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CASE STUDY

The role of climate change perceptions and sociodemographics on reported mitigation efforts and performance among households in northeastern Mexico

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Abstract
Managing and reducing the impacts of climate change depends on efficient actions from all societal scales. Yet, the household component is often missing from climate research, debate, and policies. This is problematic because households have been found to significantly contribute to of global greenhouse gas emissions and therefore have the potential to be part of a solution to climate change by mitigating climate change. This study seeks to understand which factors drive household-level mitigation actions. We conducted a household survey in Nuevo Leon, located in northeastern Mexico, to explore the extent to which climate change perceptions and the sociodemographic characteristics of households influence their reported mitigation performances and their perceived mitigation efforts. Results from linear regression analyses and generalized linear models revealed that sociodemographic characteristics are key drivers of the households' perceived mitigation efforts and reported mitigation performances and. We also found that climate change perceptions drive a household's efforts to mitigate climate change. These results could partly explain why despite the efforts households take to mitigate climate change, achieving an effective reduction of greenhouse gas emissions is challenging without further access to resources such as education and financial support. If governments intend to realize substantial reductions in future emission pathways, then household-level mitigation should be addressed with proper support.

Keywords Climate change · Mitigation · Household decision-making · Climate change perceptions · Mexico

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1 Introduction

Climate change poses an enormous challenge as average annual temperatures in Latin America are expected to increase between 2.5 and 4.5 °C compared to pre-industrial levels by the end of this century. Projections indicate that rainfall patterns in the region will become more variable and natural disasters will become more intense and frequent (Reyer et al., 2017; Romero-Lankao et al., 2014). The resulting impacts will exacerbate pre-existing challenges related to the availability of basic necessities of human living conditions, such as food, fresh water, energy production, and manufacturing goods (IPCC, 2021). Considering this, action on climate change is required to achieve both reductions in emission of greenhouse gases (GHG) and to reduce the impacts of climate change (IPCC, 2021). One of the key ways to prompt action on climate change is by understanding people's perceptions of climate change, and how their perceptions in turn shape actions (Bouman et al., 2020; Clayton et al., 2015; Corner et al., 2014; Poortinga et al., 2019).

In Latin America, where advances to curb climate change are much needed, managing and reducing its impacts depends on efficient actions at all societal scales. However, the household, representing a foundational social unit, is often missing from climate research, debate, and policies (Dubois et al., 2019; Qin et al., 2015; Shittu, 2020). The value of incorporating a household perspective in the climate debate is evident as the household level contributes up to 70% of GHG emissions directly through the burning of fossil fuels associated with electricity use, transportation, and heating and indirectly through the consumption of resources and waste production (Ivanova, 2020; Ivanova et al., 2016; Schanes et al., 2018; Vita et al., 2019). In Latin America, a growth in population, coupled with increasing levels of industrialization and urbanization can have a large impact on the region's carbon reduction target, as many countries still depend on oil and coal for electricity production (He et al., 2021; Waheed et al., 2019). Hence, household-level mitigation is vital in achieving substantial reductions in future emission pathways (Dubois et al., 2019; Ivanova, 2020; Wiedenhofer et al., 2018). A household is defined here as a person or a group of persons who live in the same dwelling and share food and other essentials and can therefore be regarded as a fundamental unit of demographic, social, and economic processes where complex decisions are made (Collins, 2015; Gibson et al., 2015; Glewwe & Grosh, 2000; Reid et al., 2010).

In order to effectively respond to climate change, households require a combination of approaches, which include mitigation, adaptation, and civic actions. If planned appropriately, these different types of actions can complement each other to reduce the adverse effects of climate change (Ayers & Huq, 2009; Sharifi, 2021; Thornton & Comberti, 2017). Because the main causes of climate change are anthropogenic in nature, mitigation is often considered one of the most important tasks in dealing with climate change (IPCC, 2021). Households can adopt a wide range of actions to mitigate climate change, which include reducing water and energy use, using public transportation, modifying food habits, reducing waste and recycling. Each of these practices have different impacts on climate change based on their potential reduction of CO_2 emissions. For example, living car free and eating a plant-based diet have been classified as some of the most effective practices households can take based on mitigating climate change, whereas conserving water and planting trees are examples of practices considered to be effective in essence, but have a much lower impact on climate change (Lacroix, 2018; Vita et al., 2019; Wynes & Nicholas, 2017). Furthermore, even though some households do undertake mitigation practices, their actions might not be as efficient in reducing GHG emissions as they believe. As such,

understanding household-level perceptions on climate change and their corresponding mitigation actions are crucial in order to improve and increase their effectiveness.

While several studies have investigated the potential for climate change mitigation among households, the majority of these have been carried out in high-income countries. In low-income income and middle-income countries of Latin America, the mitigation potential of households has not been comprehensively explored (Pardo Martínez et al., 2018; Van Valkengoed & Steg, 2019). Furthermore, the challenge remains to understand what the drivers behind their decision-making to mitigating climate change are. Considering this gap, in this study we examine climate change perceptions alongside sociodemographic characteristics of households to determine what drives a household's reported mitigation performance and perceived mitigation efforts on climate change. Our study provides insights that contribute to understanding which factors drive household-level mitigation on climate change by performing a case study in Nuevo Leon, a state in northeast Mexico.

