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RESEARCH ARTICLE

Indigenizing climate change adaptation education in a developing country context: what are the key drivers?

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Summary
Climate change has been shown to affect different aspects of society, with agriculture and the food system taking the highest hit. Several initiatives have been put in place to dampen such effects. Climate education could play an important role in the fight against climate change. Climate education ensures that farmers understand the anthropogenic causes of climate change and the principles underlying adaptation measures, hence informing adoption of sound adaptation measures. Although such theoretical underpinnings are clear, empirical evidence is lacking. We employ a multivariate probit model to empirically investigate the role of climate education in adoption of climate adaptation practices using data from Cameroon, whose humid tropical agroecology and forests are crucial to climate change mitigation in the Congo basin. Employing a linear model, we similarly evaluate the role of climate education on farm incomes as well as the role of perception of climate change. Our results show that climate education influences adoption of adaptation measures, especially simple and cost-effective measures. However, climate education does not affect farm income, neither does farmers' perception of climate change. These results suggest that indigenous farmers may be more willing to choose a simple low-cost adaptation measure. The generated results are crucial for influencing climate change policy related to awareness building, education, and training for optimal adaptation efforts.

Keywords: Indigenizing education; climate change; adaptation; technology adoption

Introduction
Climate change is a pressing contemporary challenge, with its impacts cutting across several sectors. Climate change caused by rising greenhouse gas emissions and global warming leads to varied local implications, with many sectors, regions, and populations at risk (IPCC, 2021). Climate change being increasingly characterized by shifting temperature and precipitation patterns, rising ocean temperatures, sea level rise, melting glaciers, as well as increased frequency, intensity, and duration of extreme weather events affects agriculture given its inherent dependence on land and water (IPCC, 2022). According to IPBES (2024) and the IPCC (2021), climate change is projected to have several negative effects on current ecosystems and civilizations. These changes and effects spill to other sectors such as biodiversity, energy, health, and the food system (Behnassi

et al., 2022; Madruga, 2021; Sandford and O'Riordan, 2015; Di Falco and Chavas, 2009). The food system is particularly climate-sensitive, with special effects on food security in different regions and ecologies (IPBES, 2024; Tabe-Ojong *et al.*, 2023; Tumushabe, 2018). The impacts on crops, livestock, soil, water, rural communities, and farmer livelihood are established to result in significant quantitative economic declines (Bomdzele and Molua, 2023; Dhakal *et al.*, 2022; Epule and Bryant, 2014). More stringent factors like drought, heat waves, and flooding have been shown to reduce crop yields (Ahmed and Ahmad, 2023; Brás *et al.*, 2021; Lesk *et al.*, 2016). Additionally, the resultant heat stress, parasites, and vector-borne diseases harm livestock (Biswas, 2022). Agriculture paradoxically releases greenhouse gases that cause climate change. Meeting the food and fiber needs of a growing population, agriculture seeks to adapt to ensure food security and raw material supplies. Stakeholders in the agriculture sector could adapt by reducing negative effects and maximizing benefits.

However, Indigenous peoples and local communities (IPLCs) remain principally vulnerable to climate change due to their close connections to land, water, and ecosystems (IPBES, 2024; Apraku *et al.*, 2021; Bele *et al.*, 2013). IPLCs live in ecologically sensitive areas including coastal areas, mountains, and woodlands, leaving them vulnerable to extreme weather. Yet, their dependence on traditional practices and political marginalization make them less able to adjust to rapid and harsh changes (Redvers *et al.*, 2023). These IPLCs are particularly vulnerable to climate change owing to their close relationship with the natural environment and engagement in subsistence practices such as agriculture, hunting, and fishing, as well as their cultural and spiritual affinity for outdoor activities (Leal Filho *et al.*, 2022; Leal Filho *et al.*, 2021a; Apraku *et al.*, 2021; Schramm *et al.*, 2020; Nkem *et al.*, 2013).

IPLCs use a variety of climate change mitigation strategies (IPBES, 2024; Schlingmann *et al.*, 2021). For instance, Schlingmann *et al.* (2021) observe local responses in the crop sector typically involve changes in crop mixes, cultivation practices such as soil conservation, irrigation, and manure application (Ngaiwi *et al.*, 2023; Molua, 2022). Livestock responses are dominated by changes in grazing location and changes in animal species and herd size. Some other sectoral responses include intensifying efforts to strengthen social networks, earning income through off-farm wage jobs, and public biodiversity conservation programs (Njoya *et al.*, 2022; Kalimba and Culas, 2020; Schramm *et al.*, 2020).

Indeed, the fight against climate change is taking many forms. Some studies have highlighted the use of climate smart agricultural technologies (CSATs) as one way of combatting climate change (Tabe-ojong *et al.*, 2023; Tesfaye *et al.*, 2021; Teklewood *et al.*, 2017). Others have highlighted the need to enhance the capital embedded in indigenous and local knowledge (ILK) systems (Leal Filho *et al.*, 2022; Petzold *et al.*, 2020; Makondo and Thomas, 2018; Ford *et al.*, 2016; Nyong *et al.*, 2007). The use of ILK is vital in solving the climate change crisis (Leal Filho *et al.*, 2021a; Mugambiwa, 2018), and it facilitates the transfer to contemporary adaptation methods produced through formal education-based training (Andersson, 2012). However, IPLCs encounter institutional impediments, limited resources, and technical assistance to implement education and outreach-related adaptation plans (Leal Filho *et al.*, 2023; Redvers *et al.*, 2023; Schlingmann *et al.*, 2021; Mugambiwa, 2018). IPLCs would, nonetheless, need training and finance to deliver customized programs. Overall, indigenous education empowers and drives climate action (Mbah *et al.*, 2021).

Our study attempts to contribute to the emerging literature, which addresses the nexus of climate change adaptation and education in local communities. Based on this background, we seek to address the following questions: does climate education affect choice of adaptation measures? Do farmers' perception of climate change affect their incomes? Are farmers who have undergone formal training on the nature of climate change receive higher farm income? Our research thus looks at selected communities on the frontiers of the rural landscape engaged in agriculture and non-farm productive activities. Providing answers to the questions raised is important since it is expected that smallholder farmers who rely on ILK and the use of climate-smart agricultural

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technologies (CSATs), without formal training through climate change education, are unlikely to engender efficient and profitable adaptation measures.

Empirical evidence on the role of climate education in climate adaptation is scant. Therefore, this study aims to provide evidence and shed more light on the role of education in climate change adaptation, and associated benefits. We use data from the humid tropical agro-ecologies of Cameroon to address these research questions. Cameroon like most African countries is essentially agrarian. The trends of climate variation and change in the country have been documented in previous studies (Bomdzele and Molua, 2023; Bruckmann *et al.*, 2022; Ebodé, 2022; Vondou *et al.*, 2021; Mbog *et al.*, 2020; Ayonghe, 2017; Epule and Bryant, 2014; Molua, 2006; Maley and Brenac, 1998). With five distinct ecological zones and a range of meteorological conditions that reflect the African continent, Cameroon serves as an essential test bed for the phenomenon of climate change. To our knowledge, this is the first study in the region that empirically tests the relationship between climate education, adaptation, and farmers' welfare. This research is necessary given the clarion call from the UNFCCC, which demands parties to conduct educational and public awareness initiatives on climate change and to promote public involvement in programs and information access. Our generation of information on climate change adaptation and education in local communities adds to an understanding of the role of education in climate action, and contributes to better policy planning and initiatives related to climate change communication.

The remainder of this paper is divided into four major sections. While section one has introduced the situation analysis of indigenizing climate change related education in Cameroon, the second section presents the theoretical foundation of the discourse. The materials and methods that comprise of the nature and source of data as well as the empirical modelling are presented in section three. In section four, we present the results of the analysis, the principal findings, and policy implications. The paper concludes with the summary of the findings and policy related recommendations.

Education, climate change perception, and adaptation

Although a global phenomenon, climate change impacts would be more felt in African countries, who surprisingly contribute the least to climate change through low emissions of Greenhouse gases (IPCC, 2022, Czechowski, 2020, Ogwu, 2019; Niang *et al.*, 2014). The salient impacts of climate change on the African continent have been attributed to several factors such as limited adaptation capabilities, poverty, and dearth of technology. Exacerbating these effects is the fact that the continent's agriculture still largely depends on climatic variables like rainfall and temperature. Hence, climate change directly affects agricultural production and productivity with ensuing effects on food security and income of farmers (Alotaibi *et al.*, 2020). These further pose a threat to the attainment of the continent's Sustainable Development Goals (SDGs) (Ogwu, 2019; Tumushabe 2018). Thus, various national and international forums, including the African Union with its ambitious goals for the continent, have focused on climate change mitigation.

