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Diverse farmer livelihoods increase resilience to climate variability in southern Colombia

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ABSTRACT

Climate variability affects agricultural production systems and rural communities, generating risks to food security and increasing rural poverty. Therefore, improving the capacity of rural households to adapt to climate variability has become one of the greatest challenges for international and national institutions. The objective of this study is to analyze the impact of rural households' livelihood strategies with regard to their vulnerability and adaptation to climate variability. We systematically selected 162 rural households from 10 municipalities in the department of Huila (Colombia). Households were grouped according to their livelihood strategies, using 13 variables representative of their productive characteristics. Subsequently, three indices related to climate vulnerability were determined: a. exposure (climate variability between 1990 and 2012), b. sensitivity, and c. adaptive capacity. For the latter two, the community capitals framework was used. Using the three indices above, the Intergovernmental Panel on Climate Change's proposed vulnerability index was determined. We found seven livelihood strategies: i. Cattlemen-Cocoa Farmers, ii. Livestock-Cocoa Farmers, iii. Employees-Cocoa Farmers, iv. Cocoa Farmers, v. Diversified Farmers, vi. Landlords-Cocoa Farmers and vii. Coffee Farmers. Degree of vulnerability to climate variability was related to the livelihood strategy of rural households: those best endowed with capitals and with the most diverse livelihood strategies were the least vulnerable (Cattlemen-Cocoa Farmers and Livestock-Cocoa Farmers). While it is necessary to maintain a balance between capitals in the process of adapting to climate variability in rural households, at the community level it is essential to strengthen political capital, which will make it possible to construct and reinforce strategies for adapting to climate variability.

1. Introduction

Climate change is a current global situation (Ahmed et al., 2021; Kuosmanen et al., 2020) which significantly and negatively impacts the development of countries (Arteaga and Burbano, 2018). This situation has resulted in damage to property and infrastructure, loss of crops, social security costs, unemployment, migration of the affected population, decreased family income and security threats (Arteaga and Burbano, 2018; Kuosmanen et al., 2020; Patiño et al., 2018). Climate change affects public health, influences the availability of water resources (Kuosmanen et al., 2020), and also impacts industrial productivity (Arteaga and Burbano, 2018), food security (López and Hernández, 2016), and food production (Nijmeijer et al., 2018), generating negative socio-economic impacts at the household level in rural areas.

Vulnerability to climate change is not uniform between countries, nor within them, as it depends on local conditions (climatic, socio-economic, and political) in each region (López and Hernández, 2016).

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In this sense, developing countries are most vulnerable to climate change, given their conditions of poverty and dependence on agriculture (Fahad et al., 2018). The agricultural sector is the most sensitive to changing climatic conditions (Menike and Arachchi, 2016) and inherently smallholder farmers are one of the most vulnerable social groups to this global phenomenon (McDowell and Hess, 2012). The agricultural sector faces threats of rising temperatures, changing rainfall patterns and the increasing occurrence of prolonged droughts and floods (Buitrago et al., 2018). As a result, climate change is expected to alter pest and disease infestation (Uleberg et al., 2013), decrease arable land area (Lu et al., 2020) and negatively impact crop yields (Adhikari et al., 2015) to name a few.

This is a major problem, since about 40% of the planet's land surface is occupied by agriculture and livestock (Fierros and Ávila, 2017; López and Hernández, 2016). In Latin America, the 13.1% of the total population that depends on these activities is characterized by levels of extreme poverty (FAO, 2018). Rural households in developing regions, including Colombia, are likely to be more vulnerable to climate variability (Arteaga and Burbano, 2018) and consequently increases the potential for social and economic damage (Kuosmanen et al., 2020). Specifically for Colombia, agriculture is a key sector of its economy, accounting for approximately 6% of its Gross Domestic Product (GDP), 17% of employment and sustaining the livelihoods of the rural population, which amounts to 9.5 million people, one-fifth of the total population (Sylvester et al., 2020). Colombia is a very diverse country, with coastal, valley, mountainous, and jungle settings for agriculture. Rural agriculture ranges from coffee and cocoa in mountainous and jungle regions to sugar cane plantations in major valleys, and fruit and vegetable production in each region (except on plantations). While small farmers may raise some sugar cane for local use, except for the plantations, most farmers are small holders who produce for the market, usually local and nearby cities, and for on-farm consumption. Many small farmers include a variety of livestock on their farms. Markets in nearby cities often determine production strategies. Its tropical geographic location, together with the variety of altitudes, gives Colombia a wide variety of agro-climatic conditions suitable for crop production and diversification (Gáfaro and Pellegrina, 2022). However, forecasts regarding the increase in the country's average temperature of 0.9 °C, 1.6 °C and 2.14 °C for 2040, 2070 and 2100, respectively, and the decrease in rainfall of between 10% and 40% in a third of the country (mainly in the Andean zone) puts the country's agricultural productivity at risk (IDEAM et al., 2017).

Therefore, the implementation of strategies to adapt to climate variability is an important challenge to guarantee food production and the well-being of rural Colombian households, since in addition to facing the adverse effects of climate on their livelihoods, they must continue to fight against social vulnerability. This situation of vulnerability is due to the conditions of multidimensional poverty in which more than 39.9% of the rural population of Colombia lives (Angulo et al., 2019), which is illustrated by the low access to health services, education, social security, and public services (Perez and Perez, 2002) and income that is insufficient to meet basic needs (Castaño and Cardona, 2014). Added to this is the weak participation of the state in rural areas (Ramirez, 2011), which makes it more difficult for small farmers to increase their productive potential (Castaño and Cardona, 2014), thus limiting adaptation to climate change and the improvement of living conditions in rural households.

Some studies report various adaptation strategies in rural household livelihoods to reduce vulnerability to climate variability, including, migration to non-agricultural activities (Alam and Van Quyen, 2007), reduction of arable land area (Keshavarz and Moqadas, 2021), use of climate-resilient crops (Qazlbash et al., 2021), crop diversification (Khan et al., 2020) and implementation of agroforestry systems (Beyene et al., 2019). In this regard, cocoa cultivation, which is one of the most important activities (Baena, 2019; Gutiérrez et al., 2020) within a small-scale economy production system in Colombia (Jaimes et al., 2011) and is part of the livelihood strategy of about 52,000 rural households (Gutiérrez et al., 2020), becomes an adaptation strategy in the face of climate variability (Asigbaase et al., 2019), since it has been catalogued as a climate-smart crop (Bandanaa et al., 2016). Cocoa is grown in agroforestry systems, which allows integration of multiple production objectives (Cerda et al., 2014; Vaast and Somarriba, 2014), such as the contribution of ecosystem services (Asigbaase et al., 2019) and biodiversity conservation (Wartenberg et al., 2017).

Therefore, the combination of cocoa with other agricultural livelihoods can function as an adaptive response to climate variability, especially in regions with an agricultural tradition such as the department of Huila (part of the Andean region). This department is characterized as an agricultural pantry for the country, having a highly diversified agricultural production, which covers 52.71% of the departmental area and whose sector contributes to more than 15% of the departmental GDP (UPRA, 2017). Crops that stand out for their socio-economic importance are: coffee, banana, irrigated rice, traditional corn and high-yield corn, beans, sorghum, cocoa, cassava, blond tobacco and fruit trees (IICA, 2005). However, these livelihoods have been affected negatively by the shrinking natural resource base and the alteration of rainy and dry periods due to climate variability, which has meant that, in some cases, rural households are exposed to situations of social, environmental and economic vulnerability (Roa and Plazas, 2017).

To face climate variability, in addition to knowing the regional context, it is important to identify livelihood strategies at the household level (Asante et al., 2017; Kais and Islam, 2018; Reed et al., 2013) and capitals endowments, which result in more desirable adaptation decisions. Adaptive capacity is a critical element in the adaptation process, because it highlights the available resources (Adger and Vincent, 2005) such as economic wealth, technology, information, skills, infrastructure, institutions and equity (Smit and Pilofosova, 2003), from which adaptation actions can be taken (Adger and Vincent, 2005). For example, households with fewer capitals endowments will be more vulnerable (Jamshidi et al., 2019) and will have more difficulties coping with adverse situations of climate variability (Smit and Wandel, 2006). Conversely, households with greater capitals endowments (Adger, 2000) and greater diversification of livelihood strategies may have greater capacity to adapt (Nelson et al., 2010). Therefore, it is important to understand the community context and work from its capacity and needs (Musinguzi et al., 2018), building on existing capacities, assets (Louman et al., 2016), and opportunities in different contexts, before implementing actions to reduce vulnerability (Ríos et al., 2011).