2 Drivers of climate change action

Many different factors can influence a household to take action, including climate change perceptions and sociodemographic characteristics. In recent years, studies on perceptions of climate change have gained importance, as perceptions are crucial to understand how the public engages with a changing climate (Capstick & Pidgeon, 2014; Forero et al., 2014; Jia et al., 2019; Poortinga et al., 2019). Perceptions refer to the set of processes of recognizing and interpreting sensory stimuli to make sense of our environment, and include a range of psychological constructs, such as beliefs, knowledge, and perceived risk (Goldstein, 2010; Whitmarsh & Capstick, 2018). Nevertheless, perceptions of climate change differ across contextual realities (Heyd, 2010). The reasons for differences in perceptions are complex, but include cultural values, demographic factors, political contexts, media coverage, and the exposure to extreme weather events (Capstick et al., 2015; Lee et al., 2015; Poortinga et al., 2019).

According to the literature, belief in anthropogenic climate change has a positive effect on behavior, including the willingness to address climate change (Arbuckle et al., 2015; Bouman et al., 2020). Similarly, a high environmental concern has been shown to motivate behavior to a considerable degree (Bouman et al., 2020; Hornsey et al., 2016). Findings from surveys conducted in high-income countries such as Australia and the USA have indicated that climate change is perceived by many as temporally and spatially distant (Jones et al., 2017; Singh et al., 2017; Spence et al., 2012; Xie et al., 2019). However, studies among Latin American populations present different findings with respect to trends in high-income countries. In general, Latin American populations believe in climate change, believe it is already occurring and believe it has already had an impact on their lives (Ahumada-Cervantes & García-López, 2018; González-Hernández et al., 2019a, 2019b; Pardo Martínez et al., 2018).

Among Latin Americans, evidence shows that concern about climate change is relatively high and that they consider it to be a serious threat not only to themselves, but also to their families (González-Hernández et al., 2019a; Lee et al., 2015). Interestingly, despite their expressed concern, the issue of climate change is often superseded by other matters such as corruption and the economy, which are perceived to be more pressing issues (González-Hernández et al., 2019b; INECC & PNUD, 2016; Pardo Martínez et al., 2018) However, studies argue that it is vital that the public considers and perceives climate

change as an issue, as people who prioritize climate change are more likely to change their behavior for instance by supporting public policies that promote climate strategies (Hornsey et al., 2016; O'Connor et al., 1999).

Climate knowledge has been identified as a key driver for action on climate change (Shi et al., 2016). To date, several studies have found it is useful to draw a distinction between different types of knowledge. For instance, knowing about the causes of climate change has been found to play a role in shaping concern and action (Akrofi et al., 2019; Bord et al., 2000; O'Connor et al., 1999; Shi et al., 2015). A relationship has also been observed between having more knowledge on the issue and people's willingness to adopt climate-friendly behaviors (Shi et al., 2015). Perceived knowledge has also been found to have a positive effect on reported mitigation and adaptation action (González-Hernández et al., 2019a). Furthermore, when presented with tailored information, households are more likely to demonstrate mitigation behaviors (Abrahamse et al., 2007; Salo et al., 2016). However, there are barriers that inhibit people's motivation and their use of information, such as the lack of accessible and translatable scientific information (Lorenzoni et al., 2007).

The previous literature reveals that action on climate change is also related to sociodemographic characteristics of individuals and households, including gender, age, levels of education, household size, household location, and household income (Abrahamse & Steg, 2011; Lee et al., 2015; Thaller et al., 2020). For example, studies have shown significant gender-related differences, in which women tend to consider climate change as a more serious issue than men and are more likely to take measures toward it (Brody et al., 2012; Weber, 2016). In regard to age, younger adults usually hold stronger pro-environmental attitudes compared to seniors and believe that the issue of climate change ought to be taken more seriously (Semenza et al., 2008; Weber, 2016). Education has also been identified to have an effect on climate change action. Thus far, research has shown that higher education plays an important role in people's adaptive capacities and their willingness to reduce their carbon emissions (De Silva & Pownall, 2014; Semenza et al., 2008; Wamsler et al., 2012).

Given that perceptions have been found to influence behavior in the literature, we hypothesize that higher mitigation efforts and performances will be reported in households where a pro-environment sentiment is prioritized, and who believe in climate change, believe it is happening now, consider it as a risk, have knowledge on the issue and have the knowledge on how to respond accordingly. We also expect that sociodemographic factors such as women respondents, highly educated respondents, and households in an urban area with a higher monthly income will also be predictors of household-level mitigation efforts and performances.

