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How climate awareness influences farmers' adaptation decisions in Central America?

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ABSTRACT

Central America is one of the regions with the highest vulnerability to climate change, with negative effects projected to affect its economy and food security. To address this issue, an integrative farm management approach such as Climate-Smart Agriculture can help reorient agricultural practices towards climate adaptation and food security. Past studies have shown that several factors can either hinder or encourage the adoptions of Climate-Smart practices, including subjective expectations and perceptions. Building on this literature, we analyze farmers' climate awareness and their perceptions regarding the change in climate patterns as well as their choices of farming practices to adapt to these changes. We show that reforestation was the preferred adaptation strategy among interviewed farmers and that educational profiles and the size of landholdings drive the adoption of this and other practices. Soil management and introduction of new crops are preferred by literate farms with large farmlands, whereas illiterate farmers with smaller farmland tend to move towards farm intensification with an increase in the utilization of external inputs. Our findings provide evidence to support the design of capacity development interventions targeting specific groups of farmers according to their main crop and education profile.

1. Introduction

Trends in greenhouse gases emissions to 2050 indicate a low contribution of Central America to global warming (Marchal et al., 2011), and yet the region is highly vulnerable to the effects of climate change. Several climate-related impacts have been projected for the region, indicating changes in evapotranspiration, temperature, precipitation, species suitability, farm productivity, and forest loss, mainly across the drier zones (Hannah et al., 2017; Lyra et al., 2017). Therefore, promoting farm practices to strengthen resilience and productivity of agricultural systems is crucial to help farmers in Central America adapt to climate change and thus ensure food provision and income generation.

Climate change has increased the risks and uncertainties associated with agriculture, particularly in developing countries (Altieri and Nicholls, 2017; Imbach et al., 2017). Changes in the frequency and intensity of extreme climatic events in the tropics due to climate change have increased the concerns for farm adaptation among scientists (Hannah et al., 2017; Harvey et al., 2014; Mbow et al., 2014) and farmers (Elum et al., 2017; Khatri-Chhetri et al., 2017; Singh et al., 2017). It is argued that the adoption of Climate-Smart Agriculture (CSA) practices will help vulnerable farmers cope with the effects of climate variability and change (Lipper et al., 2014; Steenwerth et al., 2014). Climate-Smart Agriculture is an integrative approach designed to help farmers reorient their agricultural practices to sustainably rise agricultural productivity to ensure increases in farm incomes and food security, while adapting and mitigating climate change. These practices include farm sustainable intensification and diversification of

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production, agroforestry, varietal selection, plant breeding, ecosystem management, crop patterns identification, and integrated practices to minimize the need of external inputs (FAO, 2010).

The adoption and impact of agricultural practices and technologies has been a focus of study for several years (see Mwangi and Kariuki (2015), for a literature review on adoption, and Ogundari and Bolarinwa (2018), for a recent meta-analysis on the impacts of agricultural technologies). The literature shows that the adoption of technologies by smallholder farmers mostly has a positive effect on welfare and production outcomes, and that adopting technology packages as opposed to individual components can further increase these benefits (Khonje et al., 2018).

Nevertheless, several socio-economic barriers can hinder technology adoption, even in countries that enjoy higher levels of technological innovation and well-established institutions (Long et al., 2016). The presence of certain policies, such as input subsidies (Koppmair et al., 2017), and technology specific characteristics (Senyolo et al., 2018; Wassie and Pauline, 2018) can also influence whether and which technologies farmers adopt. Likewise, intrinsic factors, such as perceptions and knowledge of farmers, play a role on shaping technology adoption (Meijer et al., 2015).

One strain of this body of literature on technology adoption uses the theory of planned behavior (Ajzen, 1991) to understand how perceptions and other underlying psychological constructs affect technology adoption. In a study about the adoption of improved natural grassland in Brazil, Borges et al. (2014) find that farmers' expectations about the benefits of this new technology, their perceptions about social pressure, and their perceptions about their own skills are significantly correlated with the intention to adopt. Similarly, Wauters et al. (2010) show that attitudes towards soil conservation practices are one of the biggest determinants of adoption among Belgium farmers. Regarding sustainable agricultural practices for climate adaptation, several studies conclude farmers' awareness and perceptions of climate change are correlated with adoption (Elum et al., 2017; Niles and Mueller, 2016; Schattman et al., 2016; Singh et al., 2017).

Building on this body of literature, the objective of this study is to understand how farmers' awareness of climate change and their socioeconomic profiles drive the utilization of sustainable farm management practices in Central America. We assess farmers' climate awareness by identifying farmers' perceptions of climate variability and compare it with observed climate anomalies using time series data. Additionally, we implement a Bradley-Terry model to assess how socioeconomic profiles and farm characteristics influence farmers' choices in the adoption of sustainable agriculture practices.

