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Responses of sub-Saharan smallholders to climate change: Strategies and drivers of adaptation

Silvestre García de Jalón[a,*], Ana Iglesias[b], Marc B. Neumann[a,c]

[a] Basque Centre for Climate Change (BC3), 48940, Leioa, Spain
[b] Department of Agricultural Economics, Universidad Politécnica de Madrid (UPM), 28040, Madrid, Spain
[c] Ikerbasque, Basque Foundation for Science, Bilbao, Spain

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ABSTRACT

Rural farm households in sub-Saharan Africa are vulnerable to climate variability due to their limited adaptive capacity. This paper explores how adaptation strategies are adopted by small-holders in sub-Saharan Africa as a function of their adaptive capacity. The latter is characterised by five types of capital: natural, physical, financial, human, and social. We use responses from farm households in sub-Saharan Africa dating from 1536 obtained by Climate Change, Agriculture and Food Security (CCAFS). This data provides information on the adoption of adaptation practices during the study period as well as information with which we develop indicators for the five types of capital. The results suggest that all the five types of capital positively influence adoption of adaptation practices. Human and social capital both displayed a positive and significant effect on the uptake of most adaptation practices. This finding suggests that the effect of less tangible kinds of capital such as knowledge, individual perceptions, farmers' networks and access to information may be stronger than normally assumed. Directing more development policies towards enhancing human and social capital may therefore be more cost-effective than further investments into physical and financial capital, and could help in overcoming social barriers to adaptation to climate change.

1. Introduction

Many farm households in sub-Saharan Africa (SSA) are vulnerable to climate change due to both their strong dependence on agricultural production, and a limited resilience to cope with changing conditions (Schlenker and Lobell, 2010). Moreover, agriculture in rural SSA is the main source of one's livelihood and is the main contributor to GDP. At the same time, agriculture in SSA faces enormous challenges. Firstly, in growing enough food to support the rapidly growing population; in the last two decades the population in SSA has almost doubled (from 0.64 billion in 1998 to 1.05 billion in 2018) and is projected to reach 1.7 billion by 2050 (Livingston et al., 2011). Secondly, there is increasing international pressure to not expand agricultural land at the expense of natural habitats for wildlife. Finally, climate change forecasts predict a decrease in production of between 8–22 percent in key staple crops such as maize, sorghum, groundnut, millet, and cassava by 2050. Predictions were based on various model specifications with a historic time series in the data sources (1961–2000 for NCC or 1961–2002 for CRU 2.1) (Schlenker and Lobell, 2010). These challenges need to be considered when developing policies that increase household food security, reduce poverty, improve livelihoods and facilitate climate change adaptation (Africa Adaptation Programme (AAP), 2013; Beddington et al., 2012; International Fund for Agricultural Development (IFAD), 2013).

Numerous studies in Africa have contributed to understanding how to promote the adoption of adaptation measures at the farm-level (e.g. Below et al., 2012; Bryan et al., 2013; Deressa et al., 2009; Gebrehiwot and van der Veen, 2013; García de Jalón et al., 2016, 2017; Nielsen and Reenberg, 2010; Silvestri et al., 2012). However, most studies evaluate the adaptation process by analysing how socioeconomic characteristics influence adaptation for example, by measuring farm household traits such as education, farm size, ownership, access to credit, and other variables that can be directly observed. Few studies have focused on how the adoption of practices is influenced by the five types of capital: natural, social, physical, financial, and human. This may be due to the fact that these five types of capital are difficult to characterise and quantify.

The five forms of capital are defined as stocks or flows that have the capacity to produce flows of economically desired outputs (Goodwin, 2003). All forms of capital can be seen as indicators of wealth (e.g.

* Corresponding author.
E-mail address: silvestre.garciadejalon@bc3research.org (S. García de Jalón).

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Lange, 2004; Goodwin, 2003; Figge, 2005) or resilience (e.g. Thornton et al., 2006; Nelson et al., 2005). In addition, they can act as predictors of the uptake of adaptation strategies to climate change (e.g. Wheeler et al., 2013; Below et al., 2012; Iglesias et al., 2011).

Human capital refers to the productive capacities, knowledge, and personal attributes that make an individual more productive (Pindyck and Rubinfeld, 2013). In farming systems, indicators of this capital could be the number of people in the farm-household, education and attitudes towards the environment and climate change.

Social capital consists of trust, understanding and cooperation between individuals and groups (Goodwin, 2003). Thus, the exchange of climate change information between farmers and institutions could be considered indicators of social capital. Indicators of this capital could also include memberships of agricultural associations, the access to information on climate and extreme weather events or the use of social networks (García de Jalón et al., 2018).

Physical capital is formed by manufactured assets generated by applying human productive activities and are used to provide flows of goods and/or services (Goodwin, 2003). It refers to assets such as infrastructure and technology that may improve farm production. Indicators of physical capital in farming systems could include farm assets such as mechanical ploughs, irrigation systems, electronic assets, livestock and land holdings, and agricultural inputs.

Financial capital is related to the capital stock that facilitates economic production. Indicators of this capital could be off-farm and on-farm income, access to credit, having a bank account and remittances.