3 Case study and methods

3.1 Approach

We conducted a case study in the state of Nuevo Leon in northeastern Mexico. While being highly vulnerable to climate change, Mexico is also one of the highest emitting countries of GHG in Latin America. Emissions are expected to rise even further due to population growth, economic development, energy supply growth, technological change, and land use change (IEA, 2021). Furthermore, there are three main reasons why we used households from Nuevo Leon as our case study. Firstly, studies on climate change at the household level are limited, especially within a Mexican and a Latin American context

(González-Hernández et al., 2019a). Second, Nuevo Leon is particularly vulnerable to the effects of climate change (Sisto et al., 2016) and third, its urban center, the Monterrey Metropolitan Area (MMA), drives a significant share of Mexico's GHG emissions (Gobierno del Estado de Nuevo León, 2010). To test the hypothesis, we employed a household survey, in which we collected information on household's perceptions of climate change, sociodemographic characteristics and reported actions on climate change. We then estimated the influence of the perceptions and the sociodemographic characteristics on a household's mitigation performance and perceived mitigation efforts (Fig. 1).

3.2 Case study: Nuevo Leon, Mexico

The state of Nuevo Leon is located in northeast Mexico and presents diverse climate types that range from arid to semi-arid in the north and more humid in the south (Contreras Delgado, 2007). Nuevo Leon is significant because it holds the second largest metropolitan area in the country, the MMA, which is considered the most important financial, commercial, and industrial hub of the northern region of Mexico. As a highly industrialized area, the state generates close to 10% of the national anthropogenic GHG emissions (Gobierno del Estado de Nuevo León, 2010). Future climate change projections for the region indicate an increase in the number and severity of extreme weather events such as droughts and torrential rains (Gobierno del Estado de Nuevo León, 2010; Sisto & Ramírez-Orozco, 2015; Sisto et al., 2016). Recent major climatic events in the form of droughts, hurricanes and flash floods have highlighted the vulnerability of Nuevo Leon to weather events (Sisto & Ramírez-Orozco, 2015). Given these projections, the state has taken steps to reduce their contribution to climate change by developing the Nuevo Leon Climate Change Action Program 2010–2015 with the objective of reducing over 1000 million tons of CO_2 equivalent. However, the state program fails to address behavioral changes at the smallest societal scales, i.e., the household level. These events and projections demonstrate the importance of understanding the household-level and their potential for emissions reductions.

3.3 Data collection and household survey

A household survey was designed to explore perceptions of climate change, in addition to collecting sociodemographic data and reported actions on climate change. The survey was conducted using a hardcopy questionnaire and an online version in order to maximize the number of responses and to reach a wide range of the population. The online survey, which was implemented using the Qualtrics platform, ran from August 2016 to January 2017. Potential respondents were recruited through social networks, where they received a general invitation with a link to the survey. Fieldwork in Nuevo Leon was conducted from November 2016 to January 2017 to recruit respondents for the hardcopy version of the survey. A researcher approached potential respondents in various municipalities throughout the state. The survey was in the Spanish language and both survey modes were self-administered without intervention from the researchers. The data from both surveys was combined to create a working dataset.

For this study, respondents were first asked to express in their own words what were the main concerns in their household. This was later recoded into the nominal variable, environmental concern. The intention of this question was to see if they included any climate change issues or environment-related topics in their response (González-Hernández et al., 2019a). Respondents were then asked to rate to what extent they believed climate change