Climate change will impact agriculture in diverse ways, requiring different responses (IPCC, 2021). In a diverse agro-climate like that of Cameroon, a plethora of adaptation measures are employed. In the Western highland zone, Awazi *et al.* (2019) show that farmers employ three main adaptation strategies; on-farm, off-farm, and agroforestry. The on-farm practices include shifting of planting dates, soil conservation and intercropping while some off-farm practices included increased commercialisation and trade. While agroforestry stands out as a key adaptation measure, Awazi *et al.* (2022) argue that three main kinds of agroforestry are practiced by farmers; agrosilvicultural, silvipastoral, and agrosilvipastoral systems. In the forest areas, farming practices such as crop rotation, extended fallow duration, and reseeding are common (Chimi *et al.*, 2022). Changing of food regimes, and belonging to local institutions also constitute salient adaptation

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measures among farmers in forest zones (Brown and Sonwa, 2015; Sonwa *et al.* 2012). In the Coastal areas, Evariste *et al.* (2018) show that the adaption strategies are more reactive than protective and include early harvesting, change of crops, and resowing. However, they also show that most of the adaptation strategies were ineffective and most farmers do not employ any adaption strategies at all. In the semi-arid areas, Njoya *et al.* (2022) show that use of short-cycle varieties, terrace farming and half-moon are the most common adaptation practices.

The awareness and perspectives of climate change among farmers are crucial for the development of diverse mitigation and adaption measures. Education, age of the household head, soil fertility, market access, and agricultural training have been identified as the main factors influencing farmers' perspective on climate change and adaptation strategies (Chemeda *et al.*, 2023; Mairura *et al.*, 2021; Tesfahunegn *et al.*, 2016). Education plays a crucial role in shaping the expectations and coping strategies. When farmers firmly believe that climate change is responsible for the decrease in crop and livestock productivity, depletion of water resources, and affects other associated farm activities, they make efforts to adjust to climate change by implementing farming system management, contingency crop planning, and adopting new business practices (Reddy *et al.*, 2022; Fosu-Mensah *et al.*, 2012 ; Mertz *et al.*, 2009). Collecting data on farmers' behavioral reactions could bebeneficial for policymakers to develop a climate-resilient agricultural system by guaranteeing prompt access to resources, precise weather prediction, and promoting agricultural insurance. This will enable farmers to adapt to the changing climate and improve their income and economic welfare.

Previous studies on climate change adaptation by poor vulnerable households (e.g. Trinh *et al.*, 2018; Mulwa *et al.*, 2017; Di Falco and Veronesi, 2014; Deressa *et al.*, 2011) find education to be important, albeit with context and location-specificity. Thus, one form of empowering societies is indigenizing education for climate action (Molthan-Hill and Winfield, 2023; Mbah *et al.*, 2022a; Molthan-Hill *et al.*, 2019). Education is particularly crucial to promote climate action (Mbah *et al.*, 2022b; Mbah *et al.*, 2021). It aids individuals in comprehending and addressing the effects of the climate catastrophe by equipping them with the information, expertise, values, and attitudes necessary to engage as change agents. In order to combat climate change, some studies and international organizations have thus reiterated the importance of education and training (Molthan-Hill and Winfield, 2023; Mugabe *et al.*, 2022; Mbah and Johnson, 2021). The UN Framework Convention on Climate Change (UNFCCC), Paris Agreement, and Action for Climate Empowerment (ACE) agenda urge governments to inform, empower, and involve stakeholders and important groups in climate change policies and actions. This helps people learn, understand, and adapt creatively to climate change.

Over all, education on climate change remains very relevant in the national, continental, and global development agenda. SDG 13, which mandates developing nations to promptly adopt measures
to address climate change and its consequences, is crucial for achieving sustainable development.

However, according to Mochizuki and Bryan (2015), the education sector remains underutilized as a strategic resource to mitigate and adapt to climate change. Bangay and Blum (2010) note that education responses are necessary, necessitating the provision of pertinent knowledge and skills, as well as appropriate educational infrastructure. They contend that in order for education to contribute to adaptation and mitigation measures, the complete spectrum of educational channels – formal and non-formal, and from primary through tertiary and adult education – must be leveraged. Building on this, Anderson (2012) searched for evidence on the factors that influence skills, attitude, and behaviour change, in order to determine what works for formal and non-formal climate change education content, including environmental education, climate change and scientific literacy, and education for sustainable lifestyles and consumption. The empirical evidence indicates that educational interventions are most effective when they concentrate on local, tangible, and actionable aspects of environmental education, climate change, and sustainable development, particularly those that can be addressed by individual behaviour.

Education about climate change, thus requires climate literacy. Climate literacy ensures that people understand the causes of climate change as well as the mechanisms underlying the adaptation and mitigation measures. Given that climate literacy can be achieved through climate education, studies recommend education as a critical tool for altering people's attitudes and encouraging positive behaviours to adapt to climate change (Simpson *et al.*, 2021; Cordero *et al.*, 2020; Lehtonen *et al.*, 2019: Anderson 2012). Building the capacity of the present and future generations to solve what has been deemed the most serious global issue requires incorporating the topic of climate change throughout formal and informal sectors of education (Molthan-Hill *et al.*, 2022; Cordero *et al.*, 2020; Lehtonen *et al.*, 2019). However, climate literacy remains very low, especially in developing countries (Simpson *et al.*, 2021), suggesting that many countries do not explicitly consider climate education in their fight against climate change.

Some previous studies further illustrate how education empowers communities in the context of climate change (Trædal *et al.*, 2022; Murphy *et al.*, 2020; Ardoin *et al.* 2017). The association of education to the discourse is thus important, since in some developing countries, many farmers believe that supernatural forces are causing climate change. Whether formal or informal, education can play an important role in climate change adaptation. Education will build capacity to appreciate the science behind the observed changes and encourage the uptake of cost-effective modern practices with capacity to maintain or improve productivity. Education whether classical or indigenous remains the pillar of human capital development. Besides offering literacy, it broadens the horizons of farmers and increases their decision-making ability. However, climate change education, including all formal, non-formal, and informal endeavours and initiatives, face pertinent barriers related to cognitive challenges for grasping the complexities of climate change, psychological and social challenges, behavioural challenges with reluctance to change lifestyles, structural challenges, as well as ideological and moral challenges. (Lee *et al.*, 2022; Monroe *et al.*, 2019; Masud *et al.*, 2017; Naoufal, 2014). These challenges highlight the centrality of climate change as an important social and educational question.

Nonetheless, the education sector itself is increasingly vulnerable to the rapidly growing threat of climate change. Climate change exacerbates and is compounded by other challenges to education and development. The influence of climate change on education can result in substantial disruptions for students, teachers, and their communities.

Overall, climate change education is an essential instrument for enabling citizens to comprehend and tackle the consequences of climate change. Feinstein and Mach (2020) note that education, appropriately conceived, can be a powerful tool in enabling effective adaptation to climate change. The objective is to cultivate comprehension, principles, and conduct that can promote collaborative efforts towards addressing climate change. Figure 1 provides a concise overview of the complex connection between education and climate change. Although climate change poses a barrier to education, education also offers an effective tool for addressing it. The plan encompasses efforts to both mitigate and adapt to climate change, with a particular emphasis on climate justice and, when relevant, indigenous knowledge. The components of effective climate change education encompass the acquisition of cognitive knowledge, the development of socio-emotional skills, the cultivation of action-oriented abilities, and the promotion of justice-focused communal living.

