fischer, C., & Degefa, T. (2016). Collective Action and Aspirations: The Impact of Cooperatives on Ethiopian Coffee Farmers’ Aspirations. *Annals of Public and Cooperative Economics, 87*(2), 217-238. doi:10.1111/apce.12103

Molm, L. D. (1991). Affect and social exchange: Satisfaction in power-dependence relations. *American Sociological Review, 56*(4), 475-493. doi:10.2307/2096269

Mora Cortez, R., & Johnston, W. J. (2020). The Coronavirus crisis in B2B settings: Crisis uniqueness and managerial implications based on social exchange theory. *Industrial Marketing Management, 88*, 125-135. doi:10.1016/j.indmarman.2020.05.004

Morgan, R. M., & Hunt, S. D. (1994). The Commitment-Trust Theory of Relationship Marketing. *Journal of Marketing, 58*(3), 20-38. doi:10.1177/002224299405800302

Morgan, T., Anokhin, S., & Wincent, J. (2016). Entrepreneurial orientation, firm market power and opportunism in networks. *Journal of Business & Industrial Marketing, 31*(1), 99-111. doi:10.1108/jbim-03-2014-0063

Morris, W., Henley, A., & Dowell, D. (2017). Farm diversification, entrepreneurship and technology adoption: Analysis of upland farmers in Wales. *Journal of Rural Studies, 53*, 132-143. doi:10.1016/j.jrurstud.2017.05.014

Mortreux, C., & Barnett, J. (2017). Adaptive capacity: exploring the research frontier. *Wiley Interdisciplinary Reviews: Climate Change, 8*(4). doi:10.1002/wcc.467

Muller, C., Cramer, W., Hare, W. L., & Lotze-Campen, H. (2011). Climate change risks for African agriculture. *Proc Natl Acad Sci U S A, 108*(11), 4313-4315. doi:10.1073/pnas.1015078108

Muriithi, B. W., Menale, K., Diiro, G., & Muricho, G. (2018). Does gender matter in the adoption of push-pull pest management and other sustainable agricultural practices? Evidence from Western Kenya. *Food Security, 10*(2), 253-272. doi:10.1007/s12571-018-0783-6

Murphy, M., & Sashi, C. M. (2018). Communication, interactivity, and satisfaction in B2B relationships. *Industrial Marketing Management, 68*, 1-12. doi:10.1016/j.indmarman.2017.08.020

Muthoni, J., & Nyamongo, D. O. (2009). A review of constraints to ware Irish potatoes production in Kenya. *Journal of Horticulture and Forestry, 1*(7), 98-102. doi:10.5897/JHF.9000002

Mutonyi, S. (2019). The effect of collective action on smallholder income and asset holdings in Kenya. *World Development Perspectives, 14*. doi:10.1016/j.wdp.2019.02.010

Mutonyi, S., Beukel, K., & Hjortsø, C. N. (2018). Relational factors and performance of agrifood chains in Kenya. *Industrial Marketing Management, 74*, 175-186. doi:10.1016/j.indmarman.2018.03.004

Mwambi, M., Bijman, J., & Mshenga, P. (2020). Which type of producer organization is (more) inclusive? Dynamics of farmers’ membership and participation in the decision-making process. *Annals of Public and Cooperative Economics, 91*(2), 213-236. doi:10.1111/apce.12269

Mwambi, M., Bijman, J., Mshenga, P., & Oosting, S. (2021). Adoption of food safety measures: The role of bargaining and processing producer organizations. *NJAS: Wageningen Journal of Life Sciences, 92*(1), 1-9. doi:10.1016/j.njas.2020.100337

Najafi-Tavani, S., Najafi-Tavani, Z., Naudé, P., Oghazi, P., & Zeynaloo, E. (2018). How collaborative innovation networks affect new product performance: Product innovation capability, process innovation capability, and absorptive capacity. *Industrial Marketing Management, 73*, 193-205. doi:10.1016/j.indmarman.2018.02.009

Nakano, Y., & Magezi, E. F. (2020). The impact of microcredit on agricultural technology adoption and productivity: Evidence from randomized control trial in Tanzania. *World Development, 133*. doi:10.1016/j.worlddev.2020.104997

Narasimhan, R., Nair, A., Griffith, D. A., Arlbjørn, J. S., & Bendoly, E. (2009). Lock-in situations in supply chains: A social exchange theoretic study of sourcing arrangements in buyer-supplier relationships. *Journal of Operations Management, 27*(5), 374-389. doi:10.1016/j.jom.2008.10.004

Nguyen, T. P. L., Seddaiu, G., Virdis, S. G. P., Tidore, C., Pasqui, M., & Roggero, P. P. (2016). Perceiving to learn or learning to perceive? Understanding farmers' perceptions and adaptation to climate uncertainties. *Agricultural Systems, 143*, 205-216. doi:10.1016/j.agsy.2016.01.001

Niu, Y., Deng, F., & Hao, A. W. (2020). Effect of entrepreneurial orientation, collectivistic orientation and swift Guanxi with suppliers on market performance: A study of e-commerce enterprises. *Industrial Marketing Management, 88*, 35-46. doi:10.1016/j.indmarman.2020.04.020

Nyaga, G. N., Lynch, D. F., Marshall, D., & Ambrose, E. (2013). Power Asymmetry, Adaptation and Collaboration in Dyadic Relationships Involving a Powerful Partner. *Journal of Supply Chain Management, 49*(3), 42-65. doi:10.1111/jscm.12011

O'Loughlin, J., Witmer, F. D., Linke, A. M., Laing, A., Gettelman, A., & Dudhia, J. (2012). Climate variability and conflict risk in East Africa, 1990-2009. *Proc Natl Acad Sci U S A, 109*(45), 18344-18349. doi:10.1073/pnas.1205130109

Ochieng, J., Kirimi, L., & Mathenge, M. (2016). Effects of climate variability and change on agricultural production: The case of small scale farmers in Kenya. *NJAS - Wageningen Journal of Life Sciences, 77*, 71-78. doi:10.1016/j.njas.2016.03.005

Ojo, T. O., & Baiyegunhi, L. J. S. (2020). Determinants of climate change adaptation strategies and its impact on the net farm income of rice farmers in south-west Nigeria. *Land Use Policy, 95*. doi:10.1016/j.landusepol.2019.04.007

Okello, J., Zhou, Y., Barker, I., & Schulte-Geldermann, E. (2018). Motivations and Mental Models Associated with Smallholder Farmers' Adoption of Improved Agricultural Technology: Evidence from Use of Quality Seed Potato in Kenya. *The European Journal of Development Research, 31*(2), 271-292. doi:10.1057/s41287-018-0152-5