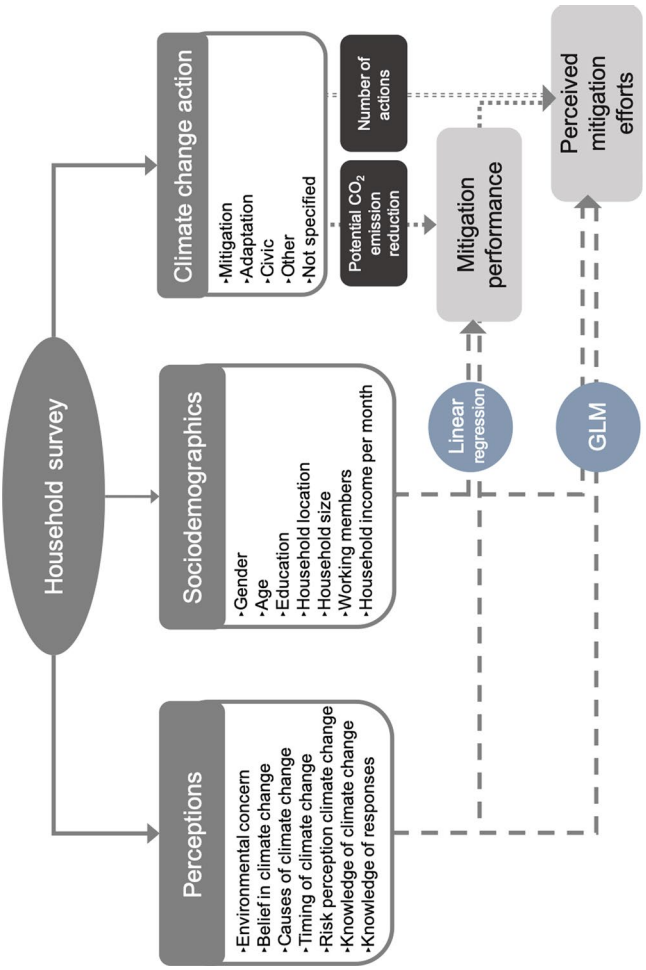

Fig. 1 Framework of research methods

is real through a 5-point scale and to indicate when they believe climate change will take place (either already occurring or in future). Next, we asked whether they considered climate change to be caused by natural causes, human activities, or both. On a 5-point scale ranging from serious consequences to beneficial effects, respondents assessed the effects of climate change on their household. We then asked the respondents to reflect on the level of perceived knowledge of their household about climate change and its effects, followed by the level of perceived knowledge of responses to climate change. Both variables were also measured using a 5-point Likert scale from strongly disagree to strongly agree. Near the end of the survey, respondents were asked through an open question to write down, if any, actions they take in their household toward climate change and its effects.

A range of household sociodemographic data was also obtained comprising household location, size, working members, and monthly income. Household location determined whether the household was located in an urban or rural area. Household income was measured in increments and then recategorized in seven classes. Household size asked about the number of members in the household. Working members recorded the number of actively working members in the household. A few questions were asked about the age (recorded in years), gender (nominal), and education level (ordinal) of the person answering the survey.

For the statistical analyses, the ordinal items with five categories, which included belief in climate change, timing of climate change, perceived climate change risk on household, knowledge of climate change effects, and knowledge of climate change action were treated as numeric values (Robitzsch, 2020). Education and household income, which were also measured through ordinal items were treated in a similar manner.

3.4 Classification of household-level actions on climate change

We first dichotomized the respondents' open-ended responses into whether they reported taking any household-level climate change action or not. Responses left blank were not considered for the rest of the analyses. From those who did report action, we subjected their responses to content analysis to count and classify the types of actions they reported. This resulted in five main categories: mitigation action, adaptation action, civic action, other types of action, and not specified. In the *mitigation action* category, we included actions that aim to reduce GHG emissions; whereas the *adaptation action* category encompassed efforts that aim to prevent or reduce the risks posed by the effects of climate change. The *civic action* category focused not so much on either mitigation or adaptation, but rather on raising awareness of climate change. The *other* category included practices that are perceived, but are effectively neither mitigation or adaptation action; albeit are related to environmental issues. The *not specified* category represented times when the participant mentioned indeed taking action, however, did not go into detail into what they did, for example by writing down: "Yes, we do take action." A full description of each of the categories is shown in Appendix.

The reported actions from the *mitigation* category were classified into effectiveness classes (EC) from least to most effective at reducing CO_2. This classification was based on a range of estimates of emissions reductions of multiple practices from individual and household behaviors identified from literature (Table 1). The practices were ordered from having the least to the highest potential to reduce CO_2 emissions equivalents and were defined as follows: *low-impact* (<0.1 tCO_2e), l*ower moderate* (0.1–0.2 tCO_2e), *moderate* (0.2–0.3 CO_2e), *upper moderate*-(0.3–0.8 tCO_2e), and *high-impact* actions (>0.7 tCO_2e). Actions that were not quantifiable, such as those from the *adaptation*, *civic*, *other*, and *not*

Table 1 Emissions potential reduction of mitigation actions

Emission class (EC)	Mitigation action in estimated CO_2 reduced per year (tons)*
6	High-impact action ($>0.7tCO_2e$)
	Reduce emissions from vehicles
5	Upper moderate (0.3–0.7 tCO_2e)
	Reduce energy use
	Install solar panels
4	Moderate (0.2–0.3 CO_2e)
	Reduce meat consumption
	Reduce consumption
	Reduce gas use
	Purchase energy efficient appliances
	Use public transport
3	Lower moderate (0.10–0.20 tCO_2e)
	Recycle
	Heat or home efficiency
	Reduce water use
2	Low-impact (<0.1 tCO_2e)
	Upgrade lightbulbs
	Plant trees
	Purchase eco-friendly products
1	Potential actions
	Adaptation, civic actions, other, not specified

*Sources: Wynes et al. (2017; 2018)

specified categories were considered as *potential actions* and were left in the analyses. We believe it is important to leave the *potential actions* in the analyses because when properly planned these types of actions can complement mitigation strategies and result in a reduction in GHG emissions (Ayers & Huq, 2009; Thornton & Comberti, 2017). All things considered, the *potential action* category was given the lowest score in order to include these types of actions, but not to give them much weight in the analyses. As a result, each of the classes (potential, low, lower moderate, moderate, upper moderate, and high) yielded an ordinal scale from 1 to 6.