Adaptation actions carried out by rural households depend on the set of capacities and assets they have at the household/family and community/local context levels widening the focus on assets related to the seven community capitals (Jamshidi et al., 2019), as climate change impacts are often geographically specific (Ahmed et al., 2021). Thus, there are major challenges for rural households in adapting to climate variability (Jamshidi et al., 2019).

This study can aid adaptation to climate variability by identifying effects of climate change and the choices of alternatives and effective adaptation strategies with the participation of the community (Boda and Jerneck, 2019). These processes of adaptation to climate change must respond adequately to the particular contexts of the communities (Zabala and Victorino, 2019) by knowing the most vulnerable types of households, what stresses they face, and what resources they have available to adapt to climate change (Ford et al., 2010). The resulting socio-ecological dynamics (Zabala and Victorino, 2019) will contribute to a climate change adaptation plan for the Colombian territory.

Identification of livelihood strategies vulnerable and resilient to climate change in the Andean region (climate vulnerable region) provides relevant information to promote rural development policies with emphasis on sustainable land use and adaptation to climate variability in developing countries. Decision makers may consider including in their rural policies different strategies to increase resilience to climate variability. Therefore, the purpose of this study is to determine the relationship between greater capitals endowments and degrees of vulnerability to climate variability in a context of configurations of rural household livelihood strategies in different municipalities in the department of Huila (Colombia). The following research questions were asked: 1. How do livelihood strategies affect the level of vulnerability to climate variability? and 2. What are the conditions or capitals that allow rural households to adapt to climate variability?

2. Methods

2.1. Study area and target population

In accordance with Colombia's third national communication to the United Nations Framework Convention on Climate Change (IDEAM, 2017) and the departmental competitiveness report (Ramírez and De Aguas, 2019), we identified areas vulnerable to climate change within a socioeconomic and environmental context. For the identification of these zones, the following parameters were considered: regional climate risk, competitiveness ranking and social welfare ranking by department.

Thus, we selected the department of Huila, which contributes 1.7% to the national GDP (DANE, 2021), has an area of 19,890 km^2 (IDEAM et al., 2015) of which 53% is devoted to agricultural activities (UPRA, 2017). Its population is approximately 1140,000 inhabitants, one-third of which is rural (Asamblea del Huila, 2020). At the end of 2018, 38% of the population still had unsatisfied basic needs (FAO and ADR, 2019), and 19. 2% were in conditions of multidimensional poverty (Asamblea del Huila, 2020).

This department is located towards the south of the Colombian Andean Region; it is an integral part of the upper basin of the Magdalena River (Colombia's main river) and the Colombian massif. The department has ecosystems ranging from very dry tropical forest, in the Tatacoa region (desert), through Andean and high Andean forest, to the perpetual snows of the Nevado del Huila (Gobernación del Huila, 2014). It has a wide variety of climates due to the diversity of thermal floors. Of the departmental surface area, 28.3% corresponds to a warm climate, 40% to a medium climate, 23.2% to a cold climate and 8.6% to a very cold climate. Total rainfall in the department varies according to the regions; there are areas with rainfall between 900 and 1000 mm/year to areas where the average rainfall exceeds 1500 mm/year (CAM, 2011).

In addition, according to projections made by the IDEAM based on the Providing Regional Climate for Impact Studies model and using the global emissions scenarios of the IPCC's Special Report on Emissions Scenarios (SRES) (SRES A2 and SRES B2) for the year 2040, an increase of 2 °C in the average temperature and a reduction in rainfall of up to 30% is reported in the department of Huila (IDEAM, 2011). Under these conditions and to determine the degree of vulnerability to climate change, we systematically selected different rural households affiliated to the Network of Associations of Cocoa Producers of Huila-APROCAHUILA, which in turn had cocoa area in production and were interested in participating in the study. A total of 162 households were selected in ten municipalities (Algeciras n = 16, Campoalegre n = 15, Iquira n = 14, Palermo n = 30, Rivera n = 18, Gigante n = 7, Tarqui n = 11, Hobo n = 8, Baraya n = 8, Tello n = 35) in the department of

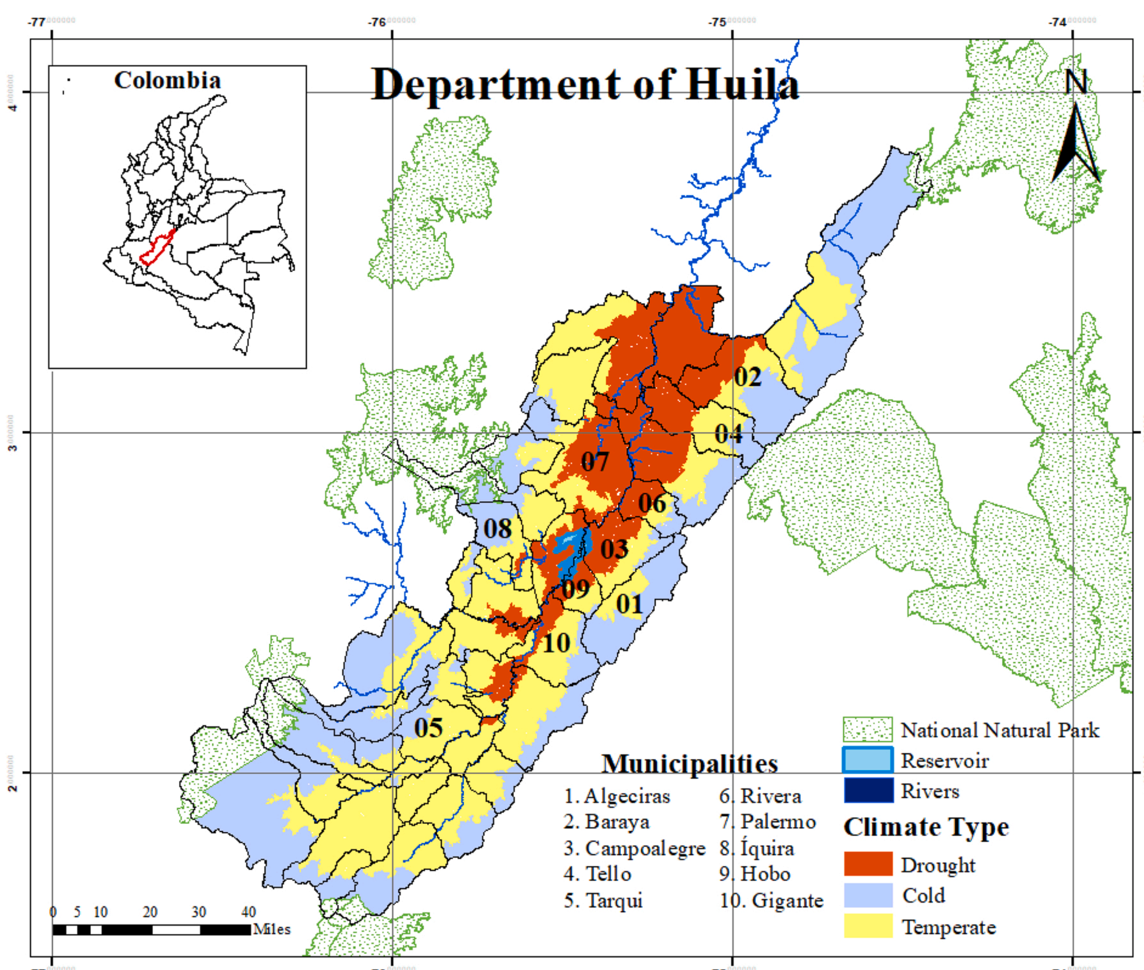


Fig. 1. Climate type in each of the municipalities in which livelihoods were characterized in the department of Huila, Colombia. Source: (IDEAM, 2017).

Table 1
Variables used for the characterization of productive livelihoods.