Okello, J., Zhou, Y., Kwikiriza, N., Ogutu, S., Barker, I., Schulte-Geldermann, E., . . . Ahmed, J. (2016). Determinants of the Use of Certified Seed Potato among Smallholder Farmers: The Case of Potato Growers in Central and Eastern Kenya. *Agriculture, 6*(4). doi:10.3390/agriculture6040055

Okello, J. J., Lagerkvist, C. J., Kakuhenzire, R., Parker, M., & Schulte-Geldermann, E. (2018). Combining means-end chain analysis and goal-priming to analyze Tanzanian farmers' motivations to invest in quality seed of new potato varieties. *British Food Journal, 120*(7), 1430-1445. doi:10.1108/bfj-11-2017-0612

Okello, J. J., Zhou, Y., Kwikiriza, N., Ogutu, S., Barker, I., Schulte-Geldermann, E., . . . Ahmed, J. T. (2017). Productivity and food security effects of using of certified seed potato: the case of Kenya's potato farmers. *Agriculture & Food Security, 6*(1). doi:10.1186/s40066-017-0101-0

Ostrom, E. (1990). *Governing the commons: The evolution of institutions for collective action*. Cambridge, UK: Cambridge university press.

Palich, L. E., & Ray Bagby, D. (1995). Using cognitive theory to explain entrepreneurial risk-taking: Challenging conventional wisdom. *Journal of Business Venturing, 10*(6), 425-438. doi:10.1016/0883-9026(95)00082-j

Pan, Y., Smith, S. C., & Sulaiman, M. (2018). Agricultural Extension and Technology Adoption for Food Security: Evidence from Uganda. *American Journal of Agricultural Economics, 100*(4), 1012-1031. doi:10.1093/ajae/aay012

Pannell, D., Malcolm, B., & Kingwell, R. S. (2000). Are we risking too much? Perspectives on risk in farm modelling. *Agricultural Economics, 23*(1), 69-78. doi:10.1016/s0169-5150(00)00058-x

Parker, M. L., Low, J. W., Andrade, M., Schulte-Geldermann, E., & Andrade-Piedra, J. (2019). Climate change and seed systems of roots, tubers and bananas: the cases of potato in Kenya and Sweetpotato in Mozambique. In *The climate-smart agriculture papers* (pp. 99-111): Springer, Cham.

Pascucci, S., Gardebroek, C., & Dries, L. (2011). Some like to join, others to deliver: an econometric analysis of farmers' relationships with agricultural co-operatives. *European Review of Agricultural Economics, 39*(1), 51-74. doi:10.1093/erae/jbr027

Patnaik, U., & Das, P. K. (2017). Do Development Interventions Confer Adaptive Capacity? Insights from Rural India. *World Development, 97*, 298-312. doi:10.1016/j.worlddev.2017.04.017

Pelletier, B., Hickey, G. M., Bothi, K. L., & Mude, A. (2016). Linking rural livelihood resilience and food security: an international challenge. *Food Security, 8*(3), 469-476. doi:10.1007/s12571-016-0576-8

Pelling, M., High, C., Dearing, J., & Smith, D. (2008). Shadow Spaces for Social Learning: A Relational Understanding of Adaptive Capacity to Climate Change within Organisations. *Environment and Planning A: Economy and Space, 40*(4), 867-884. doi:10.1068/a39148

Penrose-Buckley, C. (2007). *Producer organisations: A guide to developing collective rural enterprises*. Oxford, UK: Oxfam.

Pérez-Luño, A., Wiklund, J., & Cabrera, R. V. (2011). The dual nature of innovative activity: How entrepreneurial orientation influences innovation generation and adoption. *Journal of Business Venturing, 26*(5), 555-571. doi:10.1016/j.jbusvent.2010.03.001

Pérez, I., Janssen, M. A., & Anderies, J. M. (2016). Food security in the face of climate change: Adaptive capacity of small-scale social-ecological systems to environmental variability. *Global Environmental Change, 40*, 82-91. doi:10.1016/j.gloenvcha.2016.07.005

Perrin, A., Milestad, R., & Martin, G. (2020). Resilience applied to farming: organic farmers' perspectives. *Ecology and Society, 25*(4), 5. doi:https://doi.org/10.5751/ES-11897-250405

Petersen-Rockney, M., Baur, P., Guzman, A., Bender, S. F., Calo, A., Castillo, F., . . . Bowles, T. (2021). Narrow and Brittle or Broad and Nimble? Comparing Adaptive Capacity in Simplifying and Diversifying Farming Systems. *Frontiers in Sustainable Food Systems, 5*. doi:10.3389/fsufs.2021.564900

Phuong, L. T. H., Wals, A., Sen, L. T. H., Hoa, N. Q., Van Lu, P., & Biesbroek, R. (2018). Using a social learning configuration to increase Vietnamese smallholder farmers' adaptive capacity to respond to climate change. *Local Environment, 23*(8), 879-897. doi:10.1080/13549839.2018.1482859

Pindado, E., Sánchez, M., Verstegen, J. A. A. M., & Lans, T. (2018). Searching for the entrepreneurs among new entrants in European Agriculture: the role of human and social capital. *Land Use Policy, 77*, 19-30. doi:10.1016/j.landusepol.2018.05.014

Pino, G., Toma, P., Rizzo, C., Miglietta, P., Peluso, A., & Guido, G. (2017). Determinants of Farmers' Intention to Adopt Water Saving Measures: Evidence from Italy. *Sustainability, 9*(1). doi:10.3390/su9010077

Podsakoff, P. M., MacKenzie, S. B., Lee, J. Y., & Podsakoff, N. P. (2003). Common method biases in behavioral research: a critical review of the literature and recommended remedies. *Journal of applied psychology, 88*(5), 879-903. doi:10.1037/0021-9010.88.5.879

Poulton, C., Dorward, A., & Kydd, J. (2010). The Future of Small Farms: New Directions for Services, Institutions, and Intermediation. *World Development, 38*(10), 1413-1428. doi:10.1016/j.worlddev.2009.06.009

Quiroga, S., Suárez, C., Diego Solís, J., & Martinez-Juarez, P. (2020). Framing vulnerability and coffee farmers' behaviour in the context of climate change adaptation in Nicaragua. *World Development, 126*. doi:10.1016/j.worlddev.2019.104733

Ragasa, C., & Golan, J. (2014). The role of rural producer organizations for agricultural service provision in fragile states. *Agricultural Economics, 45*(5), 537-553. doi:10.1111/agec.12105

Ratner, B. D., Mam, K., & Halpern, G. (2014). Collaborating for resilience: conflict, collective action, and transformation on Cambodia's Tonle Sap Lake. *Ecology and Society, 19*(3). doi:10.5751/es-06400-190331

Rauch, A., Wiklund, J., Lumpkin, G. T., & Frese, M. (2009). Entrepreneurial Orientation and Business Performance: An Assessment of Past Research and Suggestions for the Future. *Entrepreneurship Theory and Practice, 33*(3), 761-787. doi:10.1111/j.1540-6520.2009.00308.x

Robinson, L. W., & Berkes, F. (2011). Multi-level participation for building adaptive capacity: Formal agency-community interactions in northern Kenya. *Global Environmental Change, 21*(4), 1185-1194. doi:10.1016/j.gloenvcha.2011.07.012

Rodima-Taylor, D. (2012). Social innovation and climate adaptation: Local collective action in diversifying Tanzania. *Applied Geography, 33*, 128-134. doi:10.1016/j.apgeog.2011.10.005

Rogers, E. M. (2003). *Diffusion of innovations.* New York: Free Press.