In using education as an important driver, the style of delivery, the curriculum, and the target audience are critical for climate change training (Kerr *et al.*, 2022; Mataya *et al.*, 2020; Schattman, *et al.*, 2019; George *et al.*, 2009). According to Schattman *et al.* (2019), accurately determining the target audience is crucial for the effectiveness of instructional initiatives. Implementing this approach during the curriculum-building phase enables developers and educators to proficiently convert technical scientific knowledge into a manner that is applicable to land managers or advisers. When designing and implementing climate change curriculum, Schattman, *et al.* (2019)

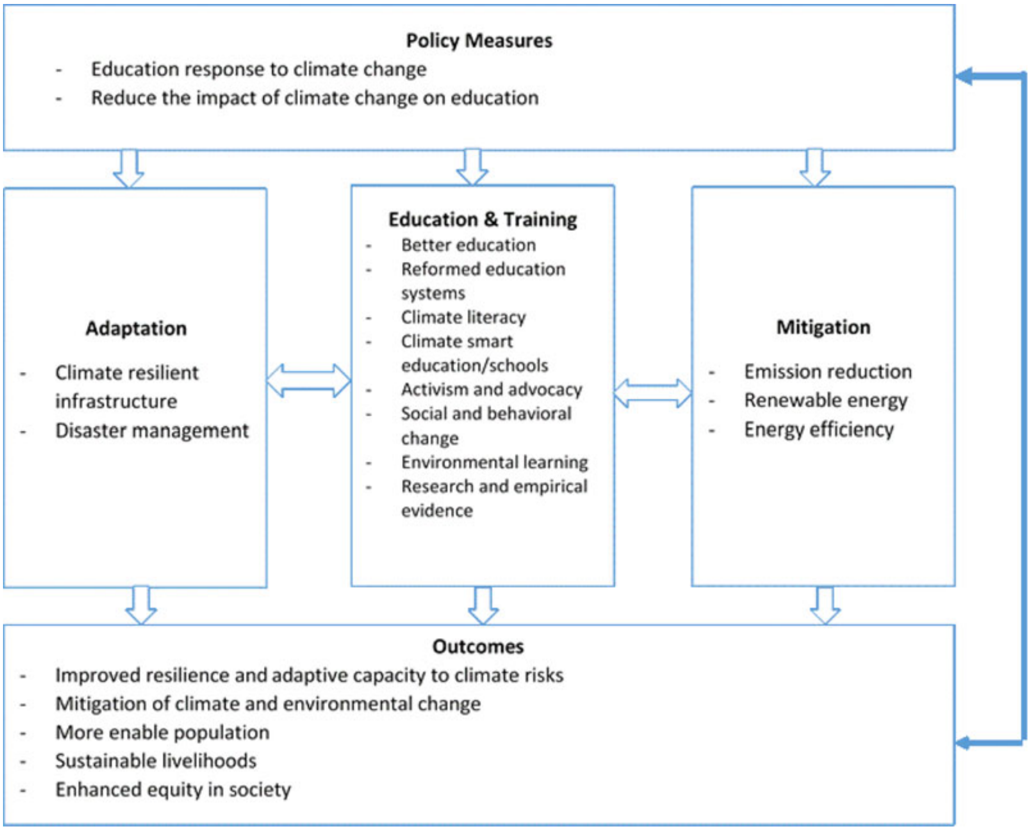

Figure 1. Conceptualization of climate change education response and outcome.

argue that there are compromises between appealing to a wide audience and addressing the requirements of particular farmers.

Robust policy initiatives are therefore required to push for climate change education. In their study, Feinstein and Mach (2020) outline three distinct but interrelated policy applications. First and foremost, ensuring the protection and execution of education infrastructure, which encompasses the social and material resources upon which education depends, can reduce vulnerability and strengthen adaptability. Moreover, improving overall education, as evaluated by indicators such as reading proficiency, school attendance, and overall academic performance, might enhance adaptive ability. Furthermore, the delivery of research-based adaptation learning support can accelerate social and policy transformation by enhancing the learning process both prior to and during adaptive decision-making. In order to enhance support for policy, collective action, and behaviour change in education, it is crucial to have efficient communication and public outreach (Evans *et al.*, 2018).

Materials and methods

Study areas

Our study areas are the Southwest and Littoral Regions of Cameroon, which are in the humid rainforest ecological regions of the country. Fundamentally, the littoral and southwest regions share similar topographic and climatic conditions yet with different indigenes. Also, though there exist great variability in the soil profiles in these two regions, there are some areas of soil profile

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similarities. Since one of our objectives is to analyse the role of indigenous knowledge in the area, two divisions were simply randomly selected based on similarities of soil profiles and farming communities. This approach ensures the isolation of the existing interaction of indigenous knowledge from other geographical and environmental variables.

In the Southwest region, Fako division was selected. Fako division lies in $9^0$10'E and $4^0$10'N spreading from Muyuka on the east to Limbe on the west, and Tiko on the South, while bounded by the Atlantic Ocean and the Mount Cameroon range on its northern flank. In the Littoral region, we studied the Moungo Division which spans 3,947 km^2 between 4.15° to 4.95°N and 9.8° and 10.65°E. It is bordered northwestward and southeastward by the Nkam and Sanaga maritime divisions, respectively. While the Wouri river forms a natural border to the northeast and the Atlantic Ocean to the southwest, providing access to the coast. The Moungo is composed of agrarian communities in Mbanga, Njombe, Loum, Manjo, Souza with the capital being Nkongsamba while Fako is split into Limbe, Tiko, Muyuka and the regional capital Buea. Both divisions are characterised by a diverse geography, which displays coastal plains, river valleys, hills, mountain and dotted display of rivers, streams, springs, and swamps.

The coastal plains and fertile river valleys support the cultivation of crops such as cocoa, coffee, palm oil, rubber, plantains, bananas, maize, and cassava. Traditionally, the interplay has encouraged the development of agricultural activities and settlement of diverse ethnicities within these areas. According to Becline *et al.*, (2022), Fako division is home to 400 000 inhabitants, 70% of whom depend on agriculture either directly or indirectly for their livelihood. They participate by either selling their labour to large scale farmers and agricultural companies like the Cameroon Tea Estate and Cameroon Development Corporation or engaging in subsistence production of a variety of crops including vegetables, cereals, plantain, oil palm, root, and tubers. The case is not any different in the Moungo division. More than 452 722 people live in the Moungo division and the local community is either gainfully employed in individual or agricultural firms like *Plantation du Haut Penja* (PHP) or self-employed in family holdings of less than 2ha producing spices, fruits vegetables, banana, cocoa, coffee, and tubers. Additionally, the availability of road infrastructure and the proximity of these areas to urban centers like Douala further enhanced the development of commercial agricultural activities. This region accounts for a bulk of agricultural exports and is critical for national food security, national unemployment reduction and foreign exchange earnings. The study areas are shown in Supplementary material Fig. S1.

With respect to the context of our study, indigenous peoples' traditional knowledge in Cameroon's Southwest and Littoral areas has been developed over many generations via routine daily activities and an intimate knowledge of the surrounding ecosystems. Among Cameroon's more than 25 million inhabitants, native communities span the entire national territory. These native communities and ethnic people reside on the borders of forests, utilizing natural resources for their sustenance (Nkemnyi *et al.*, 2016; Djeukam *et al.*, 2013). They face various socioeconomic challenges, including limited access to education, healthcare, and land resources. The rate of school enrolment is exceedingly low. The restricted availability of health services continues to be a significant issue, exacerbated by high death rates resulting from challenges in getting essential healthcare and poor rates of immunization coverage. The primary sources of income are derived from small-scale economic activities. The income sources encompass the sale of hunting or fishing items, or gathering of forest products, and traditional remedies (Ntoko and Schmidt, 2021; Djeukam *et al.*, 2013). Agriculture, encompassing tropical crops and livestock, plays a crucial role in generating income and ensuring food security (Azibo and Kimengsi, 2015). The increasing limitation on land access, coupled with the deterioration of forests, hampers their ability to obtain forest foods and traditional medicines, so adversely affecting their health (Djeukam *et al.*, 2013).

Nature and source of data

The study employs a multi-stage sampling technique to sample farming households. Buea in Fako division and Mbanga in Moungo divisions were purposively selected in the first stage based on the intensity of agricultural activities and bio-cultural diversity. Following the same selection mechanism of stage one, six villages were selected in the second stage from a pool of 18 villages that cuts across. A sampling frame was established comprising solely of farming households who identified as indigenes or natives to the locale. A total of 120 questionnaires were randomly administered by well-trained enumerators to indigenous farming household heads in the different villages on a probability proportional to size basis. Prior to administration, the questionnaires were validated through a pilot survey. The questionnaire elicited information from each native household, the household demographics, farming systems, the resource mobilization and use, the returns to the farming system, the perception to climate change, adaptive response to climate variation, indigenous knowledge as well as access to capacity development for climate change adaptation. After cleaning the data, 99 households were retained for further examination. The quantitative data is supplemented by Expert Elicitations from professionals and policy actors including extension officers, lecturers, researchers, traditional authorities, and the Ministry of Agriculture. This process involves personal interviews, which are recorded using digital recording devices. The outcome of these interviews is then transcribed word verbatim, and the information generated used to strengthen the analysis and interpretation.