3.5 Statistical analyses

We then examined which factors predicted a household's mitigation performance through linear regression analyses. We calculated a household's mitigation performance by summing the scores of each of their EC (1–6) per reported action, as described above. Based on our proposed conceptual theory, seven perceptions variables and seven sociodemographic variables were evaluated in three different linear regression models: a model only using the perceptions of climate change (perceptions model), a model only comprising the sociodemographic variables (sociodemographic model), and a model that encompassed both the perceptions and the sociodemographic variables (combined model).

Next, we examined a household's perceived mitigation efforts, which refers to the actions a household believes are useful against climate change. A household's mitigation performance on its own is not able to provide an adequate measurement of which types of factors influence a household's perceived mitigation efforts. As such, we proposed the use of an aggregated score, which we defined as the perceived mitigation efforts index (PMEI). PMEI is defined as the mitigation performance multiplied by the number of actions per household:

$$\sum EC{*}A$$

where *EC* describes a household's mitigation performance per action taken and *A* equals the number of reported actions per household. Finally, we used generalized linear model (GLM) fitting a Poisson distribution to evaluate three models: a perceptions model, a sociodemographic model, and a combined model. All statistical analyses were performed with R statistical language (version 3.5.1).

4 Results

4.1 Households' sociodemographic characteristics and how they perceive climate change

The survey resulted in 393 hardcopy and 229 online surveys. From the 622 surveys received, 11% ($n=66$) of responses were left blank when asked to report what climate change actions take place in their household. These responses were left outside of the rest of the analyses. From the 558 valid responses, 61% ($n=384$) of respondents reported taking action or have taken action on climate change in their household. A total of 28% ($n=172$) explicitly stated that they did not take or have not taken action in their household to address climate change.

With regards to the sociodemographic characteristics of valid survey responses ($n=558$), the respondents were made up of 55% women and the average age of those surveyed was 34 (Table 2). The average household size was 3.7. The predominant income per month range was $10,000–20,000 MXN (around 480–960 USD). Concerning the employment situation, the majority of households had at least one working member, and 4% had other sources of income. Among households, 91% were located in an urban area, whereas 6% were located in rural areas. At large, results show that almost half the respondents had at least a bachelor's degree.

As to how respondents perceived climate change, we observed that 92% agreed that climate change is real (Table 3). When asked about the main concerns in their household, 16% of respondents indicated a concern related to climate change or the environment. Regarding the causes of climate change, 52% believed that human activities are the main cause of climate change, 41% believed that both natural and human activities are to blame, whereas 6% believed it is explained by natural causes. Concerning the effects of climate change on their household, a total of 82% of those who responded felt that climate change would have serious consequences for their households. Approximately 58% of those surveyed agreed to some extent that their household has at least some knowledge about climate change and its effects, whereas 53% felt that their household is adequately informed about how to respond to climate change.

Table 2 Summary of household demographics ($n = 558$)

Variable	Classes	n	%
Gender	Male	247	44
	Female	305	55
Age (years)	Average	34	
Education	Less than high school	65	12
	High school	225	41
	Bachelor	189	34
	Graduate	74	13
Settings	Urban	507	91
	Rural	34	6
Income (MXN per month)	Rather not say	74	13
	< $5,000	81	15
	$5000–10,000	89	16
	$10,000–20,000	98	18
	$20,000–30,000	89	16
	$30,000–40,000	55	10
	$40,000–50,000	30	5
	$50,000–80,000	26	5
	> $80,000	14	3
Household size	Average	3.7	
Working members	1	153	28
	2	236	43
	3	84	15
	4	40	7
	≥ 5	11	2
	Other sources of income	23	4

4.2 Reported household-level action, mitigation practices and their impact on climate change

Since respondents could provide more than one action, the numbers of actions reported ($n = 939$) was higher than the number of valid respondents ($n = 558$). As seen in Fig. 2, mitigation actions were mentioned 747 times, adaptation actions were reported a total of 90 times, civic actions were only described eight times, other types of pro-environmental actions were mentioned 72 times, and the "not specified" category comprised 22 responses. For further information refer to Appendix.

Regarding mitigation practices, the most frequently mentioned were related to the categories *reduce energy use* ($n = 187$), *recycle* ($n = 174$) and *reduce water use* ($n = 149$). Other mitigation actions mentioned were from the categories of *reduce waste* ($n = 65$), *reduce emissions from vehicles* ($n = 35$), *heat or cool home efficiently* ($n = 31$). The full list is shown in Fig. 2.