Rosenbaum, P. R., & Rubin, D. B. (1983). The central role of the propensity score in observational studies for causal effects. *Biometrika, 70*(1), 41-55. doi:10.1093/biomet/70.1.41

Rosenbaum, P. R., & Rubin, D. B. (2012). Constructing a Control Group Using Multivariate Matched Sampling Methods That Incorporate the Propensity Score. *The American Statistician, 39*(1), 33-38. doi:10.1080/00031305.1985.10479383

Rosenbusch, N., Rauch, A., & Bausch, A. (2011). The Mediating Role of Entrepreneurial Orientation in the Task Environment–Performance Relationship. *Journal of Management, 39*(3), 633-659. doi:10.1177/0149206311425612

Rosenstock, T. S., Lubberink, R., Gondwe, S., Manyise, T., & Dentoni, D. (2020). Inclusive and adaptive business models for climate-smart value creation. *Current Opinion in Environmental Sustainability, 42*, 76-81. doi:10.1016/j.cosust.2019.12.005

Ruzzante, S., Labarta, R., & Bilton, A. (2021). Adoption of agricultural technology in the developing world: A meta-analysis of the empirical literature. *World Development, 146*. doi:10.1016/j.worlddev.2021.105599

Rwehumbiza, D., & Marinov, M. A. (2019). Development of entrepreneurial orientation of export manufacturers from emerging economies. *International Entrepreneurship and Management Journal, 16*(2), 667-689. doi:10.1007/s11365-019-00580-x

Santos, F. P., Pacheco, J. M., Santos, F. C., & Levin, S. A. (2021). Dynamics of informal risk sharing in collective index insurance. *Nature Sustainability, 4*(5), 426-432. doi:10.1038/s41893-020-00667-2

Schimmelpfennig, D., & Ebel, R. (2011). On the doorstep of the information age: Recent adoption of precision agriculture. *Economic Research Service, Paper No. EIB-80*.

Schmidhuber, J., & Tubiello, F. N. (2007). Global food security under climate change. *Proc Natl Acad Sci U S A, 104*(50), 19703-19708. doi:10.1073/pnas.0701976104

Schmitz, T., Schweiger, B., & Daft, J. (2016). The emergence of dependence and lock-in effects in buyer–supplier relationships — A buyer perspective. *Industrial Marketing Management, 55*, 22-34. doi:10.1016/j.indmarman.2016.02.010

Scholten, K., & Schilder, S. (2015). The role of collaboration in supply chain resilience. *Supply Chain Management: An International Journal, 20*(4), 471-484. doi:10.1108/scm-11-2014-0386

Sejian, V., Bhatta, R., Soren, N., Malik, P., Ravindra, J., Prasad, C. S., & Lal, R. (2015). Introduction to concepts of climate change impact on livestock and its adaptation and mitigation. In *Climate change Impact on livestock: adaptation and mitigation* (pp. 1-23): Springer.

Senyolo, M. P., Long, T. B., Blok, V., & Omta, O. (2018). How the characteristics of innovations impact their adoption: An exploration of climate-smart agricultural innovations in South Africa. *Journal of Cleaner Production, 172*, 3825-3840. doi:10.1016/j.jclepro.2017.06.019

Serebrennikov, D., Thorne, F., Kallas, Z., & McCarthy, S. N. (2020). Factors Influencing Adoption of Sustainable Farming Practices in Europe: A Systemic Review of Empirical Literature. *Sustainability, 12*(22). doi:10.3390/su12229719

Shahzad, K., Ali, T., Takala, J., Helo, P., & Zaefarian, G. (2018). The varying roles of governance mechanisms on ex-post transaction costs and relationship commitment in buyer-supplier relationships. *Industrial Marketing Management, 71*, 135-146. doi:10.1016/j.indmarman.2017.12.012

Shane, S., & Venkataraman, S. (2000). The Promise of Entrepreneurship as a Field of Research. *Academy of Management Review, 25*(1), 217-226. doi:10.5465/amr.2000.2791611

Shiferaw, B., Hellin, J., & Muricho, G. (2011). Improving market access and agricultural productivity growth in Africa: what role for producer organizations and collective action institutions? *Food Security, 3*(4), 475-489. doi:10.1007/s12571-011-0153-0

Shiferaw, B., Kassie, M., Jaleta, M., & Yirga, C. (2014). Adoption of improved wheat varieties and impacts on household food security in Ethiopia. *Food Policy, 44*, 272-284. doi:10.1016/j.foodpol.2013.09.012

Shrout, P. E., & Bolger, N. (2002). Mediation in experimental and nonexperimental studies: new procedures and recommendations. *Psychological methods, 7*(4), 422-445. doi:10.1037//1082-989x.7.4.422

Slijper, T., de Mey, Y., Poortvliet, P. M., & Meuwissen, M. P. M. (2020). From risk behavior to perceived farm resilience: a Dutch case study. *Ecology and Society, 25*(4), 10. doi:10.5751/es-11893-250410

Smit, B., & Pilifosova, O. (2003). Adaptation to climate change in the context of sustainable development and equity. In *Climate Change 2001: Impacts, Adaptation and Vulnerability. IPCC Working Group II* (pp. 877–912). Cambridge, UK: Cambridge University Press.