2. Materials and methods

2.1. Study area and household data

We used surveyed data from 283 households participating in the Mesoamerican Environmental Program (MAP), a rural development program conducted in Central America between 2009 and 2017 that used Farmer Field Schools (FSS) to promote CSA practices and gender integration (see Gutierrez-Montes et al. (2018), for details on the methodology applied in the FFS). We used two sets of data: *(i)* a household survey on farmer's perceptions on climate change (Appendix A), and *(ii)* household socioeconomic data and information records of practices adopted by the farmers after participating in FFS obtained from MAP's annual monitoring.

Farmers were located across the two main ecoregions of Central America (Fig. 1): the Central American Dry Corridor (or Dry Forests), corresponding to El Salvador, Guatemala, Honduras, and part of Nicaragua (districts of Jinotega and Matagalpa); and the Central American Rainforests in Nicaragua (districts of Jinotega, Matagalpa, and Atlántico Norte). Farms across the Dry Corridor have an annual average precipitation of 1400 mm (1000–2100 mm), mean annual temperature of 22 °C (14–25 °C) and mean elevation of 750 m a.s.l. (300–1950 m a.s.l.). Farms across the Rainforests present annual average precipitation of 2200 mm (1500–2400 mm), mean annual temperature of 22 °C (19–25 °C) and mean elevation of 570 m a.s.l. (240–1200 m a.s.l.) (Hijmans et al., 2005). Agricultural and livestock production are the main economic activities developed across the research sites.

Precipitation is key for determining the crop seasons in Central America, especially for the annual crops. The first growing season, called *Primera*, starts in May and ends in September, when the second season (*Postrera*) begins. The last growing season, *Apante*, starts in November and ends in January. This season presents a gradual decrease in rainfall until the beginning of the dry season (*Verano*) in January (Fig. 2).

To collect the household data, in 2014, we applied a questionnaire to identify the perceptions of farmers regarding changes in climatic patterns and how they responded to these events in terms of farm management practices. Farmers were questioned about their perceptions regarding changes in precipitation and temperature over the 10 years before the interviews (2005–2014). Farmers who reported to have felt changes in climatic patterns were asked to list the farm management practices they have adopted in their crop systems to cope with such changes. These practices were ranked by the order they were mentioned by the farmers. In Table 1 we show descriptive statistics of the socioeconomic data from the 283 households disaggregated by ecoregion.

2.2. Retrieving environmental data to validate farmers’ perceptions

We took farmers' perceptions of changes in climatic patterns and compared them to a gridded time series precipitation database from the Climate Hazards Group InfraRed Precipitation with Station data (CHIRPS) (Funk et al., 2015). This database incorporates global daily rainfall data since 1983 with a resolution of 2.5 arc-min ($\sim 5\,\text{km}^2$), which is obtained by weather stations and combined with remote sensing. Changes in precipitation were assessed by calculating three extreme precipitation indices relevant for Central America (Aguilar et al., 2005): *(i)* SDII, simple daily intensity index (precipitation amount/rainy days ≥ 1 mm); *(ii)* Rx5day, maximum 5-day precipitation (days); and *(iii)* MLDS, maximum length of consecutive dry days (< 1 mm). Information on temperature was not assessed due to the lack of consistent high-resolution time series data for Central America. We performed a multiple correspondence analysis for quantitative and categorical variables (Lê et al., 2008) to identify the association of observed changes in precipitation (based on CHIRPS data) and farmers’ perceptions.

2.3. Ranking farmers’ strategies to cope with climate variability

We analyzed the strategies each farmer claimed to have adopted to cope with perceived changes in climate patterns by using a Bradley-Terry model (Bradley and Terry, 1952; Turner and Firth, 2012) to create partial ranks of 5 (the five first strategies mentioned by each farmer). The Bradley-Terry model estimates the “worth parameter” or the relative importance of the different strategies in pairwise comparisons and, under the Model-Based Recursive Partitioning approach, identifies sub-groups of farms with similar choices (Hothorn and Zeileis, 2015; Strobl et al., 2011).

We added six variables to the splitting algorithm: *(i)* the ecoregion (Dry or Rainforest), *(ii)* the Progress Out of Poverty Index (PPI), *(iii)* the literacy level of the head of household, *(iv)* the area of the main crop system (ha), *(v)* the age of the head of household, and *(vi)* the number of practices adopted by the farmers after participating in the FFS. Under this approach, if the difference in chosen strategies was significant ($\alpha < 0.05$), then the model would create different groups. Based on practices reported by farmers, we ranked 10 options: *(i)* Change in Agricultural Calendar, *(ii)* Change in Varieties, *(iii)* Production