Table 3 Summary of household perceptions of climate change ($n = 558$)

Variable	Survey question	Response category	*n*	%
Environmental concern	What is the main concern in your household?	Did not mention environmental or climate change concerns	469	84
		Did mention environmental or climate change concerns	88	16
Belief in climate change	How much do you agree with "climate change is real"?	Strongly disagree + disagree	4	1
		Neutral	32	6
		Agree	151	27
		Strongly agree	361	65
Causes of climate change	What are the causes of climate change?	Human activities	290	52
		Both	230	41
		Natural causes	32	6
Timing of climate change	When do you think climate change will occur?	Already happening	493	88
		In future	55	10
Perceptions on climate change risk	What will the effects of climate change be on your household?	Beneficial or no effects	60	11
		Serious consequences	294	53
		Very serious consequences	159	29
Knowledge of climate change effects	How much do you agree with the statement: "My household is informed on climate change and its effects"?	Strongly disagree	13	2
		Disagree	75	13
		Neutral	140	25
		Agree	211	38
		Strongly agree	110	20
Knowledge of climate change action	How much do you agree with the statement: "My household is informed on how to respond to climate change"?	Strongly disagree	17	3
		Disagree	53	10
		Neutral	142	25
		Agree	128	23
		Strongly agree	168	30

4.3 Factors that influence a household's mitigation performance

The results of the linear regression analysis showed that both the sociodemographic model and the combined model yielded associations between *age*, *household size,* and *household income per month* with a household's mitigation performance (Table 4). We observed that *age* ($\beta = -3.155$, $p < 0.001$) and *household size* ($\beta = -3.118$ $p < 0.001$) displayed a negative association with a household's mitigation performance in the combined model. Thus, younger-aged household members and smaller-sized households are more likely to have a higher mitigation performance. *Household income per month* presented a positive relationship with a household's mitigation performance ($\beta = 1.647$, $p \leq 0.1$). This means that upper-income households are much more likely to have a higher mitigation performance than lower-income households. In contrast, we did not identify any perceptions significantly associated with a household's mitigation performance in the perceptions model or in the combined model (Table 4).

4.4 Households' perceived mitigation efforts on climate change

The results of GLM analyses showed that climate change perceptions influence a household's perceived mitigation efforts (Table 4). In the perceptions model, five variables were observed to be positively and significantly associated with the PMEI ($p < 0.05$): *environmental concern, causes of climate change, belief in climate change, perceived climate change risk* and *the knowledge of responses to climate change*. Whereas *timing of climate change* and *perceived knowledge of climate change effect*s did not significantly contribute to the PMEI. The combined model presented similar results, with the only exception being that *causes of climate change* lost its significant status: *environmental concern* ($\beta = 2.036$, $p < 0.05$), *belief in climate change* ($\beta = 2.631$, $p \leq 0.01$), *perceived climate change risk* ($\beta = 3.708$, $p = < 0.00$) and *the knowledge of responses to climate change* ($\beta = 3.626$, $p < 0.00$). While *timing of climate change* and *perceived knowledge of climate change effect*s had no significant effects on PMEI. These results imply that efforts to mitigate climate change will likely take place in households whose members are concerned about the environment, believe in climate change, perceive it as a risk for themselves, and believe they have the knowledge on how to respond to climate change.

The results of the sociodemographic model showed that all sociodemographic variables, with the exception of *household location* were significantly related to the PMEI ($p \leq 0.05$). However, in the combined model all seven sociodemographic variables presented significant association with the PMEI. There was a positive significant association between the PMEI and *gender* ($\beta = 4.929$, $p = < 0.00$), *level of education* ($\beta = 4.640$, $p = < 0.00$), *working members* ($\beta = 2.027$, $p = < 0.05$) and *household income per month* ($\beta = 4.563$, $p = < 0.00$). This means that women respondents, higher educated respondents, household with more working members and upper-income households are more likely to put more effort into mitigating climate change. In contrast, a negative significant association was observed between PMEI and *age* ($\beta = -7.485$, $p = < 0.00$), *household location* ($\beta = -2.153$, $p = < 0.00$), and *household size* ($\beta = -9.569$, $p = < 0.00$). Thus, younger-aged respondents, smaller-sized households and households located in urban areas are more likely to channel their efforts into mitigating climate change.