Smit, B., & Wandel, J. (2006). Adaptation, adaptive capacity and vulnerability. *Global Environmental Change, 16*(3), 282-292. doi:10.1016/j.gloenvcha.2006.03.008

Smith, B., Burton, I., Klein, R. J. T., & Wandel, J. (2000). An anatomy of adaptation to climate change and variability. *Climatic Change, 45*(1), 223-251. doi:10.1023/a:1005661622966

Snapp, S. S., Blackie, M. J., Gilbert, R. A., Bezner-Kerr, R., & Kanyama-Phiri, G. Y. (2010). Biodiversity can support a greener revolution in Africa. *Proc Natl Acad Sci U S A, 107*(48), 20840-20845. doi:10.1073/pnas.1007199107

Spielman, D. J., Davis, K., Negash, M., & Ayele, G. (2010). Rural innovation systems and networks: findings from a study of Ethiopian smallholders. *Agriculture and Human Values, 28*(2), 195-212. doi:10.1007/s10460-010-9273-y

Srinivasan, M., Mukherjee, D., & Gaur, A. S. (2011). Buyer–supplier partnership quality and supply chain performance: Moderating role of risks, and environmental uncertainty. *European Management Journal, 29*(4), 260-271. doi:10.1016/j.emj.2011.02.004

Sultan, B., & Gaetani, M. (2016). Agriculture in West Africa in the Twenty-First Century: Climate Change and Impacts Scenarios, and Potential for Adaptation. *Front Plant Sci, 7*, 1262. doi:10.3389/fpls.2016.01262

Sydow, A., Cannatelli, B. L., Giudici, A., & Molteni, M. (2020). Entrepreneurial Workaround Practices in Severe Institutional Voids: Evidence From Kenya. *Entrepreneurship Theory and Practice*, 1042258720929891. doi:10.1177/1042258720929891

Takahashi, K., & Barrett, C. B. (2013). The System of Rice Intensification and its Impacts on Household Income and Child Schooling: Evidence from Rural Indonesia. *American Journal of Agricultural Economics, 96*(1), 269-289. doi:10.1093/ajae/aat086

Tan, G., Ayugi, B., Ngoma, H., & Ongoma, V. (2020). Projections of future meteorological drought events under representative concentration pathways (RCPs) of CMIP5 over Kenya, East Africa. *Atmospheric Research, 246*. doi:10.1016/j.atmosres.2020.105112

Tanner, T., Lewis, D., Wrathall, D., Bronen, R., Cradock-Henry, N., Huq, S., . . . Thomalla, F. (2014). Livelihood resilience in the face of climate change. *Nature Climate Change, 5*(1), 23-26. doi:10.1038/nclimate2431

Taylor, C. R. (2003). The role of risk versus the role of uncertainty in economic systems. *Agricultural Systems, 75*(2-3), 251-264. doi:10.1016/s0308-521x(02)00068-9

Teklewold, H., Gebrehiwot, T., & Bezabih, M. (2019). Climate smart agricultural practices and gender differentiated nutrition outcome: An empirical evidence from Ethiopia. *World Development, 122*, 38-53. doi:10.1016/j.worlddev.2019.05.010

Teklewold, H., Kassie, M., & Shiferaw, B. (2013). Adoption of Multiple Sustainable Agricultural Practices in Rural Ethiopia. *Journal of Agricultural Economics, 64*(3), 597-623. doi:10.1111/1477-9552.12011

Thulstrup, A. W. (2015). Livelihood Resilience and Adaptive Capacity: Tracing Changes in Household Access to Capital in Central Vietnam. *World Development, 74*, 352-362. doi:10.1016/j.worlddev.2015.05.019

Tompkins, E. L. (2005). Planning for climate change in small islands: Insights from national hurricane preparedness in the Cayman Islands. *Global Environmental Change, 15*(2), 139-149. doi:10.1016/j.gloenvcha.2004.11.002

Touboulic, A., Chicksand, D., & Walker, H. (2014). Managing Imbalanced Supply Chain Relationships for Sustainability: A Power Perspective. *Decision Sciences, 45*(4), 577-619. doi:10.1111/deci.12087

Trinh, T. Q., Rañola, R. F., Camacho, L. D., & Simelton, E. (2018). Determinants of farmers' adaptation to climate change in agricultural production in the central region of Vietnam. *Land Use Policy, 70*, 224-231. doi:10.1016/j.landusepol.2017.10.023

Tucker, C. M., Eakin, H., & Castellanos, E. J. (2010). Perceptions of risk and adaptation: Coffee producers, market shocks, and extreme weather in Central America and Mexico. *Global Environmental Change, 20*(1), 23-32. doi:10.1016/j.gloenvcha.2009.07.006

Twine, E. E., Rao, E. J. O., Baltenweck, I., & Omore, A. O. (2018). Are Technology Adoption and Collective Action Important in Accessing Credit? Evidence from Milk Producers in Tanzania. *The European Journal of Development Research, 31*(3), 388-412. doi:10.1057/s41287-018-0158-z

Uphoff, N., & Buck, L. (2006). *Strengthening rural local institutional capacities for sustainable livelihoods and equitable development*. Paper prepared for the Social Development Department of the World Bank. Washington, DC.

Upton, C. (2012). Adaptive capacity and institutional evolution in contemporary pastoral societies. *Applied Geography, 33*, 135-141. doi:10.1016/j.apgeog.2011.10.008

van Winsen, F., de Mey, Y., Lauwers, L., Van Passel, S., Vancauteren, M., & Wauters, E. (2014). Determinants of risk behaviour: effects of perceived risks and risk attitude on farmer's adoption of risk management strategies. *Journal of Risk Research, 19*(1), 56-78. doi:10.1080/13669877.2014.940597

Vanschoenwinkel, J., Moretti, M., & Van Passel, S. (2020). The effect of policy leveraging climate change adaptive capacity in agriculture. *European Review of Agricultural Economics, 47*(1), 138-156. doi:10.1093/erae/jbz007

Veal, G., Peters, L. D., & Mouzas, S. (2010). Learning to collaborate: a study of business networks. *Journal of Business & Industrial Marketing, 25*(6), 420-434. doi:10.1108/08858621011066017

Vecchio, Y., De Rosa, M., Adinolfi, F., Bartoli, L., & Masi, M. (2020). Adoption of precision farming tools: A context-related analysis. *Land Use Policy, 94*. doi:10.1016/j.landusepol.2020.104481

Verhees, F. J. H. M., Kuipers, A., & Klopcic, M. (2011). Entrepreneurial Proclivity and Farm Performance. *The International Journal of Entrepreneurship and Innovation, 12*(3), 169-177. doi:10.5367/ijei.2011.0039

Verhees, F. J. H. M., Lans, T., & Verstegen, J. A. A. M. (2012). The influence of market and entrepreneurial orientation on strategic marketing choices: the cases of Dutch farmers and horticultural growers. *Journal on Chain and Network Science, 12*(2), 167-179. doi:10.3920/JCNS2012.x011

Villena, V. H., Revilla, E., & Choi, T. Y. (2011). The dark side of buyer-supplier relationships: A social capital perspective. *Journal of Operations Management, 29*(6), 561-576. doi:10.1016/j.jom.2010.09.001