Natural capital refers to the resources and services of the natural world which yield valuable flows of goods and services into the future (Costanza and Daly, 1992). In farming systems, natural capital is mainly represented by agro-climatic characteristics which predetermine the suitability for agriculture such as climatic (e.g., temperature, precipitation, humidity, solar radiation) and soil (e.g., texture, structure, % organic matter, pH and depth) conditions.

A large body of literature has aimed to study the drivers of adaptation at the farm-household level in SSA (e.g. Deressa et al., 2009; Nielsen and Reenberg, 2010; Silvestri et al., 2012; García de Jalón et al., 2017). The fact that only few studies focused on the effect of the five types of capital could be explained by the difficulty of characterising or quantifying these capitals, a process considerably more complex than measuring farm-household traits such as education, farm size, ownership, access to credit, etc. It is actually possible to include these farm household characteristics within the five types of capital. For instance, education or knowledge about climate change are indicators of human capital. Farm size, machinery and infrastructure are indicators of physical capital. This type of clustering of indicators into the five capitals has been done previously (e.g. Wheeler et al., 2013; Below et al., 2012).

Previous studies have demonstrated that the effect of the five types of capital on adoption, might be different for each adaptation strategy. The study of Wheeler et al. (2013) on Australian farmers showed, that in general, the five capitals positively influenced the adoption of adaptation measures, however, for each particular measure, the influence varied and was even negative in some cases. For example, low education had a positive effect on increasing irrigation area whereas it had a negative effect on changing crop mix. The study of Below et al. (2012) in the Morogoro region of Tanzania, found that some indicators of human and social capital such as education level or female headed households in some cases negatively impacted the adoption of some adaptation strategies. Their study also indicated that physical and financial capital were the greatest predictors for uptake of adaptation measures. Our study extends their research by exploring the influence of the five forms of capital on the adoption of fourteen agricultural practices in nine Sub-Saharan countries. The results may help identify barriers and incentives of adoption across Sub-Saharan smallholders and contribute to better understand how adoption may evolve as farm-household stocks and flows change over time.

Regional scale mathematical models that are spatially explicit and consider land, weather and management characteristics (e.g. partial equilibrium models such as GLOBIOM) can predict the uptake of adaptation strategies over time. However, the actual uptake often turns out to be different from that predicted by the models as some key biophysical and/or socioeconomic characteristics at farm scale are not taken into account. Therefore, a better understanding of the determinants of adoption on the farm scale could ultimately serve to improve the accuracy of such regional scale models.

This paper explores the adoption of fourteen agricultural practices during a 10-year time period in order to better understand farm scale effects. We assess how the adoption of these practices is affected by the five forms of capital at the farm-household level. By taking into account farm-level dynamics the results of this study may contribute to better understand how adoption may evolve in Sub-Saharan Africa.

2. Materials and methods

2.1. Data

This study used three sources of publicly available data: survey data at the household level, social indicators at the district level and climate indicators at the regional level.

Survey data was obtained from the survey of the CGIAR Research program on Climate Change, Agriculture and Food Security (CCAFS) which, was conducted in late 2010 and early 2011 (Kristjanson et al., 2011). The survey was based on face-to-face interviews at the farm-household level and included 1538 farm households in 80 villages as part of 11 case studies across 9 countries (Burkina Faso, Ghana, Mali, Niger, Senegal, Ethiopia, Kenya, Tanzania, and Uganda). The CCAFS survey was designed with the purpose of developing simple and comparable cross-site household-level indicators for which changes in agricultural practices could be evaluated over time (more information available from Kristjanson et al. (2011)).

Additional indicator data to evaluate the natural capital were collected from different data sources. Agro-climatic data was obtained from WorldClim (www.worldclim.org/) and included annual precipitation as well as the difference between precipitation and potential evapotranspiration. This difference between precipitation (water supply) and potential evapotranspiration (water demand) could be used as an indicator of suitability for rain fed agriculture in terms of water availability. The duration of the growing period was obtained from FAO GeoNetwork (www.fao.org/geonetwork/).

2.2. Uptake of the adaptation practices

In this study, the dependent variable is the adoption level of adaptation practices in the farm-households surveyed within the CCAFS research program. Our study assesses the adoption level of fourteen adaptation practices which are classified into six groups: i) Introducing more resistant crop varieties, ii) Introducing or improving irrigation, iii) Improving soil conservation, iv) Introducing integrated pest and crop management v) Increasing the use of fertilisers and agrochemicals and vi) Changing planting and cropping practices.

In the literature, increasing the use of fertilisers and agrochemicals has been previously identified as necessary for sustained agricultural growth in Sub-Saharan Africa (Larson and Frisvold, 1996; Schreinemachers and Tipraqsa, 2012) and considered as an adaptation strategy to climate change since a correct application can enhance water use in water-limited environments (Debaeke and Aboudrare, 2004).

The drivers of adoption of the adaptation practices are classified according to the five kinds of capital: human, social, physical, financial, and natural.

Table 1 shows the selected indicators of the five kinds of capital used to assess adoption. Within human capital, the indicators are education, size of the farm-household, and attitudes towards the