Variable	Unit	Description
Cocoa Area/Farm size	Proportion	Relationship of the cocoa area of the farm to the total size of the farm (ha)
Pasture Area/Farm size	(%)	Relationship of the area in pasture of the farm with the total size of the farm (ha)
Coffee Area/Farm size		Relationship of the coffee area of the farm to the total size of the farm (ha)
Other Areas/Farm Size		Relationship of the area with agricultural crops (banana, grape, passion fruit, citrus fruit, avocado, among others) with the total size of the farm (ha)
Agricultural Area/Farm Size		Relationship of total agricultural area to total farm size (ha)
Income Cocoa/Farm Income		Relationship of the income from the sale of cocoa to the total income that enters the farm (Dollar)
Livestock Income/Farm Income		Relationship of income from the sale of live cattle or milk with the total income that enters the farm (Dollar)
Income Coffee/Farm Income		Relationship of the income from the sale of coffee with the total income that enters the farm (Dollar)
Other Agricultural Income/Farm Income		Relationship of the income from the sale of agricultural products (banana, grape, passion fruit, citrus fruit, avocado, among others) with the total income that enters the farm (Dollar)
Other Livestock Income/Farm Income		Relationship of the income from the sale of pigs, fish, chickens and eggs with the total income that enters the farm (Dollar)
Non-Agricultural Income/Farm Income		Relationship of the income received from wages, pensions, urban businesses, among others with the total income that enters the farm (Dollar)
Diversity of Non-Agricultural Activities	Number	Sum of the number of non-agricultural activities (wages, pensions, urban businesses, among others)
Diversity of Agricultural Activities		Sum of the number of agricultural activities

Huila. The criteria used for the selection of the municipalities were: production, planted area, harvested area, yield (AGRONET, 2020), suitable land and/or land with moderate limitations (García et al., 2007).

Fig. 1 shows the characteristic climate in each municipality. The cocoa growing area is located predominately in drought-prone areas and is therefore more vulnerable to climate change.

We used a mixed-methods approach as each sampled unit (a rural household that grows cocoa) was surveyed (quantitative information) and interviewed (qualitative information) through semi-structured interviews (Sibelet et al., 2013). For data collection, a team of 12 researchers was in charge of making the visits to the farms of the rural 162 households, after scheduling the appointment through telephone calls and in cases of difficult access, the producers met at strategic points such as schools, community centers or farms of the presidents of the Community Action Board. The interviews were conducted with heads of household familiar with all the household's livelihoods, a decision that was agreed upon by the family members based on their knowledge of the farm and availability of time. Each interview lasted approximately one hour. Informed consent was requested and obtained from the participants prior to each interview.

2.2. Analytical framework

The research was conducted using a mixed analytical framework, where the Sustainable Livelihoods Approach (DFID, 1999) and the Community Capitals Framework (DFID, 1999; Flora et al., 2004) which includes the seven capitals (human, cultural, social, political, natural, financial and built) were integrated with agro-climate information and the perceptions of rural producers.

For each of the rural households that grow cocoa, different livelihood strategies were identified through diverse variables that characterize productive livelihoods (Table 1). Based on these variables, rural households that grow cocoa were grouped according to similarity between livelihood characteristics (Imbach, 2016; Tawfic et al., 2014; Wang et al., 2016) using cluster analysis, the Ward method and Euclidean distance (Balzarini et al., 2008). Once the typologies of rural households that grow cocoa were established, an analysis of variance was carried out to identify the variables that characterized the types of rural households. Quantitative variables were analyzed using Linear Mixed Models (Di Rienzo et al., 2011) and Fisher's LSD test ($p < 0.05$). The association between typologies of rural households with cocoa activities and their location (municipality) was identified using contingency tables (Balzarini et al., 2008). To graphically identify the significant associations, a biplot was made from the correspondence analysis.

2.3. Vulnerability to climate variability

Degree of vulnerability to climate variability of rural households with cocoa activities was identified using the equation proposed by the Intergovernmental Panel on Climate Change (IPCC, 2007), where Vulnerability = (Exposure + Sensitivity) - Adaptive Capacity. This equation has been used in other studies of vulnerability to climate variability (Pandey et al., 2017; Tawfic et al., 2014).

The analysis of the vulnerability index and its component (Sensitivity, Exposure, and Adaptive Capacity) was carried out using analysis of variance (ANOVA) by linear and mixed models (Di Rienzo et al., 2011) to identify statistically significant differences between typologies. The LSD Fisher test ($p < 0.05$) was used to separate means. The analyses were performed with the InfoStat statistical software (Di Rienzo et al., 2019). The effect of the different indicators of each index on the typologies were evaluates using heat maps.

2.4. Exposure to climate variability index

Exposure to climate variability at the municipal level was determined using climate parameters for the period 1990–2012, information that was provided by ten IDEAM weather stations. The climate parameters used were: Total Rainfall (TR) and Number of Rainfall Days (NRD) by municipality. Based on these variables, 26 new sub-variables were created that correspond to the monthly and annual variation coefficient of the TR and NRD in the period from 1990 to 2012. Once the 26 climate variables per municipality were identified, a Principal Component Analysis (PCA) was carried out and the following equation was applied to calculate the exposure index (EI):

$$EI = (PC_1 \times V_1) + (PC_2 \times V_2)$$

where:

EI: Exposure index.
PC_1: Principal Component 1.
V_1: Variability Explained for PC_1.
PC_2: Principal Component 2.
V_2: Variability Explained for PC_2.

2.5. Sensitivity index

Sensitivity index to climate variability was constructed from the sum of three sub-indices.

i. Sub-index 1. Incidence of climate variability on livelihoods: open-ended questions were coded on the negative effects of high and low rainfall, high temperatures, droughts and floods on the main agricultural activities (cocoa, coffee, and livestock). The negative effects were determined by an increase in pests and diseases in plants and animals, consequences in flowering and production stages, tree death and decrease in fodder supply, to name a few. Dummy variables with the negative effects were created and summed and then taken to intervals of 0-1.
ii. Sub-index 2. Producers' perceptions of climate and current climate constraints in production systems: open-ended questions were coded on the difficulties in the production of the main agricultural activities (cocoa, coffee and livestock). Dummy variables were created with climate-related constraints. These difficulties were summed and then taken to intervals of 0-1.
iii. Sub-index 3. Conflicts over access to water: open-ended questions were coded on the availability and restrictions on water sources and community aqueducts that supply rural households. Dummy variables were created and summed and then taken to intervals of 0-1.

2.6. Adaptive capacity index

The adaptive capacity index of rural households that grow cocoa was determined from the seven capitals endowments of each rural household: human, social, cultural, political, natural, physical and financial (Emery and Flora, 2006; Flora et al., 2004; Lachapelle et al., 2020). The index for each capital was constructed from variables of the seven household capitals (Supplementary 1,Tables 1, 2 and 3). The variables for the adaptive capacity index were chosen based on studies by Keshavarz et al. (2017) and Pandey et al. (2017).

Each of the above indices is composed of indicators. The sensitivity index has three indicators and the adaptive capacity index has seven capital indicators, which correspond to the seven capitals mentioned in the analytical framework. The indicators are constructed from the sum of the 99 capital variables that are transformed at 0–1 intervals. Sensitivity and adaptive capacity index are calculated as the sum of the indicators that are transformed at 0-1 intervals and the operation is performed assuming that they all have the same weight (Pandey and Jha, 2012).

In the adaptive capacity index, the value [1] indicates less vulnerability and in the sensitivity index, the value [1] represents greater vulnerability (Pandey et al., 2017). The equations used to convert the values, adapted from Keshavarz et al. (2017), are as follows:

$$SuIAC = [(H_x - H_{\min}) \div (H_{\max} - H_{\min})] + [(S_x - S_{\min}) \div (S_{\max} - S_{min})] + \ldots + [(FP_x - FP_{\min}) \div (FP_{\max} - FP_{\min})]$$

where:

SuIAC is the adaptive capacity sub-index Capacity to Climate Variability without standardization,

H_x, S_x, FP_x is the original value of the indicator of Human, Social and Financial Productive Capital,

H_{min}, S_{min}, FP_{min} is the minimum value of the Human, Social and Financial Productive Capital indicator.

H_{max}, S_{max}, FP_{max} is the maximum value of the indicator of Human, Social and Financial Productive Capital.

AC index = $(SuIAC_x - SuIAC_{min}) \div (SuIAC_{max} - SuIAC_{min})$ where:

AC Index is the adaptive capacity index.

$SuIAC_x$ is the original value of the adaptive capacity sub-index.

$SuIAC_{min}$ is the minimum value of the adaptive capacity sub-index.

$SuIAC_{max}$ is the maximum value of the adaptive capacity sub-index.

The above equation is used in the same way to find the Climate Variability Sensitivity Index.