Ethical clearance was sought through the University of Buea Ethics Committee (UBEC). At the time of commencement of the research, the UBEC granted Ethical waiver following a clear demonstration of respect for persons (the research consent process ensures autonomy for individuals – 'informed' consent, confidentiality of data etc.), beneficence (the intention to do no harm – to maximize possible benefits and minimize possible risks to people involved in research), and justice (fairness in distribution of research inclusion and exclusion). During the field research, the Survey Manager presented the research permit to respective region, district, and village leaders. In addition, we sought verbal agreement from all respondents prior to the interviews to guarantee their willingness to participate. To protect confidentiality, respondents' names and personal information are kept anonymous.

Description of variables and measurement

Our outcome variables of interest are climate adaption measures and net farm income. Here, we consider four agricultural adaptation measures; crop rotation, agroforestry, mulching, and intercropping. These adaptation measures are widely used in the area and have also been used by previous studies (Ngaiwi *et al.*, 2023; Tabe-Ojong *et al.*, 2023; Tabe-Ojong *et al.*, 2024). These variables are measured as dummy variables that take a value of one if a farmer agrees that they use it in any of their plots and zero otherwise. Net farm income is measured as the difference between revenue generated from sale of agricultural produce and farm expenditure over the previous season. Our treatment variables of interest are climate change education, climate training, and perception of climate change. Climate change education is measured as a dummy variable that takes a value of one if the farmer agrees that he was taught about climate change in school while climate training takes a value of one if a farmer agrees that he has ever undertaken any training related to climate change and zero otherwise. Climate perception is measured as a dummy if a farmer agrees that they have noticed a change in temperature or rainfall. Other control variables such as household size, age, and education are measured as the average of household members. Since some climate adaptation practices may require considerable labour, the availability of such labour may depend on the household characteristics rather than the characteristics of the household head. For example, the use of mulching may depend on the availability of household labour to generate and apply the mulch. Hence, a farmer may wish to adopt such a measure but may be stifled by limited labour. As such, we chose to focus on factors at the household level rather than individual level. Access to extension is measured as a dummy variable if a farmer agrees that he has been visited by an extension officer.

Analytical framework

To estimate the effect of perception as well as climate education on farm income, we employ a multiple linear regression approach. The model is presented as follows

$$Y_i = \mathbf{W}'\sigma + C_i\beta + \mu_i \quad (1)$$

where Y_i is farm income earned by a farming household, **W** represents a vector of household and farm factors that may affect farm income, C_i is a dummy for climate change education or perception of climate change as the case may be. In the case where our objective is to estimate the relationship between climate change education and farm income, C_i takes a value 1and 0 for households with and without access access to climate education, respectively. However, in the case where the objective is to assess the relationship between perception of climate change and farm income, C_i takes a value 1 or 0 to differentiate households that perceived and those that did not perceived climate change, respectively. β and σ are parameter estimates and μ is the error term. According to Green (2000), the estimated coefficients are considered unbiased only if the error term is uncorrelated with the explanatory variables. It is obvious that our treatment variable; climate change education, training or perception are all endogenous. However, due to data limitations, we cannot appropriately address these endogeneity issues. Our estimates should therefore be interpreted as correlations.

We are also interested in estimating the effect of climate education on adoption of adaptation measures. Since adoption of adaptation practices is not mutually exclusive, and there exists possible technical relationships such as substitutability and complementarity between the practices, we employ the multivariate probit model (MVP) following (Capellari and Jenkins 2003; 2006). While the MVP model allows for the estimation of observed factors that may jointly affect choice of adaptation measures, it also allows for the estimation of the effect of unobserved factors that may jointly affect such decisions through a correlated error structure whereby a positive correlation implies a complementarity while a negative correlation implies a substitution. The MVP model involves a set of bivariate choice models that are related to each other through the correlations in their error terms. In our case, since we have four types of adaptation practices; agroforestry, mulching, crop rotation, and intercropping, the MVP model involves four set of bivariate choice models, wherein each represents a particular practice. The model consists of one equation describing the binary outcome of interest and a second equation that characterizes whether the first outcome is observed (Capellari and Jenkins 2006). The error terms are assumed to be multivariate normally distributed. The MVP model is estimated through a simulated maximum likelihood (SML) approach following Capellari and Jenkins (2003, 2006).

The model is given as

$$C^*_{in} = \mathbf{X}'\pi + \varepsilon_{\text{in}} \quad (2)$$

$$C_{in} = 1 \; if \;\; C^*_{in} > 0 \; and \; 0 \; otherwise \quad (3)$$

where C_{in} is the choice of adaptation measure, i indexes a household and n is the number of adaptation measures, **X'** is the vector of observed characteristics, and ε is the error term.

Climatology of the study areas

With two different seasons – the dry and the wet – Cameroon is a tropical country in Central Africa on the Gulf of Guinea. Its climate is quite diversified. The North, South Central, and Coast

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Table 1. Descriptive statistics sampled households

Variables	N	Mean	SD
Household (HH)size	99	3.747	2.379
Age of HH (years)	99	.29.14	18.16
Education of HH (years)	99	9.414	.4.571
Access to extension(1/0)	99	0.596	0.493
Net farm income (FCFA)	99	3.230e+06	3.967e+06
Climate training(1/0)	99	0.273	0.448
Climate education(1/0)	99	0.758	0.431
Perception of climate change (1/0)	99	0.939	0.240
Agroforestry (1/0)	99	0.111	0.316
Intercropping (1/0)	99	0.333	0.474
Crop rotation (1/0)	99	0.434	0.498
Mulching (1/0)	99	0.576	0.497

Age and education are mean values of all household members. HH denotes household Climate training refers to have taken part in any climate change-related training, while climate education refers to formally learning about climate change in school.

are the three distinct climatic zones. The south-central plateau experiences milder temperatures, the north experiences a semi-arid and hot climate, and the coast experiences hot, humid weather with slight temperature drops during the rainy season. However, because the country is near the equator and in the tropics, the temperature is hot all year round, with variations depending on elevation. The hottest and driest months of the year are December through March. From April through November, there is variable amounts of rain across the country, with the quantity of rain decreasing from south to north.

The effect of climate change is visible in the study areas. The 30-year above-ground mean temperature is highest during the dry months of the year and lowest at the peak of the precipitation period in August for the Southwest Region. Relative to the Littoral, the average periodic temperature conditions are lower in the Southwest than in the Littoral, though both regions show similar rainfall distribution patterns (Supplementary material Fig. S2a,b). In Supplementary material Fig. S3a,b, we present additional relevant climatic information or patterns that might influence the adaptation measures chosen by farmers. These are trends in climate to understand the context of the naturally occurring variability, derived from observed, historical data for the country. As shown in Fig. S3a,b, the spatial variation of the climatology for the Southwest and littoral regions, captures both the annual and seasonal cycles.

Given the high dependence of the area on rainfed agriculture, it is highly likely that farmers may be alarmed by rainfall variability – volume and distributions of rainfall (Laux *et al.*, 2010). Also, since the area is relatively plain, it is possible that farmers may be affected by high-speed winds. The situation might be more concerning for farmers of crops like maize, plantain, banana, and cocoa as these plants are susceptible to toppling over from wind. Farmers may also be affected by temperature increases as it may affect the scheduling of their agricultural activities. Accordingly, such climate variability influences the cropping calendar of the region, and farmers that perceive changes may select measures that allow them to cope with agricultural production.

Results and discussion

Biogeographic profile of households

Household demographic factors like gender, age, household size, and education play key roles in explaining the adaptation behaviours of many rural communities. In most cases, the outcome of these variables is dependent on the geography and culture of the communities. In some communities, age may increase perception of climate change and in others, the reverse. A similar

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situation could be said of gender, education, and marital status. Regardless, their role remains capital for the study of perception and adaptation studies.

The households in the native farming communities are relatively large with an average size of about four people (Table 1). The average age of all members in the household is around 29 years suggesting that households have relatively younger people. However, the average age of household head is about 42 years which is equally relatively young for an African smallholder farmin household. Youthfulness implies openness and willingness to explore new options which is usually important for driving adoption of new technologies in agrarian communities. In addition, household members are relatively literate with an average education of over nine years of schooling. For the household heads, the average education is 11 years which also suggests that they are literate. This indicates that most of the farmers have attained at least primary education, with the First School Leaving Certificate, which gives them the ability to read and write. This provides the base for farmers to further their education or participate in activities related to climate change to improve on their knowledge. According to Christoffels and De Groot (2004) & Purcell-Gates (2004), basic reading and writing abilities translate to cognitive power, which is relevant for engagement and comprehension of educative materials of various types.