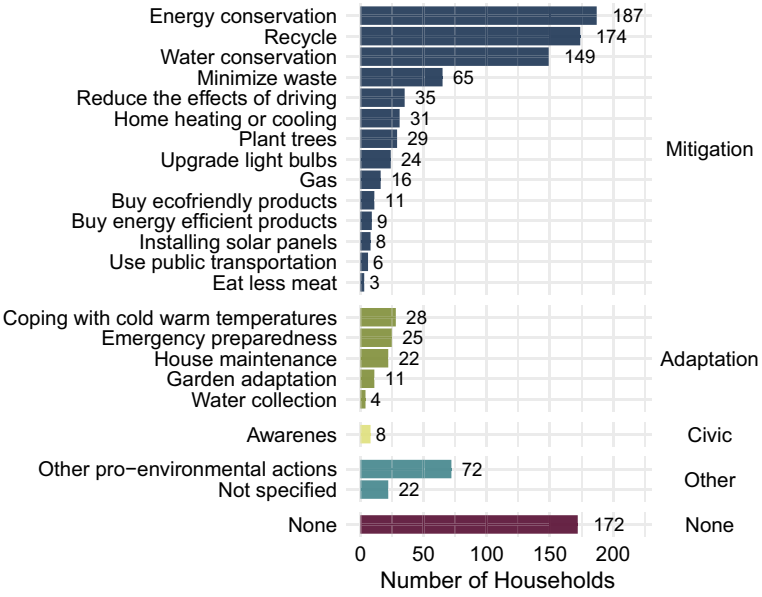

Fig. 2 Classification of household actions

5 Discussion

Our analysis revealed that the majority of households reported taking action on climate change, with many households adopting more than one practice. We observed that the focus of a household's actions was mainly on mitigation practices. When taking a closer look into the different types of mitigation actions, many of the reported actions were the ones which are be relatively easy to perform, such as switching off lights and unplugging electrical devices. However, these types of actions usually have a small-to-moderate effect on the reduction of CO_2 emissions and consequently have a limited impact on climate change mitigation (Wynes & Nicholas, 2017). We also observed that mitigation practices that have a higher impact on climate change, were less mentioned by the respondents. This may be due to the fact that higher impact actions require more effort and sacrifices to produce (Dubois et al., 2019; Sköld et al., 2018). Building from these findings, we observe that households have the potential to make a larger contribution to emissions reduction, therefore communications are needed to motivate households to adopt more high-impact actions to keep track of national and global emissions targets set in place.

Adaptation and civic actions were described by respondents with less frequency than mitigation practices. This may be explained by the fact that climate policies and debate have thus far predominantly been characterized by addressing its causes, rather than its effects (Sharifi, 2021). Furthermore, we observed that a substantial number of households are reporting not taking any type of action on climate change. These findings indicate that more attention should be paid to encourage households to take diverse actions to reduce the adverse effects of climate change.

With respect to a household's mitigation performance, we provide evidence that their mitigation performances are dependent on their sociodemographic characteristics. Our results support the contentions of others (e.g., Abrahamse & Steg, 2011; Lee et al., 2015) that mitigation actions are more likely to take place among younger-aged household

Table 4 Linear regression to predict the influences of perceptions and sociodemographic characteristics on a household's mitigation performance

	Perceptions model				Sociodemographic model				Combined model			
	Coef	S.E	Std. β coeff	p	Coef	S.E	Std. β coeff	p	Coef	S.E	Std. β coeff	p
Perception variables												
Environmental concern	0.439	0.571	0.770	0.44					0.330	0.574	0.574	0.57
Belief in climate change	0.608	0.501	1.213	0.23					0.245	0.492	0.498	0.62
Causes of climate change	0.274	0.452	0.605	0.55					0.030	0.437	0.069	0.94
Timing of climate change												
(already occurring/future)	−0.064	0.883	−0.072	0.94					−0.093	0.860	−0.108	0.91
Perceived climate change risk on household	0.312	0.402	0.777	0.44					0.346	0.387	0.893	0.37
Knowledge on climate change effects	0.087	0.298	0.293	0.77					0.148	0.289	0.512	0.61
Knowledge of responses to climate change	0.281	0.246	1.142	0.25					0.238	0.243	0.979	0.33
Sociodemographic variables												
Gender (male/female)					0.315	0.453	0.696	0.49	0.393	0.476	0.825	0.41
Age					−2.213	0.649	−3.408	$<0.00^{***}$	−2.156	0.683	−3.155	$<0.00^{***}$
Level of Education					0.391	0.329	1.187	0.24	0.373	0.336	1.109	0.27
Household location (urban/rural)					−0.654	1.064	−0.614	0.54	−0.706	1.084	−0.651	0.52
Household size					−0.695	0.204	−3.405	$<0.00^{***}$	−0.648	0.208	−3.118	$<0.00^{***}$
Working members					0.103	0.147	0.700	0.49	0.136	0.152	0.896	0.37
Household income per month					0.312	0.186	1.680	0.09†	0.312	0.189	1.647	0.10†

Significant at $\dagger p \leq 0.10$; $*p < 0.05$; $**p < 0.01$; $***p < 0.001$

members, smaller-sized households and upper-income households. We did not observe a significant link between the perceptions of climate change and a household's mitigation performance.

Our findings indicate that all seven sociodemographic variables in our analysis are significantly associated with household's perceived mitigation effects. Our study found that women respondents and highly educated individuals are more likely to put effort into mitigating climate change. Similar results have been found in earlier observations, which showed that women and highly educated individuals are more willing to adopt actions (Brody et al., 2008; De Silva & Pownall, 2014; Wamsler et al., 2012; Weber, 2016). The results reveal that efforts to mitigate climate change decrease with age, which seems to be consistent with other research that has found that older individuals are less willing to adopt mitigation practices, compared to younger individuals (Semenza et al., 2008; Weber, 2016).