2.7. Enabling conditions for adaptive capacity to climate variability in rural households that grow cocoa

The conditions that generate adaptive capacity were analyzed through the positive and negative interactions that occur between community capitals in response to sensitivity and exposure to climate variability (Gutiérrez-Montes, 2005). In this way, the positive interactions determine the capitals that are most important for achieving the degree of adaptation. A regression tree model was used to identify the capitals that show the greatest correlation with the sensitivity and adaptive capacity index. This model separates the data into two subgroups. The procedure is repeated for each node until the complete tree is constructed. The regression variables used are the seven capitals, so that the heterogeneity at the sensitivity and adaptive capacity level is minimal according to the measure of heterogeneity (10) selected (Balzarini et al., 2008; Keshavarz et al., 2017). To identify the capitals that have the greatest influence on the generation of conditions that enable adaptive capacity, a classification analysis was performed using the random forest algorithm (Louman et al., 2016), using the statistical program InfoStat (Di Rienzo et al., 2019) and its interface with R (R Core Team, 2021). Additionally, textual quotes obtained from the semi-structured interviews were used to express the perception of rural households on the conditions that enable adaptation to climate variability, as used in the capital endowment study by Hernández et al. (2021).

3. Results

3.1. Livelihood strategies of rural households with cocoa activities in Huila department

We identified seven types of rural households with significant differences among them ($p < 0.05$). According to the livelihoods characteristics of each type of rural household, they are referred to as i. Cattlemen-Cocoa Farmers (CaCoF), ii. Livestock-Cocoa Farmers (LiCF), iii. Employees-Cocoa Farmers (ECF), iv. Cocoa Farmers (CocF), v. Diversified Farmers (DF), vi. Landlords-Cocoa Farmers (LaCF) and vii. Coffee Farmers (CoF) (Table 2).

Cattlemen-Cocoa Farmers (n = 21 farms, 13% of total farms): Rural households whose average farm area is larger than the others (26 ha), where 68% of the farm area corresponds to pastures dedicated to cattle farming, 20% to cocoa crops and 10% to conservation area (forest) (Supplementary 1, Table 4).

Livestock-Cocoa Farmers (n = 19, 12% of total farms): The main economic activity is the production of small animals, such as fish, pigs and chickens, which provides 46% of the income. In addition, they grow cocoa on 70% of the farm area (8 ha). The income received from cocoa represents 44% of household income.

Employees-Cocoa Farmers (n = 24, 15% of total farms): These are rural households whose main economic activities are off-farm and include non-agricultural (i.e., pensions, public employment, own business) and agricultural activities such as selling labor (wages). These activities generate 50% of total household income. These households produce cocoa, which is grown in the entire productive area of the farm (3 ha) and complements the economy of these households by 40%.

Cocoa Farmers (n = 36, 22% of total farms): These are households that are economically dependent (95%) on cocoa cultivation. On average, 85% of the farm area is established in cocoa. Thirteen percent of cocoa farmers have farms with areas ranging from 7 to 17 ha, with the remaining households having no more than 7 ha. Eighty-five percent of the farm is dedicated to cocoa production, the remainder being established in secondary forest or stubble fields.

Diversified Farmers (n = 20, 12% of total farms): They are rural households with approximately 5 ha. of land. Thirty percent of the area is established in grape, avocado, tangerine, and banana cultivation; 70% is established in cocoa. These activities contribute approximately 45%

Table 2
Types of rural household livelihood strategies. Mean ± standard error of the ANOVA to test mean difference between typologies. Means with a common letter are not statistically different (Fisher LSD, $p < 0.05$).

Variable	Cattlemen-Cocoa Farmers	Livestock-Cocoa Farmers	Employees- Cocoa Farmers	Cocoa Farmers	Diversified Farmers	Landlords-Cocoa Farmers	Coffee Farmers
Cocoa area/Farm area	0.19 ± 0.05^{d}	0.71 ± 0.06^{b}	0.80 ± 0.05^{a}	0.85 ± 0.04^{a}	0.61 ± 0.06^{b}	0.19 ± 0.08^{d}	0.48 ± 0.04^{c}
Pasture/Farm Area	0.68 ± 0.03^{a}	0.07 ± 0.03^{c}	0.01 ± 0.03^{c}	0.01 ± 0.02^{c}	0.04 ± 0.03^{c}	0.01 ± 0.04^{c}	0.15 ± 0.02^{b}
Coffee area/Farm area	0.01 ± 0.03^{b}	0.01 ± 0.04^{b}	0.01 ± 0.03^{b}	0.01 ± 0.03^{b}	0.07 ± 0.03^{b}	0.08 ± 0.05^{b}	0.38 ± 0.03^{a}
Other Areas/Farm Area	0.01 ± 0.02^{b}	0.06 ± 0.02^{b}	0.02 ± 0.02^{b}	0.02 ± 0.01^{b}	0.03 ± 0.02^{b}	0.59 ± 0.03^{a}	0.01 ± 0.02^{b}
Area Other Agricultural Crops/ Area Farm	0.01 ± 0.03^{b}	0.02 ± 0.03^{b}	0.01 ± 0.02^{b}	0.03 ± 0.02^{b}	0.29 ± 0.03^{a}	0.03 ± 0.04^{b}	0.01 ± 0.02^{b}
Income Cocoa/Farm Income	0.37 ± 0.05^{b}	0.44 ± 0.05^{b}	0.49 ± 0.04^{b}	0.95 ± 0.03^{a}	0.41 ± 0.05^{b}	0.43 ± 0.07^{b}	0.37 ± 0.04^{b}
Income Coffee/Farm Income	0.01 ± 0.03^{c}	0.01 ± 0.04^{c}	0.01 ± 0.03c	0.01 ± 0.03^{c}	0.04 ± 0.04^{c}	0.33 ± 0.05^{b}	0.46 ± 0.03^{a}
Earned Income/Farm Income	0.46 ± 0.02^{a}	0.02 ± 0.02^{b}	0.01 ± 0.02^{b}	0 ± 0.02^{b}	0.01 ± 0.02^{b}	0.01 ± 0.04^{b}	0.05 ± 0.02^{b}
Other Agricultural Income/ Farm Income	0.01 ± 0.02^{c}	0.02 ± 0.02^{c}	0.01 ± 0.02^{c}	0.05 ± 0.02^{bc}	0.42 ± 0.02^{a}	0.03 ± 0.03^{bc}	0.07 ± 0.02^{b}
Other Livestock Income/Farm Income	0.01 ± 0.02^{b}	0.46 ± 0.02^{a}	0.01 ± 0.02^{b}	0.01 ± 0.01^{b}	0.06 ± 0.02^{b}	0.01 ± 0.03^{b}	0.01 ± 0.01^{b}
External Income/Farm Income	0.15 ± 0.03^{b}	0.08 ± 0.04^{c}	0.50 ± 0.03^{a}	0.01 ± 0.03^{c}	0.05 ± 0.04^{c}	0.21 ± 0.05^{b}	0.03 ± 0.03^{c}
Number of External Activities	0.43 ± 0.08^{b}	0.42 ± 0.09^{b}	0.96 ± 0.08^{a}	0.01 ± 0.06^{c}	0.15 ± 0.08^{c}	0.33 ± 0.13^{b}	0.09 ± 0.07^{c}
Quantity Agricultural Activities	2.86 ± 0.20^{b}	3.47 ± 0.21^{a}	2.33 ± 0.19^{c}	1.53 ± 0.16^{d}	3.65 ± 0.21^{a}	2.22 ± 0.31^{c}	3.09 ± 0.16^{b}

and 40% of the economic income, respectively, and 15% is complemented by the production of eggs, transitory crops, etc.

Landlords-Cocoa Farmers ($n = 9$, 5% of total farms): They are rural households that base their economy on two activities: on the sale of cocoa beans, for which they allocate 20% of the farm area to the production of this crop, and on leasing the remaining farm area for raising livestock. Given this configuration, 68% of income comes from the sale of cocoa and 32% comes from leasing land.

Coffee Farmers ($n = 33$, 20% of total farms): Thirty percent of the coffee growers have farms with areas between 8 and 16 ha and the rest do not exceed 8 ha. The main production is coffee (46% of the income), followed by cocoa (37% of the income) and in some cases they complement it with cattle raising as a form of savings (5% of the income).

The superscripts (a, b, c) with a common letter are not statistically different ($p < 0.05$).

Not all seven types of rural households were present in each of the 10 municipalities studied (Fig. 2). The largest number of Cattlemen-Cocoa Farmers are in the municipalities of Tello (27%), Palermo (16%) and Rivera (16%). Similarly, the percentage of Cocoa Farmers and Diversified Farmers is higher in the municipalities of Tello (39% and 20%), Palermo (27% and 15%) and Tarqui (12% and 20%). Livestock-Cocoa Farmers are more numerous in the municipalities of Palermo (31%) and Iquira (26%). Employees-Cocoa Farmers predominate in the municipalities of Algeciras (20%), Rivera (29%) and Hobo (16%). Finally, Landlords-Cocoa Farmers are mainly present in the municipalities of Palermo (33%), Campoalegre (22%) and Rivera (22%).