Over 60% of households sampled have access to extension services. With about 60% of households having access to extension implies that they have access to agricultural information. Net farm income from agriculture is relatively large. On average households earn over 3 million FCFA (US$ 6,000) annually from all their agricultural activities. More important, about 23% of households have attended a training related to climate change. This indicates that many households take climate change seriously by attending some form of trainings that can help them understand and cope against it. With respect to climate education, about 76% of the sampled households report that they were at least taught about climate change while in school. Considering that education enhances farm productivity (Ninh, 2021; Paltasingh and Goyari, 2018), providing in-service education for farmers will improve on adaptation mechanisms for climate change which Dhakal *et al.* (2022) found that it mitigates the risk associated with climate change and increase resilience. In terms of perception, over 94% of farmers report increased climate variability and perceived climate change either through definite changes in rainfall patterns and temperature. Perhaps, farmers have been very keen on these changes since they directly affect their agricultural production decisions by altering their production calendars.

The lower section of the table focuses on some adaptation practices adopted by farmers. Few farmers use agroforestry as a climate change adaptation strategy. A plausible explanation for this low number is that agroforestry may be very costly for the farmers and influenced by land tenure constraints. Identifying the most important trees to incorporate into the farm as well as the cost of planting them may be prohibitive. About one-third of the farmers practice intercropping, possibly to account for food supplies and promote adaptation as well as mitigation (Ndip *et al.*, 2023). Crop rotation is practiced by halfof the sampled farming households. Mulching is the most widely used adaptation measure with over half of the sampled households using it as a natural conservation technique (Le Moine and Ferry, 2018).

Analytical nexus of education for climate change

Through the face-to-face structured interviews with each of the farmers, we established an enhanced and positive perception of the roles of education in climate change discourse. Given their farming activities, farmers indicate the need for climate-related capacity to boost their farm productivity. They suggest possible areas for which capacity building is needed to include training on how to adapt to reduce the effects of climate change, as well as training on how to mitigate or prevent climate change from happening. These observations corroborate previous field experiments in the tropics and beyond. In Senegal, Malawi, and Kenya, Kalimba & Culas (2020) showed capacity building to be important for smallholder farmers. Mataya *et al.* (2020)

indicate that long-term education and short-term training have complementary roles in influencing design and implementation of successful adaptation practices. With a carefully calibrated field study, Kakumanu *et al.* (2019) addressed the issue of capacity building for agricultural water management and showed that water saving increased crop yields and increased farmers' income, while decreasing the cost of cultivation.

Farmers in the study areas employ ILK in adapting their farming practices to changing climate (Supplementary material Table S1). The ILK in adapting farming practice to changing climate include mulching, green-manuring, water capturing, improved crop-rotation practice, staking and wind braking, as well as water collection. Farmers reported that these techniques have been helpful over the years (Table S1). Given the benefits of such information, farmers reported that they would like to get more information on ILK employed by other agrarian communities. Somestudies provide support for the notion that IPLCs have adopted various strategies to address and alleviate the effects of climate change (Leal Filho *et al.*, 2023; Leal Filho *et al.*, 2022; Schlingmann *et al.*, 2021; Naess, 2013). Africa has abundant experience-tested and situation-specific ILK that is employed to adapt to climatic fluctuation and change. For instance, Schlingmann *et al.* (2021) demonstrate that IPLCs address climate issues by incorporating knowledge from many knowledge systems. They also highlight the diversified nature of IPLC local responses to climate change, which encompass social, ecological, and economic adaptations. As per the observations of Leal Filho *et al.* (2023), ILK is largely employed in Africa to augment agricultural output, provide food security, improve livelihoods, and generate revenue to mitigate vulnerability and alleviate poverty. In addition, ILK has been applied in other contexts such as predicting and controlling both natural and human-caused risks.

When probed on whether they have ever attended any training programme on climate change, the educated members of the households reported affirmatively. These programmes, with varying curricula, included seminars and workshops by the Regional Delegations of Agriculture, Forestry, and the Environment. Some studies have indicated that both the mode of delivery and the content of the curriculum are strategically important (Kerr *et al.*, 2022; Mataya *et al.*, 2020; Schattman, *et al.*, 2019; George *et al.*, 2009). Mataya *et al.* (2020) argue that short-term training workshops are most effective when they are customized to meet the specific requirements of participants, involve active participation in the design and implementation process, and are structured with examples that are relevant to the local environment. According to George *et al.* (2009), professional development courses that focus on climate are crucial. These courses cover key subjects such as climate and weather, the effects of climate on agricultural systems, and strategic thinking and planning choices for businesses. In their study, Kerr *et al.* (2022) outline the development of a novel curriculum that combines agroecology, nutrition, climate change, gender, and other aspects of social equity. This curriculum is specifically designed to provide explicit training to smallholders who have less formal education. They proposed an educational program that is intensively interactive, using principles from popular education, transformative and experiential learning, and theatre. Schattman et al (2019) offer suggestions for the successful delivery of climate change curricula to adult audiences in the fields of agriculture and forestry.

Farmers report general conversance with the existence of training programmes to improve their productivity. When probed on the relation of these training programmes to addressing and coping with climate variation and change, farmers in the study regions reported trainings related to '*effects of deforestation and on how to increase food availability through afforestation, use of improve seeds that are resistant to climate change, agroforestry, organic farming, regenerative agriculture, creating awareness for climate smart technology, managing deforestation, integrated pest management, sustainable farming System, and farmer cooperative and network management.*' The goal of this capacity building schemes was to provide knowledge to improve crop yields, ensure food security, improve human and livestock health, consolidate farm incomes, and promote growth of farmer-owned enterprises. Some other studies have employed varied techniques and curricula. For instance, Kerr *et al.* (2022) used an integrative training approach to link agroecology with climate change, human and soil nutrition, gender, and related components of social equity. However, whether these capacity-building efforts were enough to give relevant information or training on adaptation to climate change was acknowledged by few farmers as being adequate. The majority who reported the insufficiency based their views on, "*the lack of enough time to prepare and attend the trainings, distance to training venues, late reception of information and their unavailability due to other socioeconomic pressures*."

The farmers generally perceived climate to be changing and were enthusiastic to improve on their coping and adaptive capacity. Kerr *et al.* (2022) similarly noted farmers' enthusiasm in the curriculum training, demonstration of high interest, comprehension of material, and interest in immediate application to their lives. Most of the farmers in our study expected more information on water and irrigation management; farm pest management; weather prediction and adaptation to fluctuating weather parameters; and harvest and post-harvest management practices to enhance their enhance your farming practice. Their expectations for the content of organized trainings included desire for information on farming practices/techniques, weather forecast, irrigation techniques, and household-based coping strategies. With respect to the best method for delivering climate change content, farmers identified class-based, regular workshops, seminars, and farmer-field school. Rather than a one-size fits all approach, the trainings by the different organisations accounted for local specificities. Schattman *et al.* (2019) caution that the appropriateness of specific climate adaptation approaches varies depending on the geographic region in which the farm or forest is located, as well as the type of production and land use, access to resources, and land manager goals, among other variables

Beyond our study area, Kerr *et al.* (2022) observed challenges in training, which included clashes of language, cultural norms, and terminology for conveying technical information.

Activities undertaken in formal institutions (schools, colleges, and universities) that support farmers with relevant skills, knowledge, or information include University-based institutions such as the Faculty of Agriculture and Veterinary Medicine of the University of Buea through its outreach programmes. Others include technical and vocational training centers and outposts of the National Institute for Agronomic Research (IRAD). Additional benefits from local institutions such as the university is toincrease awareness, developing of standards for effectiveness training, and it trails ground for developing new techniques (Mbah and Johnson, 2021; Molthan-Hill *et al.*, 2019). Some studies have indicated that climate awareness is strongly predicted by education, and the effect is greater in high-quality education systems (Paltasingh and Goyari, 2018). Since agriculture peculiarly contributes to GHG emission, education may contribute to accelerate green transitions by addressing information, knowledge, and skills gaps that impede comprehensive climate action. The conduit of education's role spans through empowering teachers, learners, and practitioners with the knowledge, skills, attitudes, and behaviours needed to mitigate and abate climate change. Reimers (2021) strongly emphasizes that as climate change is one of the most pressing issues of our contemporary era, it is particularly crucial to foster students' ability to act as catalysts for change. Equally crucial would be enhancing the ability of elementary and secondary schools to provide education on climate change, by depending on their collaboration with universities. Leal Filho *et al.* (2021b) argue that incorporating climate change into teaching programs and coursework across academic disciplines necessitates overcoming obstacles such as the insufficient preparation of teaching staff. Furthermore, in order to support curricular innovations, it is necessary to establish international collaborations for the development of climate change education and provide more chances for the exchange of experiences across institutions.