Vincent, K. (2007). Uncertainty in adaptive capacity and the importance of scale. *Global Environmental Change, 17*(1), 12-24. doi:10.1016/j.gloenvcha.2006.11.009

Vlasov, M., Bonnedahl, K. J., & Vincze, Z. (2018). Entrepreneurship for resilience: embeddedness in place and in trans-local grassroots networks. *Journal of Enterprising Communities: People and Places in the Global Economy, 12*(3), 374-394. doi:10.1108/jec-12-2017-0100

Vroegindewey, R., & Hodbod, J. (2018). Resilience of Agricultural Value Chains in Developing Country Contexts: A Framework and Assessment Approach. *Sustainability, 10*(4). doi:10.3390/su10040916

Wainaina, P., Tongruksawattana, S., & Qaim, M. (2016). Tradeoffs and complementarities in the adoption of improved seeds, fertilizer, and natural resource management technologies in Kenya. *Agricultural Economics, 47*(3), 351-362. doi:10.1111/agec.12235

Waldman, K. B., Ortega, D. L., Richardson, R. B., & Snapp, S. S. (2017). Estimating demand for perennial pigeon pea in Malawi using choice experiments. *Ecol Econ, 131*, 222-230. doi:10.1016/j.ecolecon.2016.09.006

Walker, B., Holling, C., Carpenter, S. R., & Kinzig, A. (2004). Resilience, adaptability and transformability in social–ecological systems. *Ecology and Society, 9*(2), 5. doi:http://www.ecologyandsociety.org/vol9/iss2/art5

Wang, J., Brown, D. G., & Agrawal, A. (2013). Climate adaptation, local institutions, and rural livelihoods: A comparative study of herder communities in Mongolia and Inner Mongolia, China. *Global Environmental Change, 23*(6), 1673-1683. doi:10.1016/j.gloenvcha.2013.08.014

Wang, L., Yeung, J. H. Y., & Zhang, M. (2011). The impact of trust and contract on innovation performance: The moderating role of environmental uncertainty. *International Journal of Production Economics, 134*(1), 114-122. doi:10.1016/j.ijpe.2011.06.006

Wang, Q., Bradford, K., Xu, J., & Weitz, B. (2008). Creativity in buyer–seller relationships: The role of governance. *International Journal of Research in Marketing, 25*(2), 109-118. doi:10.1016/j.ijresmar.2007.12.006

Washington-Ottombre, C., & Pijanowski, B. C. (2012). Rural organizations and adaptation to climate change and variability in rural Kenya. *Regional Environmental Change, 13*(3), 537-550. doi:10.1007/s10113-012-0343-0

Welter, F. (2011). Contextualizing Entrepreneurship-Conceptual Challenges and Ways Forward. *Entrepreneurship Theory and Practice, 35*(1), 165-184. doi:10.1111/j.1540-6520.2010.00427.x

Welter, F., & Gartner, W. B. (2016). *A research agenda for entrepreneurship and context*. Cheltenham, UK: Edward Elgar Publishing.

Westermann, O., Förch, W., Thornton, P., Körner, J., Cramer, L., & Campbell, B. (2018). Scaling up agricultural interventions: Case studies of climate-smart agriculture. *Agricultural Systems, 165*, 283-293. doi:10.1016/j.agsy.2018.07.007

Wiklund, J., & Shepherd, D. (2005). Entrepreneurial orientation and small business performance: a configurational approach. *Journal of Business Venturing, 20*(1), 71-91. doi:10.1016/j.jbusvent.2004.01.001

Williams, P. A., Crespo, O., & Abu, M. (2019). Adapting to changing climate through improving adaptive capacity at the local level – The case of smallholder horticultural producers in Ghana. *Climate Risk Management, 23*, 124-135. doi:10.1016/j.crm.2018.12.004

Williamson, O. E. (1979). Transaction-Cost Economics: The Governance of Contractual Relations. *The journal of Law and Economics, 22*(2), 233-261. doi:10.1086/466942

Wong, W. P., Sinnandavar, C. M., & Soh, K.-L. (2021). The relationship between supply environment, supply chain integration and operational performance: The role of business process in curbing opportunistic behaviour. *International Journal of Production Economics, 232*. doi:10.1016/j.ijpe.2020.107966

Wooldridge, J. M. (2010). *Econometric analysis of cross section and panel data*. Massachusetts: MIT press.

World-Bank, & CIAT. (2015). *Climate-Smart Agriculture in Kenya. CSA Country Profiles for Africa, Asia, and Latin America and the Caribbean Series.* The World Bank Group. Washington D.C.

Wossen, T., Abdoulaye, T., Alene, A., Haile, M. G., Feleke, S., Olanrewaju, A., & Manyong, V. (2017). Impacts of extension access and cooperative membership on technology adoption and household welfare. *Journal Rural Studies, 54*, 223-233. doi:10.1016/j.jrurstud.2017.06.022

Wu, M. Y., Weng, Y. C., & Huang, I. C. (2012). A study of supply chain partnerships based on the commitment-trust theory. *Asia Pacific Journal of Marketing and Logistics, 24*(4), 690-707. doi:10.1108/13555851211259098

Xhoxhi, O., Dentoni, D., Drini, I., Skreli, E., & Sokoli, O. (2021). Does Farmers' Trust towards Buyers drive their Entrepreneurial Orientation? *Journal of Agribusiness in Developing and Emerging Economies, (in press)*.

Xhoxhi, O., Pedersen, S. M., & Lind, K. M. (2018). How does the intermediaries' power affect farmers-intermediaries' trading relationship performance? *World Development Perspectives, 10-12*, 44-50. doi:10.1016/j.wdp.2018.09.004

Yaro, J. A., Teye, J., & Bawakyillenuo, S. (2014). Local institutions and adaptive capacity to climate change/variability in the northern savannah of Ghana. *Climate and Development, 7*(3), 235-245. doi:10.1080/17565529.2014.951018

Yegbemey, R. N., Kabir, H., Awoye, O. H. R., Yabi, J. A., & Paraïso, A. A. (2014). Managing the agricultural calendar as coping mechanism to climate variability: A case study of maize farming in northern Benin, West Africa. *Climate Risk Management, 3*, 13-23. doi:10.1016/j.crm.2014.04.001

Yegbemey, R. N., Yabi, J. A., Tovignan, S. D., Gantoli, G., & Haroll Kokoye, S. E. (2013). Farmers' decisions to adapt to climate change under various property rights: A case study of maize farming in northern Benin (West Africa). *Land Use Policy, 34*, 168-175. doi:10.1016/j.landusepol.2013.03.001