3.2. Vulnerability to climate variability of rural household types

The vulnerability index to climate variability showed statistically significant differences ($p < 0.05$) between different rural household types (Table 3). Coffee Farmers (CoF), Cocoa Farmers (CocF) and

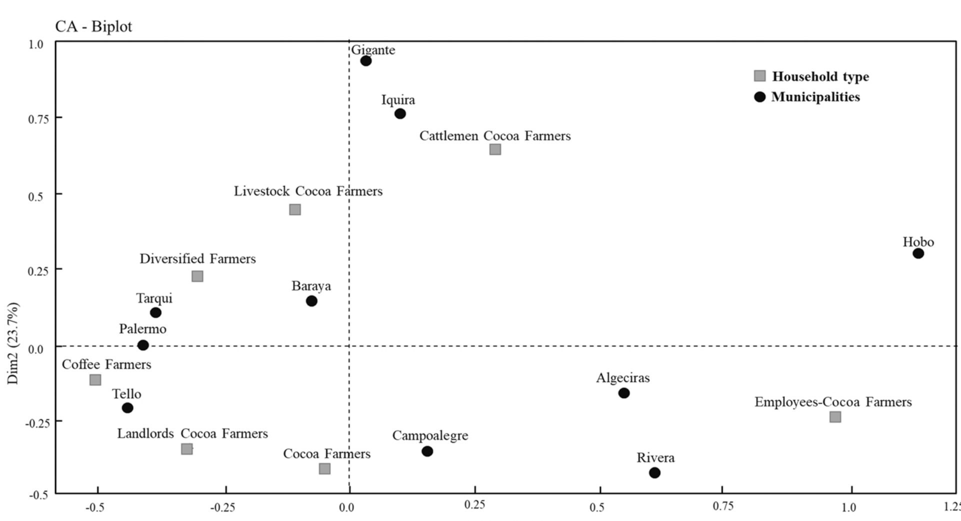


Fig. 2. Biplot obtained from a simple correspondence analysis between the household types and the municipalities of Huila department.

Table 3
Exposure, sensibility, adaptive capacity, and vulnerability indexes to climate variability in rural household types. Mean ± standard error of the ANOVA to test mean difference between typologies. [a, b, c] Means with a common letter are not statistically different (LSD Fisher, $p < 0.05$).

Livelihood strategies of rural households	Cattlemen-Cocoa Farmers	Livestock-Cocoa Farmers	Employees-Cocoa Farmers	Cocoa Farmers	Diversified Farmers	Landlords-Cocoa Farmers	Coffee Farmers	p-value
Index of Exposure	**0.58±0.08**	**0.48±0.08**	**0.65±0.07**	**0.72±0.04**	**0.64±0.06**	**0.63±0.08**	**0.70±0.05**	**0.0580**
HC	0.49±0.05	0.58±0.05	0.43±0.04	0.32±0.03d	0.48±0.05	0.33±0.07d	0.53±0.04	
CC	0.49±0.05	0.38±0.05	0.27±0.04	0.36±0.04	0.27±0.05	0.48±0.07	0.37±0.04	
SC	0.38±0.04	0.50±0.04	0.40±0.04	0.38±0.03	0.31±0.04	0.36±0.06	0.43±0.03	
PC	0.30±0.05	0.26±0.05	0.20±0.05	0.23±0.04	0.18±0.05	0.21±0.08	0.34±0.04	
NC	0.50±0.04	0.51±0.04	0.39±0.03	0.39±0.03	0.40±0.04	0.49±0.06	0.38±0.03	
BC	0.54±0.04	0.47±0.05	0.50±0.04	0.41±0.03	0.48±0.04	0.37±0.07	0.45±0.03	
FC	0.37±0.04	0.32±0.04	0.12±0.04	0.12±0.03	0.29±0.04	0.21±0.06	0.22±0.03	
Adaptive capacity index	**0.46±0.03a**	**0.45±0.03ab**	**0.31±0.03d**	**0.29±0.03d**	**0.33±0.03cd**	**0.34±0.05bcd**	**0.39±0.03abc**	**0.0001**
Effects PLv	0.22±0.05	0.15±0.05	0.14±0.04	0.12±0.03	0.21±0.05	0.20±0.07	0.21±0.04	
Perception CCh	0.23±0.03	0.05±0.03	0.03±0.03	0.05±0.02	0.04±0.03	0.04±0.04	0.27±0.02	
Water Difficulties	0.43±0.09	0.42±0.0	0.56±0.08	0.31±0.07	0.20±0.09	0.11±0.13	0.38±0.07	
Sensitivity index	**0.39±0.05a**	**0.28±0.05abc**	**0.33±0.04ab**	**0.21±0.04bc**	**0.20±0.05bc**	**0.16±0.07c**	**0.38±0.04a**	**0.0021**
Índice de Vulnerabilidad	**0.51±0.04ab**	**0.40±0.04b**	**0.59±0.04a**	**0.58±0.03a**	**0.51±0.04ab**	**0.47±0.07ab**	**0.60±0.03a**	**0.0059**

Human capital (HC), cultural capital (CC), social capital (SC), political capital (PC), natural capital (NC), built capital (BC), and financial capital (FC), PLv: Productive Livelihoods, CCh: Climate Change.The color signifies the level of vulnerability, exposure, sensitivity and adaptive capacity to climate variability. Values in red color means high level of vulnerability, exposure, sensitivity and low adaptive capacity; values in yellow color means medium level of vulnerability, exposure, sensitivity and adaptive capacity; and values in green color means low level of vulnerability, exposure, sensitivity and high adaptive capacity.

Employees-Cocoa Farmers (ECF) are the most vulnerable to climate variability, with indices of 0.60, 0.58 and 0.57 respectively. In the words of vulnerable rural households: "I don't know what we are going to do to maintain production with such low prices, super expensive inputs and roads in bad condition", "we are being hit very hard by drought, and crop pests and diseases", "it is difficult to face climate change alone because there are no guarantees to sell our products and we have no help from the government, we are alone".

Diversified Farmers (DF), Cattlemen-Cocoa Farmers (CaCoF), Landlords-Cocoa Farmers (LaCF) and Livestock-Cocoa Farmers (LiCF) are the least vulnerable compared to the first 3 types of rural households, with values of 0.51, 0.49, 0.47 and 0.40, respectively. A CaCoF said: "thinking about our future, we decided to diversify the farm, not only cows" and a producer DF added "It is everyone's duty to sow several things in order to survive, because in the future, what will we eat?".