Impact of education on farm system choice

Here we present the correlates of adaptation practices and climate education. Before we interpret the results, a cautionary note is in order. These estimates are mere correlates since we do not control for endogeneity of climate education and climate training. Therefore, we steer clear of any

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causal interpretation. From the results, climate education is positively correlated with mulching (Table 2). That is, farmers who have formally learned about climate change are more likely to engage in mulching. This result is expected since mulching is an old practice that farmers have been using. Moreover, it is cheap and desirable to implement as it does not warrant the buying of any extra materials. Mulching is a natural conservation technique which is cost effective but labour demanding (Le Moine and Ferry 2018; Prosdocimi *et al.* 2016). The technique traps soil water through organic matter covering on the soil thus making it more available for crop reabsorption as well as enhancing soil organic matter content for sustainable production (Prosdocimi *et al.* 2016). Mulching offers other benefits such as reducing soil evaporation, conserving moisture, controlling soil temperature, reducing weed growth, and improving microbial activities and crop yield (Iqbal *et al.*, 2020; Fraga and Santos, 2018). During land preparation, farmers usually end up with material that can serve as mulch. Instead of getting rid of this material, it is more advantageous that they use it as mulch. Probably, by formally learning about climate change, they better understood the benefits of mulching which makes it easier for them to use.

In terms of other variables, the older the household members, the less likely they will adopt crop rotation. Well, crop rotation may involve the preparation of new plots. The drudgery that comes with preparation of new plots may deter older household members from engaging in such a practice. Furthermore, crop rotation requires embracing new farm techniques and crop types that might be alienated to the old but more acceptable to the young. As such, young farmers turn to be more concerned as they have more to live for whereas older farmers less to live for or lose. Thus, older famers may appear less concerned and less interested in adopting any technique that requires some level of planning as is the case of activity sequencing in crop rotation. The results are shown in Table 2 and Figure 2.

The more educated the household members, the more likely they are to engage in crop rotation (Table 2). Crop rotation is based on strong agronomic principles. To be employed as an adaptation strategy, users must understand what kinds of crops need to be rotated (Mohler and Johnson, 2009). This kind of solid agronomic foundation is most likely to be available to more educated household members. This can also be obtained through extension access, reason why farmers who have access to extension are more likely to engage in crop rotation as well. Extension may provide such information through awareness creation, education and guidance needed to reduce the uncertainty associated to adoption of new techniques (Tabe-Ojong *et al.*, 2023). However, more formally educated household members are less likely to employ agroforestry. Perhaps, agroforestry is costlier to implement, requiring at least semi-permanent access to land. Hence, even if farmers are aware of its benefits, the associated cost may deter their adoption of the said practice. It is plausible that educated households are more equipped to analyse risk and opportunities associated to various practices thus causing them to shy from the cost and labour associated with agroforestry.

Larger households are more likely to engage in mulching (Table 2). As mentioned earlier, the mulch usually comes from land preparation activities. Hence, larger households that may prepare more land may in turn have more mulch. Under situations of limiting resources, household turn to adapt risks by building from their point of resource abundance. This validates the reason why larger household with an abundance of labour optimally chose mulching, whereas those with higher farm income opt for more financially intensive agroforestry. The lower section of Table 2 that focuses on the correlation coefficients shows that most of the coefficients are statistically significant, suggestive of joint decision in choosing adaptation measures. This further supports the use of a MVP model.

Role of climate education and training on farm income

Here, we discuss the correlates between climate training and education on farm performance measured by net farm income. The results suggest that both climate training and education are

Table 2. Simulated maximum likelihood estimates of climate education and climate adaptation choices

Variables	Agroforestry	Mulching	Crop rotation	Intercropping
Age of HH	0.009	0.0111	−0.0189*	−0.010
	(0.012)	(0.010)	(0.010)	(0.010)
Education of HH	−0.0908**	−0.0455	0.0524*	0.00871
	(0.046)	(0.032)	(0.031)	(0.032)
Climate education	0.319	0.888***	0.0242	0.476
	(0.435)	(0.325)	(0.306)	(0.330)
Access to extension	−0.234	0.0515	0.473*	0.153
	(0.352)	(0.273)	(0.269)	(0.269)
Household size	0.0283	0.199***	−0.0545	−0.0889
	(0.101)	(0.073)	(0.065)	(0.069)
Constant	−0.927	−1.132*	−0.229	−0.321
	(0.806)	(0.641)	(0.599)	(0.612)
P21	−0.303			
	(0.220)			
P31	−0.585**			
	(0.262)			
P41	0.315			
	(0.229)			
P32		0.238		
		(0.165)		
P42		−0.270*		
		(0.157)		
P43			0.165	
			(0.179)	
Observations	99	99	99	99

Standard errors in parentheses.

***$p < 0.01$, **$p < 0.05$, *$p < 0.1$.

HH denotes household. Age and education are mean values of all household members. Climate training pertains to have taken part in any climate change-related training, while climate education refers to formally learning about climate change in school. Lower section of table (P) shows correlations coefficients between the climate adaptation practices, where practice 1 is agroforestry, 2 is mulching, 3 is crop rotation and 4 is intercropping.

weakly correlated with farm income (Table 3). A plausible explanation for this weak positive correlation is that the sample size may be too small to detect any meaningful statistical significance. In addition, there may be very little variation in the outcome variable. While climate training and education are expected to positively affect income, their effects may be different. Climate training may provide more direct effects since farmers can quickly implement what is learned from trainings. The effects are expected to manifest earlier. On its part, climate education's effects may delay given that farmers may learn about climate change but encounter some difficulties in implementing the strategies in the field. As such, the effects may be less direct. Additionally, climate training is likely to focus on adaptation measures while climate education provides a more holistic view about climate change, its effects and potential adaptation measures. The results are presented in Table 3 and Figure 3.

Therefore, the finding that climate training may quickly spur adaptation and affect farm income complements findings by Dhakal *et al.* (2022), who highlight a strong positive correlation between climate change adaptation and farm revenue. The significance and relevance of perception remain, as demonstrated by Ojo & Baiyegunhi (2021), who indicate that the income of farmers is impacted by their perception of climate change and their socio-economic attributes. Furthermore, they show that the net farm income is sensitive to marginal fluctuations in both temperature and precipitation. Ojo & Baiyegunhi (2021) corroborate the finding that farm revenue on implementing the adaptation measures is significantly greater than that of those who did not. Capacity building and training are important to strengthen the resilience of farmers. According to Zakaria *et al.* (2020), the participation in climate change capacity-building training is determined by internal factors and is positively influenced by farmers' accessibility to agricultural extension services and their affiliation with farmer-based organizations. Hence, the level of

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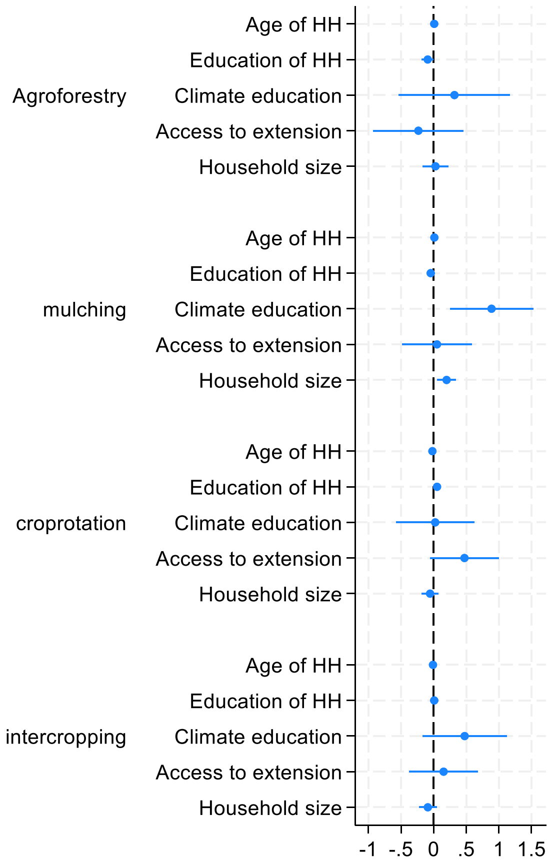

Figure 2. MVP estimates. HH denotes household. Age and education are mean values of all household members. Climate education refers to formally learning about climate change in school. The various adaptation practices (agroforestry, mulching, crop rotation, and intercropping) are defined as dummy variables, which take a value of 1 if the household uses the practice and zero otherwise.

farmers' adaptation is influenced by their involvement in capacity building training and agricultural insurance.