Yohe, G., & Tol, R. S. J. (2002). Indicators for social and economic coping capacity—moving toward a working definition of adaptive capacity. *Global Environmental Change, 12*(1), 25-40. doi:10.1016/s0959-3780(01)00026-7

York, J. G., & Venkataraman, S. (2010). The entrepreneur–environment nexus: Uncertainty, innovation, and allocation. *Journal of Business Venturing, 25*(5), 449-463. doi:10.1016/j.jbusvent.2009.07.007

Zeweld, W., Van Huylenbroeck, G., Tesfay, G., Azadi, H., & Speelman, S. (2020). Sustainable agricultural practices, environmental risk mitigation and livelihood improvements: Empirical evidence from Northern Ethiopia. *Land Use Policy, 95*. doi:10.1016/j.landusepol.2019.01.002

Zeweld, W., Van Huylenbroeck, G., Tesfay, G., & Speelman, S. (2017). Smallholder farmers' behavioural intentions towards sustainable agricultural practices. *J Environ Manage, 187*, 71-81. doi:10.1016/j.jenvman.2016.11.014

Zhao, X., Huo, B., Flynn, B. B., & Yeung, J. H. Y. (2008). The impact of power and relationship commitment on the integration between manufacturers and customers in a supply chain. *Journal of Operations Management, 26*(3), 368-388. doi:10.1016/j.jom.2007.08.002

Zhou, J., Liu, Q., & Liang, Q. (2018). Cooperative membership, social capital, and chemical input use: Evidence from China. *Land Use Policy, 70*, 394-401. doi:10.1016/j.landusepol.2017.11.001

Summary

Climate change poses major and growing threats to global food security and livelihoods. Climate change affects food security and livelihoods in complex ways. For instance, it affects food production directly through changes in climatic conditions and indirectly through affecting incomes, demand and distribution of agricultural production. To minimize the impacts of climate change, farmers need to adapt their farming practices to continue producing food products and earning an income. Consequently, national governments, non-governmental organizations and development agencies are making investments in improving the ability of farmers to cope with and adapt to climate change.

However, given the uncertain future, in terms of the frequency and severity of adverse climatic events, designing risk management strategies that require the identification of risks likely to occur in the future is no longer sufficient. In addition to designing risk management strategies, there is a need to invest in building resilience. At the farm level, resilience is the ability to ensure the continuity of farm functions when facing multiple shocks and risks through strengthening the absorptive, adaptive and transformative capacities of the farm. The concept of resilience is relevant for adapting to farm risks as it takes into account the complexity and uncertainty of risks.

This thesis focused on farmers' adaptive capacity as a key building block of farm resilience. There are at least three reasons for this focus. First, with the increasing frequency and severity of adverse climatic events, it is no longer feasible for farmers to just absorb the risks. In other words, it is no longer sufficient to only rely on the absorptive capacity in responding to climate change; farmers also need to adapt. Second, although transformation may be seen as a suitable response, smallholders particularly in sub-Saharan Africa have limited resources, knowledge and skills to move into new systems. Third, existing climate change adaptation studies have identified a lack of adaptive capacity as the main reason for the low adoption of climate adaptation strategies; yet, studies on how it can be improved are still scarce. Generally, adaptive capacity is the ability to adjust when facing changing conditions. At the farm level, adaptive capacity represents the farmer's potential to use existing and new resources into effective adaptation strategies.

From the foregoing, it is evident that farmers' adaptive capacity needs to be improved. This thesis took a step back and asked the overarching question of how farmers' adaptive capacity be improved? The thesis addressed the overarching question through four specific research questions employing both qualitative methods, including a literature review, and quantitative methods. To set the stage for this

study, Chapter 2 took the first step in answering the overarching question by identifying the determinants of farmers' adaptive capacity:

RQ1: *What are the determinants of farmers' adaptive capacity and how can it be improved?*

This research question was answered through a review of the literature at the intersection of climate resilience, farmer entrepreneurship and value chain collaboration. The review found that several factors improve farmers' adaptive capacity, including access to the resources that farmers can draw upon in times of need; the flexibility to make strategic changes; ability to organize and act collectively; ability to learn; and the agency to determine whether, when and how to make changes. In addition, this thesis identified three determinants herein collectively referred to as the pathways for improving farmers' adaptive capacity. These determinants are (1) farmer entrepreneurial orientation (EO), (2) membership of a farmer organization (FO) and access to the services of the FO, and (3) farmer-buyer relationship.

Chapter 3 examined in detail the proposition that farmer EO determines farmers' adaptive capacity which is reflected by the ability to adopt climate adaptation strategies. We use survey data from smallholder potato farmers in Kenya to determine whether farmer EO supports climate change adaptation, specifically the adoption of climate-smart agriculture (CSA) practices. The following specific research question was answered:

RQ2: *Does farmer entrepreneurial orientation matter for smallholders' adaptation to climate change?*

To respond to this research question, we draw from entrepreneurship, technology adoption and climate change adaptation literature. We used data from 792 smallholder potato farmers. Data were collected on the characteristics of the farm and the farmer, on institutional factors and the three dimensions of farmer entrepreneurship orientation (i.e., risk-taking, innovativeness and proactiveness). Six CSA practices were considered, namely irrigation, change in cultivation calendar, certified seed, crop rotation, soil testing, and intercropping. The results of the multivariate probit models reveal that, overall, farmer EO supports the adoption of individual CSA practices. Additionally, when the intensity of resources required to adopt CSA practices is considered, we find that risk-taking increases the adoption of finance-intensive CSA practices while innovativeness reduces the adoption of finance-intensive CSA practices. As such, Chapter 3 provides evidence that farmer entrepreneurship matters for climate change adaptation.

Chapter 4 examined whether and how FOs support farmers' ability to adapt to climate change. The premise is that membership and access to the services of FOs improve farmers' adaptive capacity and thereby enable the adoption of climate adaptation strategies. The following research question was addressed:

RQ3: *How do membership and access to FO services impact on smallholders' adaptation to climate change?*

The impact of membership and access to FO services on CSA adoption is evaluated through a quasi-experimental design. The survey data allowed for disaggregation based on membership and access to FO services. Three services were considered: access to credit, access to extension and access to markets for farm produce. To estimate the impact of membership and access to FO services on CSA adoption, we employed a doubly robust inverse probability weighted regression adjustment approach with conditional analysis to account for the heterogeneity in membership and access to the different services. The analysis was done taking into account three constellations relating to membership and access to FO services: (1) comparison between members and non-members; (2) comparison between members with access to FO services and members without access to FO services; and (3) membership with conditional access to services.