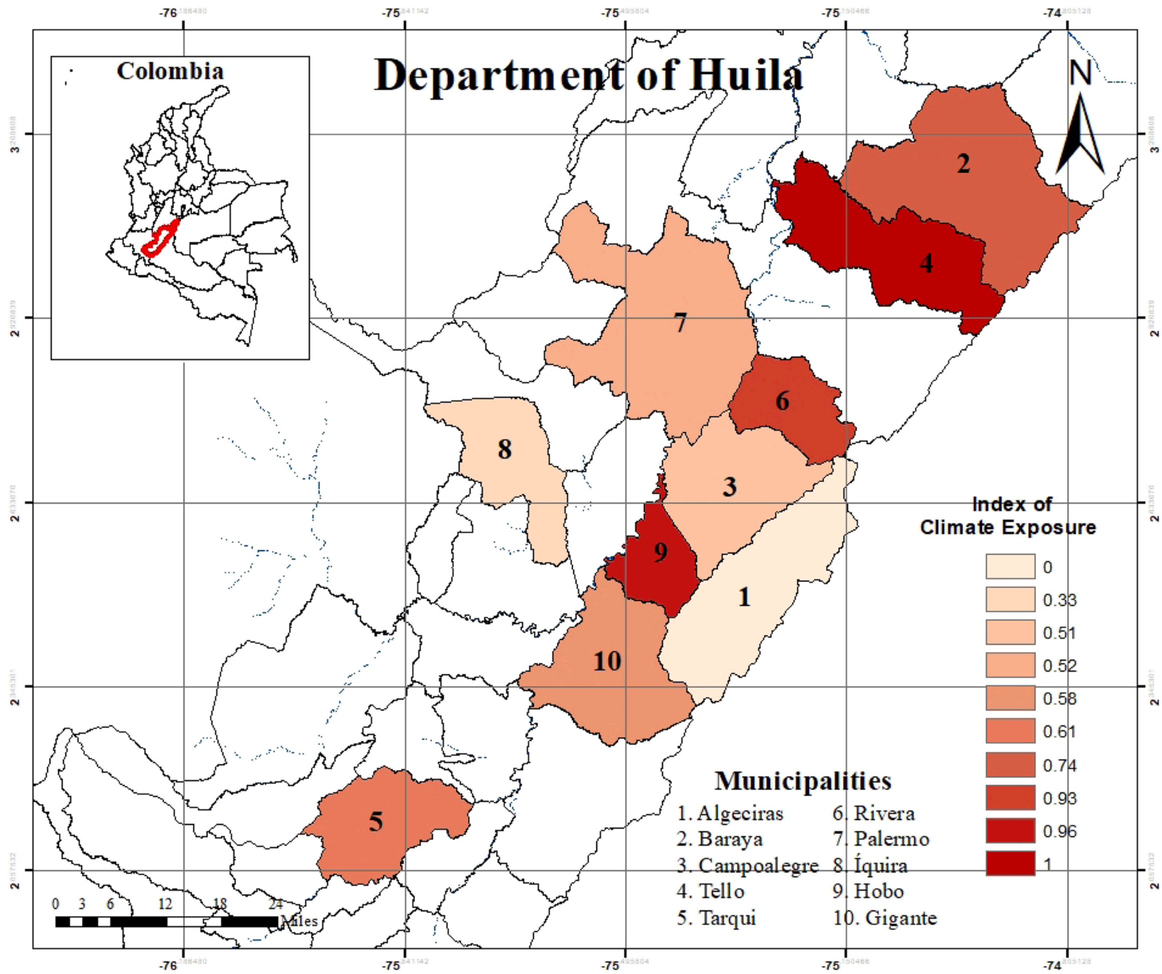
3.2.1. Exposure to climate variability

The municipalities with the highest degree of exposure to climate variability are Tello, El Hobo, Rivera, Baraya and Tarqui with indices above 0.60 (Fig. 3a) in decreasing order; this is due to the greater variation in the amount and distribution of monthly and annual precipitation. For example, Tello was one of the municipalities where the annual rainfall was lower than the other municipalities and the fluctuation was greater from one year to another (it fluctuated between 505.1 mm and 1926 mm) (Fig. 3b). In contrast, Gigante, Palermo, Campoalegre, Algeciras and Iquira present the lowest degree of exposure with indices lower than 0.58 (Fig. 3a).

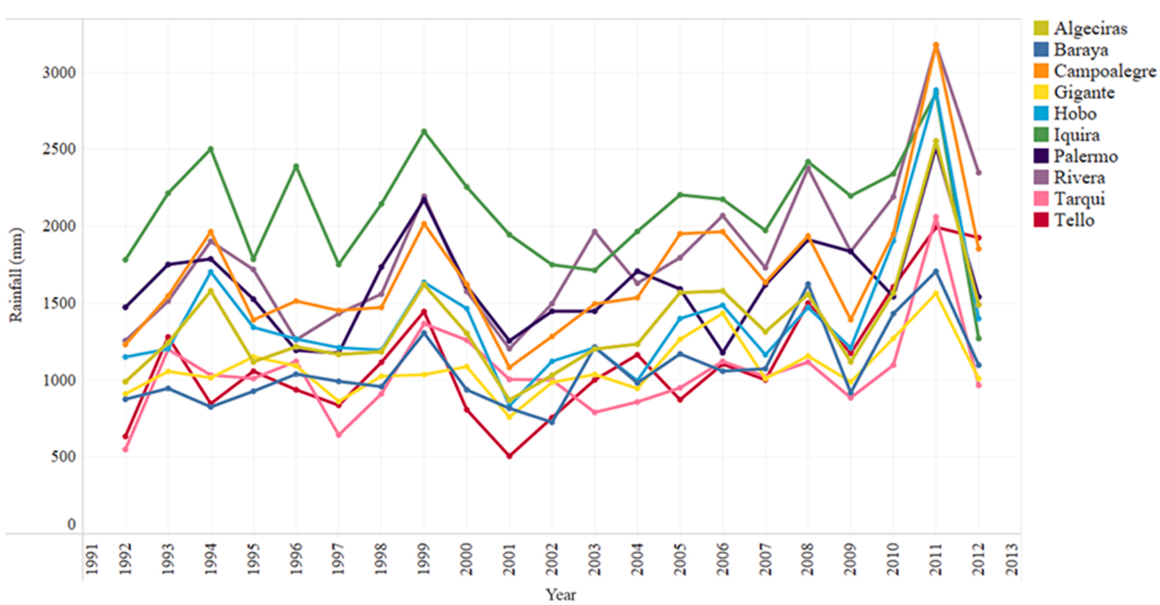
3.2.2. Sensitivity to climate variability

The index of sensitivity to climate variability showed significant differences ($p = 0.0021$) between the types of rural households (Table 3). The Cattlemen-Cocoa Farmers (CaCoF), and Coffee Farmers (CoF) presented the highest sensitivity to climatic variability with values of 0.39 and 0.38 (rojo), while the other types presented lower averages (green and yellow). The indicators Climate Change Perception (CCh) and Water Difficulties present differences between the types of rural households. Cocoa Farmers and Cattlemen Cocoa Farmers perceive the climate change as a negative factor (red) for the sustainability of their productive livelihoods due to drought that has led to a decrease in coffee production caused by the death of trees and decrease in the fodder supply as pastures dry up. The Livestock-Cocoa Farmers, Employees-Cocoa Farmers, Diversified Farmers, Cocoa Farmers, and Landlords-Cocoa Farmers (green) do not highlight the importance of the effects of climate change as a limiting factor for the sustainability of their livelihoods. They perceive that their main constraints are the high costs of production, labor costs and lack of economic resources (Table 3).

The households with the greatest difficulty in accessing water are the Employees-Cocoa Farmers, followed by the Cattlemen-Cocoa Farmers (red). Of these, 68% and 57% of the households, respectively, have problems due to drought and 50% and 25% of the households have



(a)



(b)

Fig. 3. Exposure to climate variability. Index of exposure to climate variability in the municipalities of Huila department. Value [1] represents greater exposure to climate variability**b** Exposure to climate variability, total rainfall (mm) for the year 1990–2012 in Huila's municipalities.

problems with shared water in the community irrigation districts. Water-access issues also occur for other households. Some Coffee Farmers (33%), Landlords-Cocoa Farmers (30%), Cocoa Farmers (28%), Livestock-Cocoa Farmers (21%) and Diversified Farmers (10%) do not have access to irrigation.

3.2.3. Capacity to adapt to climate variability

Cattlemen-Cocoa Farmers have the greatest capacity to adapt to climate variability compared to any other rural household production type (green) (Table 3). The human, cultural, built and financial capitals are significantly different among the seven types of rural households. In the voice of producers: "the planting of cocoa, pasture and other crops has improved my family's economy and at the same time we conserve nature", "to face climate change we have installed an irrigation system on the farm, we keep the crops well pruned and continue planting trees for shade in times of drought", "The shade trees for cocoa and cows has been fundamental to maintain production because it is cooler". While the Cattlemen-Cocoa Farmers have the highest endowment of cultural, built and financial capital, the Livestock-Cocoa Farmers have the highest endowment of human capital (Supplementary 1, Tables 2 and 3).

3.3. Enabling conditions for adaptation to climate variability

The most important capitals for enabling the capacity to adapt to climate variability in the seven types of rural households are cultural and political capital (Fig. 4). Cultural capital is important because the depletion of natural resources (forest, water, and soil) has progressively transformed the environmental culture of rural households "our task is to continue conserving forests and at the same time plant crops and reforest", "it is better to plant than to deforest". Additionally, people have realized that change in the way of producing and living with the environment is necessary; in the voice of a producer "the transition to organic production is urgent because it does not intoxicate the soil, takes care of the environment and is more economical", "I am already in the process of growing organic crops to improve the quality of life of my family and to give a better product to the consumer". Cultural capital creates a sense of belonging to the environment and engenders local actions aimed at conservation of natural resources.

Political capital is complementary to cultural capital in that it facilitates "voice and vote" capabilities among rural households to address needs with local responses in decision-making scenarios such as community action boards, associations and municipalities. Without political capital is it not possible to achieve structural changes, which lead to successful adaptation to climate variability (Supplementary 1, Table 3).