In addition, Ojo & Baiyegunhi (2021) demonstrate that the socio-economic indicators, institutional factors, and locational variables significantly impact the selection of climate change adaptation measures. Institutions unequivocally have a crucial role. In their study, Ojo and Baiyegunhi (2021) propose that the government, stakeholders, and donor agencies should offer capacity-building innovations in agricultural extension systems and climate change education using information and communication technology. This investment in knowledge is crucial for development and would incentivize farmers to embrace suitable climate change adaptation measures. More important, our observations reinforce the findings of decision-making models, which consider behavioural entropy response proposed in Foley (2017). Following this model, the decision maker turns to make decision that seeks to minimize their losses rather than maximize farm gains. In our case, farmer choose to adopt technics as a means cushion against climate loses and not necessarily as a means for profit optimization. In smallholder settings, farm decisions are made first for subsistence and then the surplus is commercialised.

Table 3. Ordinary least squares estimates of climate education and climate training on net farm income

Variables	Net farm income	Net farm income
Age of HH	−32 729	−35 732
	(28 314)	(28 557)
Education of HH	103 760	113 114
	(93 393)	(93 887)
Climate training	209 994	
	(899 360)	
Access to extension	1.367e+06	1.357e+06
	(826 289)	(818 670)
Household size	19 296	2,690
	(202 532)	(203 386)
Climate education		−677 542
		(936 239)
Constant	2.263e+06	2.901e+06
	(1.585e+06)	(1.793e+06)
Observations	99	99
R-squared	0.067	0.072

Standard errors in parentheses.
***$p < 0.01$, **$p < 0.05$, *$p < 0.1$.
HH denotes household, age and education are mean values of all household members. Climate training pertains to have taken part in any climate change-related training while climate education refers to formally learning about climate change in school.

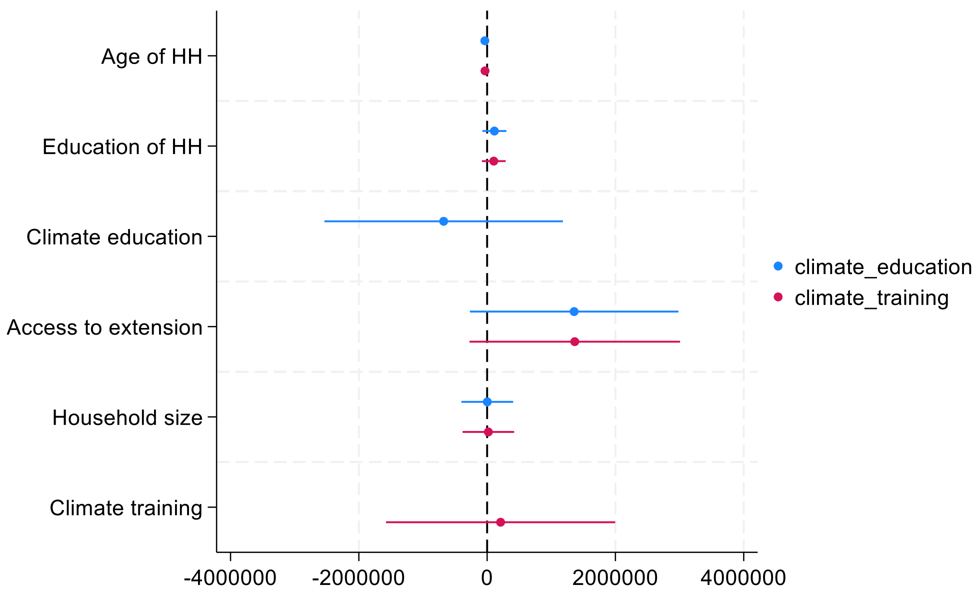

Figure 3. Ordinary least square estimates of climate education and climate training on net farm income. HH denotes household. Age and education are mean values of all household members. Climate training pertains to have taken part in any climate change-related training, while climate education refers to formally learning about climate change in school.

Climate change perception and farm income

The correlates of perception of climate change and farm income are presented in this section. The results reveal that perception of climate change is negatively correlated with farm income. As alluded to before, small sample size and little variation in the outcome variable may be driving the results. Focusing on perception, the result is not counterintuitive. The fact that farmers perceive climate change may warrant that they employ necessary adaptation measures to counter the effects. Hence, perception may not affect their farm income. Moreover, perception in itself may

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not imply climate change. Farm income may be likely driven by other exogenous factors that may not be related to climate change, and less so by farmers' perception. This may explain why other variables such as household size and education level are positively correlated with farm income. A large household size may imply readily available labour while higher educational levels may improve farmers' ability to identify better adaptation strategies, further attenuating the effect of climate change. Better education may thus off-set the effect of climate change perception. However, Nyanga *et al.* (2011) note that actors involved in promoting adaptive agriculture have frequently overlooked smallholder farmers' perceptions of climate change and conservation agriculture as an adaptation strategy and that adoption of conservation agriculture is significantly correlated with perceptions regarding floods and droughts. Nonetheless, farmers who are generally risk averse may be less likely to adopt new practices whose benefits on farm income have not been established. Despite perceiving climate change, they may not employ necessary measures to overcome it. The results are presented in Table 4 and Figure 4.

Our observations corroborate studies that have addressed farmers' risk preference in the uptake of adaptation and agricultural conservation measures (Yu *et al.*, 2021; Jianjun *et al.*, 2015; Greiner *et al.*, 2009). In their study, Greiner *et al.* (2009) observe that the willingness to accept a new conservation practice is mostly determined by the farmer's characteristics and circumstances, as well as the features of the practice itself, particularly its comparative advantage over current practices and the landholder's capacity to experiment with the practice. Given that risk concerns impact input usage and technology adoption, it is crucial to note that a risk-neutral farmer, as stated by De Pinto *et al.* (2013), will strive to maximize the present value of the stream of net benefits that come from farming land. A study conducted by Yu *et al.* (2021) reveals that the level of risk aversion among farmers has a notable and favorable influence on their membership in cooperatives, as well as a notable and unfavorable influence on their adoption of green control techniques. Furthermore, their involvement in cooperatives not only facilitates the adoption of green control techniques but also mitigates the inhibitory effect of risk aversion on such adoption. In their study, Jianjun *et al.* (2015) demonstrate a negative and substantial correlation between farmers' risk aversion and their adoption of adaptation techniques such as planting new crop varieties and adopting new technology. However, they also find a considerably positive relationship between farmers' risk aversion with their procurement of weather index crop insurance. Jianjun *et al.* (2015) also establish that farmers' adaptation decisions are influenced by their degree of education, agricultural experience, farm size, household income, and perception of climate change effects. Significantly, farmers embrace an innovation contingent upon their anticipation that the technique will facilitate the attainment of their objectives, including economic, social, and environmental aims (Greiner *et al.*, 2009).

Robustness check

We employ different approaches to assess the robustness of our results. In the main analysis, we employed the MVP since the decision on the choice of adaptation measure can be jointly made by farmers as confirmed by the correlation coefficients. However, even if these decisions are not jointly made, we expect that the coefficients remain the same if we estimate independent probit models for the different outcomes. To this end, we estimate independent probit models for the outcomes as well as linear probability models, which are less dependent on functional form assumptions. The results are thus similar to those obtained by the MVP model suggesting that our results are robust (Figure 5). The results in both the independent probit and LMP models suggest that climate education increases the likelihood of using local methods such as mulching and modern techniques such as crop rotation as climate adaptation strategies. Institutional factors like access to extension also increase the likelihood of using these practices. Access to extension further supports the role of climate education given that extension is a medium through which climate education can be disseminated.

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Table 4. Ordinary least squares estimates of perception of climate change on net farm income

Variables	Net farm income
Age of HH	–41 479
	(28 187)
Education of HH	120 944
	(94 021)
Perception	–584 346
	(1.713e+06)
Household size	12 358
	(205 841)
Constant	3.803e+06*
	(2.094e+06)
Observations	99
R-squared	0.039

Standard errors in parentheses.
***$p < 0.01$, **$p < 0.05$, *$p < 0.1$.
HH denotes household Age and education are mean values of all household members.