Three highlights can be distinguished from the results. First, even without considering access to FO services, FOs support smallholders' adoption of CSA practices. Second, when access to FO services are considered impact varies, with market access producing the highest impact followed by access to credit and extension respectively. Third, market access conditional on access to extension, and access to credit conditional on access to extension present extension as a catalyst service; it enables market access and access to credit to produce additional impact. These results are robust to different estimation strategies. This chapter provides evidence that FOs support smallholders in climate change adaptation and that membership alone does not fully explain the impact of FO; instead, access to FO services need to be taken into account.

Chapter 5 examined whether and how farmer-buyer relationship supports climate change adaption. The general hypothesis is that farmer-buyer relationship improves farmers' adaptive capacity by enabling the farmers to access production resources and to share risks with buyers. The following specific research question was answered:

RQ4: *Do farmer-buyer relationship influence smallholders' adaptation to climate change?*

In Chapter 5, the thesis sought to examine the association between farmer-buyer relationship and farmers' adaptive capacity through structural equation modelling (SEM), using the survey data of 792 smallholder potato farmers. The study draws from social exchange theory and is based on the farmers'

perspective of the farmer-buyer relationship. The SEM analysis uses the second-order confirmatory factor analysis. In addition, mediation analysis was conducted with farmer EO as mediator. The results indicate that the farmer-buyer relationship is not directly associated with farmer's adaptive capacity, however, when the relationship is mediated by farmer EO a positive relationship is established. These findings suggest that farmers need to use their entrepreneurial orientation in order to exploit the benefits of farmer-buyer relationship for adapting to climate change.

In sum, the four chapters have contributed to the understanding of the pathways for building and strengthening farmers' adaptive capacity. This capacity is necessary for improving farm resilience to climate change. Several implications can be drawn from this thesis. First, there is a need for targeted entrepreneurship training by smallholders. Second, there is a need for policies that encourage membership in FOs and support FOs to provide adaptive-capacity supporting services to their members. Third, there is a need for interventions that support building and maintaining relationships between farmers and buyers as these encourage entrepreneurial behaviour, which, in turn, improve farmers' adaptive capacity.

Acknowledgements

During my PhD journey, I spent a lot of time thinking and researching about resilience, collaboration and networks of support. Studying these concepts taught me the importance of being resilient, collaborating and building networks in life. This thesis, therefore, presents not only the opportunities for building farm resilience but also represents my resilience, the collaboration and networks of support that I received from remarkable individuals who directly or indirectly made contributions throughout this journey. I gratefully wish to acknowledge them.

First, I am grateful to my thesis supervisory team Dr Jos Bijman and Prof. Domenico Dentoni "the dynamic duo". First, thank you for hiring me as a PhD candidate within the 3R project. I know this was not an easy decision to make given that Mercy (my wife) was at the time doing her PhD under the supervision of Jos Bijman, but still, you trusted me and gave me the opportunity. Second, I thank you for giving me the freedom to follow the research concepts and topics that I am passionate about and at the same time making sure that I stayed on track. I deeply appreciate your patience, constructive critics, valuable comments, suggestions and spending time editing all the chapters presented in this thesis. Your encouragements, passion and interest in my work ensured that I remained focused. Third, I cannot thank you enough for teaching me how to express my ideas and arguments scientifically. Whenever we had our biweekly meetings, all of us met 99% of the time. This for me was a sign of dedication and interest in my work. All our meetings started with at least 5 minutes of talking about personal issues, family, weekend activities etc. This was particularly encouraging especially during the period of the COVID-19 pandemic, it also showed that you were not only concerned about my academic life but also my social life, I will treasure those moments and will surely miss the meetings.

Jos, you taught me how to write concisely and the importance of consistency in scientific writing. Your door was always open and I could step in even without an appointment, thank you for clarifying concepts, frameworks and for helping to interpret the research findings whenever I was stuck. I am grateful also for spending your time to teach me how to review academic papers. Domenico, thank you for teaching me how to critique literature, how to target different types of journals and for being always available virtually whenever I needed to consult you. I am also grateful for offering yourself to be our voice (me and other PhD students in the group) when we faced housing problems within the university.

My sincere appreciation to the 3R project team Laurens Klerkx, Irene Koomen, Catherine Kilelu, Ingrid Coninx, Jan van der Lee, Joyce Gema, John Keige, Jessica Koge, Felix Opola and Jane Chege. Catherine, thank you for checking on me, encouraging and for being available to guide and provide critical comments on my ideas and work. Thank you also for organizing a working space at ACTS offices in Nairobi. Irene, thank you for your interest in my work and for introducing me to numerous and very resourceful experts working on potato value chains in Kenya and the Netherlands. I am grateful also for your invitation for coffee at the CDI offices. Jan van der Lee, thank you for being part of this PhD journey in so many ways. First, I am honoured to have been a co-author of one of your PhD chapters. We worked long hours and sometimes on weekends coding and writing the systematic literature review paper. I learned a lot from your years of experience, your pragmatic approach to issues and your dedication to work. I am also grateful to you for spending your time to organize visits to the Dutch farms around Wageningen. On a personal level, thank you for dinner invitations to your lovely home and also for making our stay in the Netherlands stress-free as you supported in many ways including sending you with “*salamu*” whenever you were travelling to Kenya. Joyce, thank you for sharing your field experience on smallholder farming in Kenya and for allowing me to use your office and office resources at Tradecare. John, I appreciate the time you took to show me how to program my survey tool in SurveyCTO, without this, data collection would have been a tedious, inefficient and expensive exercise. Felix and Jane, thank you for sharing the ups and downs of this PhD journey I know that soon your PhD journey will also come to an end.

Along this PhD journey, I collaborated with Francisco Cecchi of the Development Economics Group at WUR and Monica Parker of the International Potato Center (CIP) both of who later become co-authors. Francisco, I sincerely appreciate you for finding time in your busy schedule to teach me different Impact Assessment methods. I particularly enjoyed and learnt a lot from your detailed explanation of econometrics techniques. Monica, thanks for your insightful and critical comments on Chapter 5 of this thesis and for sharing your experience in potato farming in Kenya.

The research leading to this PhD achievement would not be possible without research data. In this regard, I would like to thank individuals and organizations that supported me get the data. First, special appreciation goes to the farmers in Meru and Nakuru counties of Kenya who gladly accepted to participate in this research. No amount of words can express my appreciation for the time and information you shared about your farm businesses. To the leaders of the numerous farmer organizations and cooperatives that we visited, thank you for allowing us to visit your farmers.