The adaptive capacity of Livestock-Cocoa Farmers, Landlords-Cocoa Farmers, Employees-Cocoa Farmers, Diversified Farmers, and Cattlemen-Cocoa Farmers is determined by human capital, while for Cocoa Farmers and Coffee Farmers, built capital is decisive. For Livestock-Cocoa Farmers and Landlords-Cocoa Farmers, human capital is the only significant predictor. The index values separating adaptive capacity for 77% of the Livestock-Cocoa Farmers households is less than 0.54 and less than 0.78 for 84% of Landlords-Cocoa Farmers households (Fig. 4). Political capital is the main determinant of the adaptive capacity of Employees-Cocoa Farmers and Diversified Farmers. The index value separating adaptive capacity for 70% of Employees-Cocoa Farmers households and 80% of Diversified Farmers households is less than 0.3. Cultural capital is the most significant predictor for Cattlemen-Cocoa Farmers. The index value separating adaptive capacity for 76% of the Cattlemen-Cocoa Farmers households is less than 0.638. Built capital is the most significant predictor for the Coffee Farmers. The index value separating adaptive capacity for 66% of the Coffee Farmers households is less than 0.241. Natural capital is the most significant predictor for

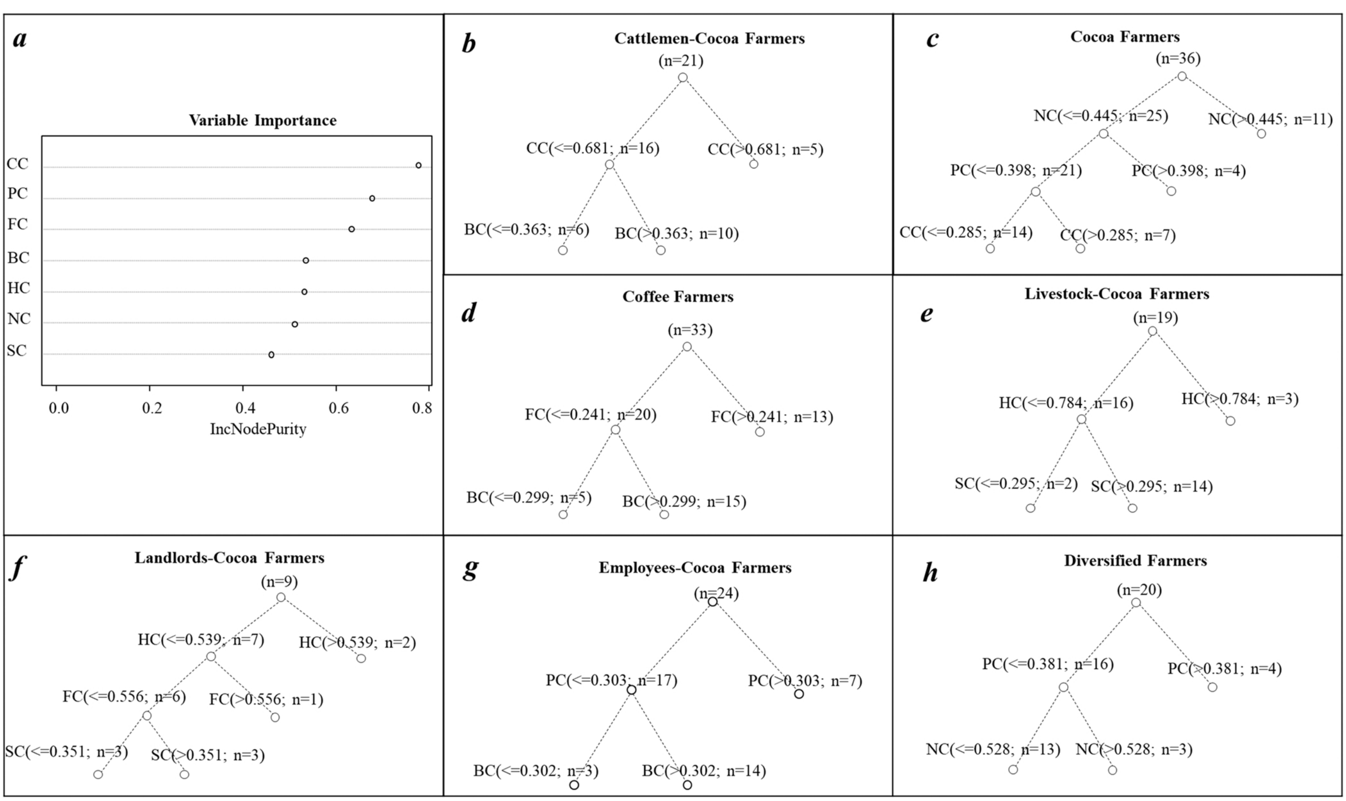


Fig. 4. Importance of capitals in the Adaptive Capacity index (ACI) to climate variability. a) Determining capitals in the ACI by means of random forest, b) regression tree of the ACI of Cattlemen-Cocoa Farmers, c) regression tree of the ACI of Cocoa Farmers, d) regression tree of the ACI of Coffe Farmers, e) regression tree of the ACI of Livestock-Cocoa Farmers, f) regression tree of the ACI of Landlords-Cocoa Farmers, g) regression tree of the ACI of Employees-Cocoa Farmers, h) regression tree of the ACI of Diversified Farmers. Human capital (HC), cultural capital (CC), social capital (SC), political capital (PC), natural capital (NC), built capital (BC), and financial capital (FC).

Cocoa Farmers. The index value separating adaptive capacity for 69% of the Cocoa Farmers households is 0.445.

4. Discussion

4.1. Huila's Rural household livelihood strategies

A great diversity of livelihood strategies was found, so were grouped into seven types of rural households. The heterogeneity in the livelihood strategies of rural households, resulting from the historical dynamics of Huila, is due to structural changes such as price fluctuation, land concentration, poverty and climate variability (Perez and Perez, 2002; Salcedo, 2016). Additionally, the transition towards a more sustainable economy in recent governments in Colombia (Sierra et al., 2017), has had implications for the heterogeneity of productive livelihoods (Wang et al., 2016). Under this dynamic, rural households diversified into various activities such as coffee, cocoa and livestock. Coffee has been promoted by the State since the 1970 s (Salcedo, 2016) and more recently cocoa by being categorized as a "crop for peace" (USAID and USDA, 2016). Despite the cultural rootedness for certain crops and institutional policies, climate change forces rural households to make changes in their livelihood strategies (Nyairo et al., 2020). This leads many producers to switch from agriculture to livestock farming on land unsuitable for the latter, especially on small farms (Pérez, 2004), resulting in the deterioration of natural capital.

Some communities choose to alternate their main livelihoods with forestry production and off-farm activities, due to the successful experience of their ancestors and the agro-climatic context of the region (Melvani et al., 2020). Another alternative is the replacement of one livelihood for another, for example, in Ghana, households shifted from cocoa to cereal farming, however they reversed this choice due to low yields and storage challenges, returning to cocoa production, albeit with a new production model (Asante et al., 2017).

While in Huila, the decline in coffee and cocoa production due to climate stress has forced households to combine agricultural production with non-agricultural activities, including the sale of labor, food and clothing ventures, construction jobs, dressmaking, among others, for which they may not be adequately remunerated (Kay, 2009). In this sense, the contribution of non-agricultural income to the economy of rural households is part of the livelihood strategy, with variability in the availability of jobs among the different municipalities studied (Gebru et al., 2018). Diversification in the development of off-farm activities offers the opportunity to obtain additional income and to have alternative economic resources as a buffer to economic and climatic shocks (coffee and cocoa prices, cold spells, temperature increases). The development of these income-generating labor activities outside the production unit depends largely on human capital (better education, training and experience in the development of labor), a situation that limits most farmers (Kay, 2009).

4.2. Vulnerability of livelihoods strategies to climate variability

The types of households that were most vulnerable to climate variability were: Cocoa Farmers, Coffee Farmers and Employees-Cocoa Farmers. These types of rural households are the most exposed and the ones that perceive the greatest effects of climate variability; they also have the least capacity to adapt (lower capitals endowment). Vulnerability to climate variability is not a situation isolated from the socio-economic and biophysical conditions of the communities (Aryal et al., 2014). It was found that climate variability depended largely on the spatial distribution of the study areas, which contributed significantly to household vulnerability. According to the multi-temporal analysis, there have been abrupt changes in rainfall patterns over the last 20 years, most notably in some coffee growing municipalities such as Tello. In that municipality, November is the month with the highest rainfall. However, the amount can vary depending on the beginning, duration and intensity of the dry periods (Tang, 2019).