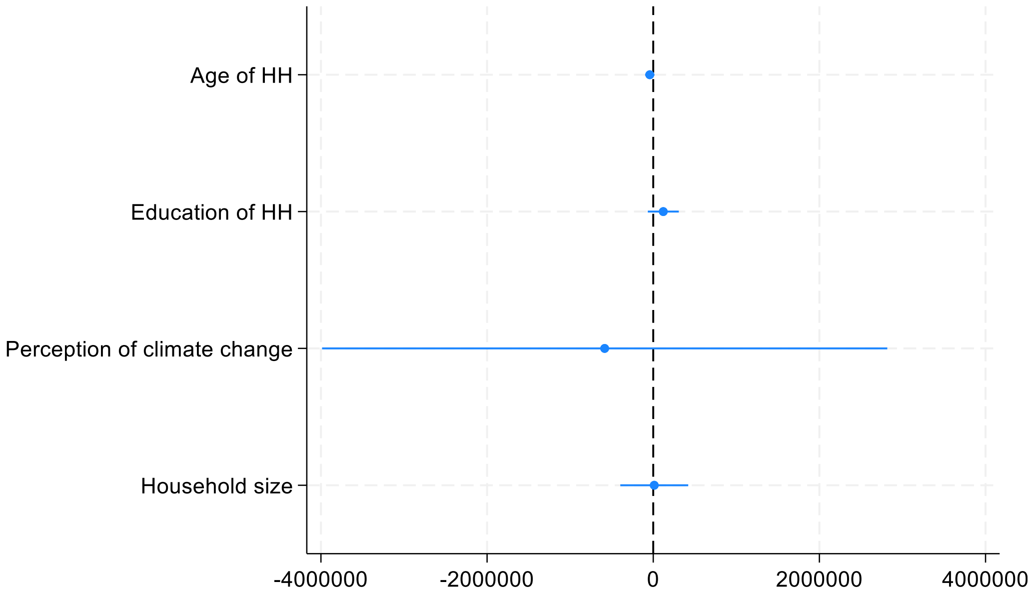

Figure 4. Ordinary least square estimates of perception of climate change on net farm income. HH denotes household. Age and education are mean values of all household members.

Policy implications

In developing countries such as Cameroon, the stress from climate change remains prevalent. The susceptibility to climate threats is reinforced recently by the COVID-19 epidemic (Botzen *et al.*, 2021). According to the IPCC, three factors affect one's susceptibility to climate change: exposure to risks (like decreased rainfall), sensitivity to risks (like an economy predicated on rain-fed agriculture), and capacity to adapt to risks (like whether farmers have the resources or expertise to grow more drought-resistant crops) (IPCC, 2022). By lowering sensitivity or increasing adaptive capacity, for example, adaptation techniques can assist decrease vulnerability. They can also help populations take advantage of possibilities provided by climatic change, such as cultivating new crops in previously inappropriate places (Molua, 2022, Molua, 2011; Molua *et al.*, 2010; Molua, 2009).

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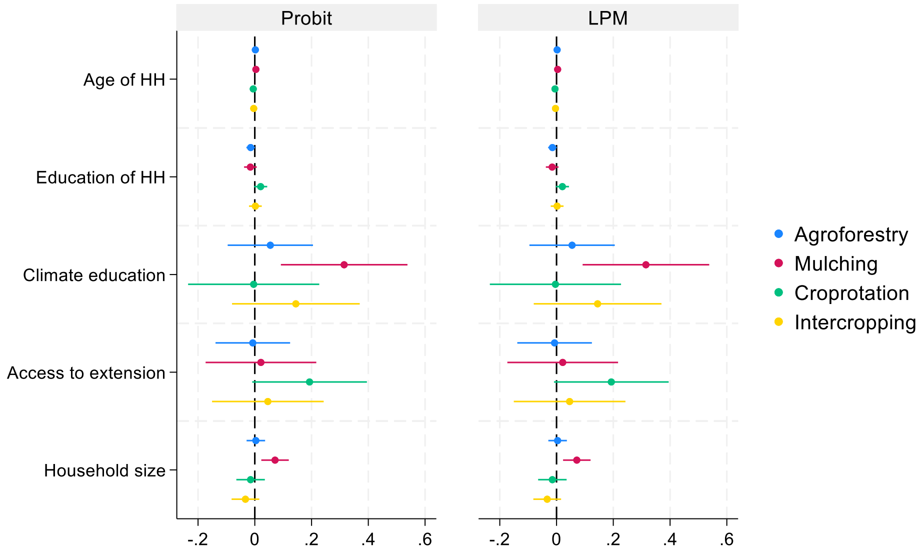

Figure 5. Independent probit and linear probability models for climate change adaptation. HH denotes household age and education are mean values of all household members. Climate education refers to formally learning about climate change in school. LPM is linear probability model. The various adaptation practices (agroforestry, mulching, crop rotation, and intercropping) are defined as dummy variables, which take a value of 1 if the household uses the practice and zero otherwise.

According to Molua (2022), Cameroons' agricultural sector is highly vulnerable and necessary strategies needs to be implemented in the mid to near future in other advert its implication on farm incomes. Farm income effects were also higher without adaptation as compared to with adaptation scenarios. Thus, pointing to the power of enhanced adaptation strategies in improving climate resilience. However, there still exist wide gap between expected adaptation rates and observed adaptation rates of various adaptation strategies all over Africa.

Some studies (e.g., Hanna, 2023; Whitmarsh *et al.*, 2012; Hoffmann *et al.*, 2007) point to the divide between developing techniques and communicating such techniques to communities that in turn are partially determined by farmer's perception of the usefulness of such techniques within their context. For these difficulties to be overcome and to enhance farmers' resilience, there is need for more studies that communicate climate change from farmers' perspective. Studies and results on perceptions such as ours provide a unique perspective into understanding rural dynamics, which is necessary. Climate change is dynamic, so are its effects on different sectors of the economy (IPBES, 2024), and though global, climate change effects are mostly local, thus indicating that context matters.

Our results show that overcoming the climate change challenge on agriculture requires innovative choices. We observe that farmers are aware and interested in conservation agriculture and the accompanying group of sustainable practices that help manage the environment and provide food security. The implementation of conservation technologies does not, however, preclude farmers' socio-psychological capacity and education. There are, however, modern methods within the research-extension system which could support farmers. Nonetheless, an effective foundation for facilitating such technology transfer process as espoused in Choi's (2009) model of technology transfer will require bridging the farmer-research-extension gap, which will allow for the communication of salient information hoarded in the research-extension chain in most developing countries like Cameroon.

In a broader logic, while we use Cameroon as case study, this paper provides analytical context that befits global development policy for addressing SDG13 and target 3, which emphasize the

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need to 'improve education, awareness-raising and human and institutional capacity on climate change mitigation, adaptation, impact reduction, and early warning.' Policymakers, governments, and other stakeholders must therefore develop pathways and put into practice effective strategies. Indigenizing education for climate action may provide an important conduit for climate change adaptation. Accordingly, Mochizuki & Bryant (2015) as well as Hügel & Davies (2024) equally assert that considering education as a major agent of change, it helps individuals to better understand the issues related to the climate change crisis and provide grounds for empowerment with knowledge, skills, values, and attitude needed to act as change agents.

Conclusion

While a plethora of adaptation measures are in existence, teaching farmers about such measures may be more beneficial. This study thus fills this gap by providing empirical evidence on the role of climate change education.

Using cross-sectional data from smallholder farmers in Cameroon, we empirically tested the role of climate change education on climate adaptation and farm performance by employing multivariate probit regression and multiple linear regression models. The results suggest that climate change education is correlated with the use of local methods for adaptation. This implies that climate change education may affect the choice of adaptation. While the battle against climate change ensues, the major focus has to be on developing cheap and easy-to-implement adaptation measures. Climate education is a step in the right direction in this regard. Our study has some limitations which include a small sample, which may lead to power problems in our estimates. Again, we focus only on two regions in Cameroon, which may limit the generalizations of our findings. While we acknowledge that adoption of climate adaptation practices are location and context-specific, future research with larger sample size and wider geographical coverage could be worthwhile, particularly on themes that address farmers' education with respect to climate change adaptation for sustainability. Above all, farmers' education regardless of the nature whether formal or informal, and setting is an indispensable policy tool for enhancing farmers' adaptive capacity and resilience.

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