This work was not going to be anywhere close to success without the assistance of my team of research assistants, to whom I owe a big thank you. These are Dennis, Dorothy, Makumi, Collins, Janet, Judy, Faith, Beth and Purity thank you for your dedication and ethics in collecting the data. Sometimes you needed to brave the rain and cold weather of Mt. Kenya and Keringet in search of sampled farmers, you did this with no complaints. To the agriculture extension officers specifically Joseph Muruatetu, Maina, Gachanja and Gitonga in Meru; Noah and Lang'at in Nakuru, thank you for allowing me to conduct my research in your areas. To Wachira Kaguongo and Charity Mukami of the National Potato Council of Kenya (NPCK) thank you for providing me with the lists of farmer organizations. To Corine H. of Agrico; V. Klass and B. Ndolo of SNV; W. Kibet and M. Parker of the International Potato Center (CIP); J. Oyoo and N. Ng'ang'a of the Kenya Agriculture and Livestock Research Organization (KALRO); E. Osena and P. Chelang'a thank you for sharing your practical experiences about potato farming in Kenya.

Indirectly, the completion of my PhD thesis has benefited from many generous and selfless contributors and I must acknowledge that this milestone would not have been achieved without their support. I want to thank my family and friends to whom I often had to explain again and again what I was doing and when I would be done with going to school. First, to my parents Francis Tibai and Esther, and my brothers and sisters thank you for instilling in me the importance of education, your prayers and messages of goodwill kept me going. To my grandparents with whom I shared most of my early years, although they did not live to witness my achievement of this highest degree, I am sure that they are proud of this milestone. To my parents-in-law Ezekiel Mwambi and Prudence Mwadime, and sisters-in-law words cannot express my appreciation for your generosity and the sacrifices that you willingly made to take care of my son Louis (Kim) from when he was only 9-months old to allow me and Mercy to pursue our PhD studies in the Netherlands. We couldn't have asked for any form of support to accomplish this dream. To my wife Mercy, what an opportunity to have done a PhD in the same Chair group, under the same supervisor at the same time! It was always a privilege to share the ups and downs of PhD life. To my son Louis (Kim) to whom this thesis is specially dedicated, while I was not present most of the time to give you the attention you deserved, I am comforted that your caring grandparents stepped in and you enjoyed your time with them. You are such a resilient boy! I am glad that the PhD is done now and we can spend time together.

Second, my friends and colleagues thank you for making this journey worthwhile. Colleagues at the Business Management & Organisation (BMO) group thank you for the academic and moral support that you provided me. Special mention to the current and former PhD fellows including Francisco, Sophia, Annemarie, Alice, Camila, Timothy, Jasmina, Katty, Robert, Fanny, Rob, Mmapatla, Amin, Etriya, Delelegne, Ardinesh among others. Sophia, Francisco and Timothy, I appreciate your interest in my work and for the insightful discussions we had. To the teaching staff including Jacques, Emiel, Geoffrey, Valentina, Maral, Wilfred, Onno, Maria, Verena among others thank you for the friendly working environment you created. To the former and current administrative staff at BMO including Ina, Linette, Brigit, Marloes and Liesbeth you played a big role in ensuring that I settled in well and received office resources, flight tickets and finances on time, this is highly appreciated. My paranymphs Francisco Benitez Altuna and Severin Dery, thank you for supporting me during the preparation of this PhD defence.

Life in Wageningen was not only about academics. I made friends with lovely and interesting people from different parts of the world who made life enjoyable. The *Immaculacy* crew, including Francisco (Equador), Sebastian, Marce, Fernando and David (Costa Rica), Anatol (Switzerland), Justina and Carlo (Italy). Guys, it was always fun to join the weekend and Christmas dinners, beers and dancing by the river during the summer and the football matches. I am glad that we fully participated in the last Carnival festival in Maastricht and Eindhoven before the COVID-19 disrupted life. Francisco, it was always fun and reenergizing to meet for dinners and play video games during the COVID-19 lockdown period. Severin, Joshua, Mercy, Faith, Alex, Bernard (Prof) and Sydney thank you so much for the get-together evening meetings it was also fun to cycle to and from Rhenen. Arouna Dissa, I am grateful for the time we shared discussing about smallholder farming in Africa and more especially I enjoyed the time we spent cycling in the woods and along the dykes.

To the Kenyan community at WUR, you made life enjoyable away from home, *asanteni sana!* My sincere gratitude to the International Catholic Community, it was always a pleasure to fellowship together and sing in the African choir. To the wonderful Vestlink family back in Kenya thank you for always checking on me and your best wishes. My former colleagues at ILRI especially P. Chelang'a thank you for your critical comments on my work and for always encouraging and pushing me to get this PhD done.

Daniel Kipkurui Kangogo

Wageningen School of Social Sciences (WASS)

Completed Training and Supervision Plan

Name of the learning activity	Department/Institute	Year	ECTS*
A) Project related competences			
Quantitative Data Analysis: Multivariate Techniques, YRM - 60306	WUR	2017	6.0
Entrepreneurship in Emerging Economies, BMO - 56806	WUR	2018	2.0
Qualitative Data Analysis: Procedures and Strategies, MAT- 50806	WUR	2019	6.0
Advanced Econometrics, YSS - 34306	WUR	2020	6.0
Research Proposal writing	WUR	2017	6.0
B) General research related competences			
WASS Introduction Course	WASS	2017	1.0
"Determinants of farm resilience to climate change: the role of farmer entrepreneurship and value chain collaboration"	13th Wageningen International Conference on Chain and Network Management (WICaNeM), Ancona, Italy	2018	1.0
"Adoption of climate-smart agriculture among smallholder farmers: Does farmer entrepreneurship matter?"	WASS PhD Day, Wageningen University	2020	0.5
"Farmer Organisations and Climate Change Adaptation: the effects of membership and access to services"	ICA Conference, held in Paris, France, as an online version	2021	1.0
C) Career related competences/personal development			
Information Literacy including EndNote Introduction	Wageningen University Library	2017	0.6
The Essentials of Scientific Writing and Presenting	Wageningen In'to Languages	2017	1.2
Data Management and Planning	Wageningen University Library	2020	0.45
Autumn school: Food Value Chain Research; Understanding Inter-Organizational Relationships	WASS	2017	1.5
Reviewing a Scientific Manuscript	WGS	2020	0.1
Total			**33.35**

*One credit according to ECTS is on average equivalent to 28 hours of study load

The research described in this thesis was financially supported by the Embassy of the Kingdom of The Netherlands in Kenya, through the 3R (Robust, Resilient and Reliable) project.

Cover designed by: Baharaddin Adam Mohammed
Printed by: Digiforce || ProefschriftMaken
Contact via: kangogodan@yahoo.com

Copyright © 2022, Daniel Kipkurui Kangogo, Kenya