Climatic variability affects coffee (Gomes et al., 2020) and cocoa (Asante et al., 2017; Gateau et al., 2018). It affects coffee production, since the increase in average daily temperature causes the flowers to abort (DaMatta, 2004) and is advantageous for the development of pests such as the coffee berry borer (*Hypothenemus hampei*) (Jaramillo et al., 2009). Furthermore, the combination of variation in temperature and rainfall increases the proliferation of rust (*Hemileia vastatrix*) (Ghini et al., 2011). Cocoa is subject to water stress in times of drought (Schroth et al., 2016), which decreases the yield and puts its development and productivity at risk (Gateau et al., 2018). Though the amount of water cocoa receives annually is important, even more so is the distribution of rainfall throughout the year (Jacobi et al., 2013). Similar situations are projected in Central America, where the main crops lose their suitability, natural ecosystems are modified, and therefore, so are the provision of ecosystem services and the availability of water (Hannah et al., 2016).

In our study, rural households of Cocoa Farmers, Coffee Farmers and Employees-Cocoa Farmers perceived the greatest sensitivity to climate variability, where the limited access to water for crops is a limiting factor for production. Two producers said: "There is not enough water for everyone. Some have diverted the streams so that we do not get water", "The water that comes from the irrigation district has decreased, so to get enough, one neighbor takes water from others without respecting shifts". This situation coincides with that proposed by Adaawen et al. (2019), who state that water scarcity generates competition among farmers to such an extent that it leads to violent actions. However, in the department of Huila these problems are 1. solved through dialog with the intervention of local institutions, 2. the problem is perceived but has not been solved. This coincides with a study by Waldman et al. (2019), where 98% of farmers perceive the problems caused by the climate, but do nothing to solve them because environmental concerns (droughts, variability in rainfall regime) are not as decisive in the adoption of adaptation strategies as is the concern for the availability of food for the family.

Another precursor to the state of vulnerability of the Cocoa Farmers, Coffee Farmers and Employees-Cocoa Farmers is the low endowment of financial capital for all three groups, and human capital endowment for the Cocoa Farmers. Human capital is fundamental because the knowledge of Cocoa Farmer households allows them to receive, evaluate and disseminate knowledge that would enhance adaptation strategies, through access to information and technology (Tian and Lemos, 2018), taking into account that socio-economic factors such as innovation-action, institutions and policy configurations that increase the capacity to adapt (Kelly and Adger, 2000). This is reaffirmed by Ahmed et al. (2021) who concluded that ensuring education in general, especially to middle-aged (36–50 years) and elderly (>51 years) farmers, would likely improve the execution and adoption of different climate change adaptation strategies in their farming systems. In addition to human capital, built and financial capital are also in crisis due to specialization in cocoa production, without investment in bean quality, or infrastructure to improve prices (Espinosa, 2016). Therefore, it is necessary to diversify productive activities, without abandoning cocoa cultivation (Tuesta et al., 2014). In the case of coffee producers, one opportunity is to alternate this crop with others that have equally attractive market prices (Tittonell, 2014) and cultivate species for self-consumption (Kosoe and Ahmed, 2022) or, if possible, invest in social, political and financial capital to increase the technological level and yield of the crop (Suarez et al., 2021). Among the diversification strategies are non-agricultural sources of income, as they are less susceptible to the effects of climate change (Nelson et al., 2010). While Employees-Cocoa Farmers households meet this diversification characteristic, they still have little financial capital. A similar situation was reported in a fishing community, in the Sahelian floodplains of North Africa where livelihood diversification was not sufficient to decrease their vulnerability (Morand et al., 2012). A good adaptation strategy does not depend on the amount of productive activities but on the sustainability of the livelihood (Martin and Lorenzen, 2016) and sufficiency of human and structural capital, such as labor availability, location (i.e. access to marketing channels) or social networks (Knickel et al., 2018).

Taking into account the analysis of the factors that have influenced the high vulnerability of the three types of rural households mentioned previously, it is also important to know the conditions that have allowed other rural households in this study to adapt to climate change, in particular the Livestock-Cocoa Farmers and the Cattlemen-Cocoa Farmers households. In the case of the Livestock-Cocoa Farmers, they are not at risk of exposure to climate variability, and have low sensitivity, unlike the Cattlemen-Cocoa Farmers. However, both have a high potential to respond in climate stress scenarios because of their balanced capitals endowment, since balance between capitals is an emerging strategy that allows communities to cope with social, economic and environmental threats (Emery and Flora, 2006), and to generate adaptation strategies to climate change (Brüssow et al., 2019). Bouroncle et al. (2015) also mention that capitals endowments expressed in access to basic services, access to information, assets for innovation, and to maintain their productive systems are key for rural communities to successfully adapt to climate change.

4.3. Conditions that generate adaptive capacity

In this study, cultural and political capital were the most decisive resources in the adaptive capacity of rural households in Huila, due to the culture of environmental conservation (active response to climate variability) and institutional support thanks to the relationship or influence of the community with external agents. Similar results were reported from a community in Fiji, where the influence of socio-cultural identity and values on the choice of adaptive strategies is highlighted (Neef et al., 2018). Kuruppu (2009) found that cultural values related to livelihoods are important in adaptation. Other studies highlight the importance of political capital, because of its potential to strengthen household adaptation by influencing the implementation of laws and government programs to finance projects (Smith et al., 2001) that allow farmers to make appropriate choices about adaptation strategies (Al-Amin et al., 2019). In agreement, Suarez et al. (2021) in studies carried out in areas close to our research, found that political capital is a driver of the other capitals in the case of rural coffee-growing households. In addition, the greater the social capital, the greater the investment in built resources (Chriest and Niles, 2018) and human capital, due to the links established with external actors that help them mobilize resources (Chaudhury et al., 2017).

5. Conclusion

The livelihood strategies of rural households in Huila are complex due to the diversity of productive activities carried out by this population, mainly dependent on agricultural livelihoods. The main productive activities found in the households were cocoa cultivation, coffee cultivation and livestock raising. Typologies that combine two or more livelihoods, such as livestock and cocoa production, are highlighted.

In this study, all rural households are affected by climate variability; however, the degree of vulnerability and adaptive capacity differ among the seven household types and depend on the balance of capital endowments and livelihood diversity. Households with lower livelihood diversity and lower human, cultural, physical and financial capital endowments are less resilient to climate variability. These conditions are present in Coffee farmers and Cocoa Farmers which puts them at a disadvantage since coffee is a crop that is very sensitive to climatic variations and cocoa to water stress. Having a climate-smart crop (cocoa) does not reduce the degree of vulnerability per se, if it is not accompanied by a diversity of livelihoods and a balance in capital endowment. It is not only the type of livelihood that determines adaptive capacity to climate variability, but how it is done and in what productive environment it is carried out.

Therefore, this study demonstrates that the choice and combination of sustainable livelihoods in each territory is a strategy for adaptation of rural households to climate variability that allows them to maintain the balance in their capital endowment and invest in other capitals such as natural capital. This should be incorporated into development plans and regional plans on climate change to initiate an adaptation path from the local level. This study also reveals that at the community level, cultural and political capital are determinants in the capacity to adapt to climate variability; first the perspectives on climate change and natural resources are transformed and then the communities act accordingly, participating in decision-making scenarios that allow them to manage their adaptation.

Given these results, institutional interventions should consider a differential approach that prioritizes needs, resources and motivations based on livelihood strategies to reduce climate vulnerability. This will lead households to generate sustainable actions and initiate a path towards empowerment in climate-smart agriculture. We propose to include in land use policies in relation to climate change, strategies that promote the resilience of rural household livelihoods in the face of climate stress, including: a. programs that promote the simultaneous and alternating combination of vulnerable livelihoods (coffee and cocoa farmers) with environmentally sustainable, climate resilient, economically profitable and socially acceptable agricultural and livestock activities, moving towards climate-smart agriculture; b. promotion of crop and livestock production of species for household self-sufficiency in order to buffer against food insecurity; c. strengthening of agricultural strategies and insurance to cope with crop failure and/or to implement buffer crops, so as not to put household welfare at risk; and d. training and capacity building programs under a public-private partnership scheme to strengthen the adaptation and resilience processes of rural household livelihoods to climate change.

The take-home message is oriented towards continuing to contribute from science and research towards How to articulate this evidence with emerging policies of integrated rural development based on sustainable land uses?

Declaration of Competing Interest

The authors declare no conflict of interest.

Data Availability

The data are part of a research project that is under development, therefore, they cannot be shared yet.

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Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.landusepol.2023.106731.

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