Another finding was that urban households were more likely to take mitigation efforts, which contrasts to previous research indicating that urban households consume more energy than their rural counterparts (Heinonen & Junnila, 2014). It seems possible that these results are due to the small number of rural households in our study, as such it would be useful to examine a larger group of rural households. Household size presents a strong effect, albeit negatively, on a household's mitigation efforts. Somewhat similar findings have been observed when analyzing a household's energy use, as households larger in size tend to use more resources than households smaller in size (Abrahamse & Steg, 2011). Furthermore, we observed that the greater the number of working members in the household, the less likely mitigation efforts will take place. This may be explained by the fact that working members are spending less time at home, which in turn makes it harder for them to adopt action (González-Hernández et al., 2019b). In addition, the importance of household income in shaping a household's mitigation efforts concurs with previous findings (Lee et al., 2015). It appears that higher income households have the choice and assets to perform more effective mitigation practices (i.e., by investing in solar panels). These findings confirm that sociodemographic characteristics are key factors that drive effective mitigation actions at the household level. For that reason, it is important to strengthen a household's sociodemographic profile, which would require support from the government, the private sector, or community-based organizations.

Our results proved that, even though sociodemographic characteristics are strong predictors of a household's perceived mitigation performance, climate change perceptions also play an important role in the explanation of a household's perceived mitigation efforts. This highlights the importance of incorporating insights from the social and behavioral sciences, since many policies and debate focus on economic and technological incentives (Clayton et al., 2015; Nielsen et al., 2020).

Even though less than 20% of respondents referenced an environmental concern or climate change issue, we found that being concerned about issues related to the environment or climate change is important as it presented a positive and significant link with a household's mitigation efforts. These results present similarities to previous research that suggest that environmental concern increases the willingness to address climate change (Hornsey et al., 2016; O'Connor et al., 1999). The great majority of respondents in this study (over 90%) believe to some extent in climate change and over half consider that climate change presents a risk to their household. Moreover, we found that these two factors, believing in climate change and perceiving it as a risk on the household, had a positive and significant impact on a household's mitigation efforts. This indicates that there is a general awareness on the issue and that it is believed to be a serious problem, reflecting previous research (González-Hernández et al., 2019a). It may be that because the Nuevo Leon population has already been exposed to a wide range of extreme weather

events (Gobierno del Estado de Nuevo León, 2010; Sisto & Ramírez-Orozco, 2015), the respondents already perceive climate change as a high risk on their household. In this context, we believe that risk communications can play a crucial role in increasing a household's mitigation performance.

In general, households who assigned themselves as having high levels of knowledge of the responses to climate change were more likely to express having taken efforts to mitigate climate change. These findings provide supportive evidence that knowledge is a crucial predictor of the adoption of mitigation actions (Akrofi et al., 2019; Bord et al., 2000; Shi et al., 2015). However, it becomes apparent that different types of knowledge play certain roles in explaining mitigation action, as only the perceived knowledge of responses to climate change was found to have a positive association with a household's perceived mitigation efforts, whereas perceived knowledge of the effects was not significant. These results are consistent with previous findings (Abrahamse et al., 2007; Shi et al., 2015). Accordingly, we strongly recommend that future interventions facilitate clear information to households on how to take effective action (Table 5).

Despite our contributions, there are inevitable limitations in our study. First, these results do not imply that household action is only dependent on the aforementioned perceptions and sociodemographic characteristics. Other research has shown that experience, media exposure, political affiliations, among other factors are correlated to the willingness to engage with climate change. As such, future work should incorporate other factors into their research design. Second, a self-reported questionnaire was used to determine a household's mitigation performance, which may differ from observed measures of actual behavior. However, research has shown that individuals have a good grasp on recalling their behavior (Jones & Tanner, 2017; Short et al., 2009), therefore we believe we can rely on the self-reported measures. Third, we did not examine actual CO_2 levels emitted by households, only the potential emissions that may be reduced, which were based on lists of developed countries. However, these findings may help us understand how CO_2 emissions from the household sector in Latin America can be reduced, which is an issue that needs to be urgently addressed. Fourth, certain groups are over- or underrepresented, as we find that in comparison to the general population of Nuevo Leon, a disproportionately high share of respondents have obtained a higher education degree, which makes these findings limited in generalizability.

6 Conclusion

We can conclude that our study provides an important opportunity to advance the understanding of how households perceive climate change, and how their perceptions in turn shape their mitigation action on climate change. We focused on households in Latin America, specifically in the state of Nuevo Leon in Mexico, a scale and place which have greatly unattended in the climate literature thus far.

Our results emphasize the importance of distinguishing between a household's mitigation performances and their perceived mitigation efforts. In doing so, we identified the pivotal role of sociodemographic characteristics on a household's mitigation performance, while finding that perceptions, alongside sociodemographic characteristics, influence a household's mitigation efforts. Although households are making efforts to mitigate climate change, achieving a higher mitigation performance is difficult for a household to achieve without access to resources, such as education and financial support. These findings have

Table 5 Results of the GLM to predict household's perceived mitigation efforts (PMEI) by influences of perceptions and sociodemographic characteristics

	Perceptions model				Sociodemographic model				Combined model			
	Coef	S.E	Std. β coeff	p	Coef	S.E	Std. β coeff	p	Coef	S.E	Std. β coeff	p
Perception variables												
Environmental concern	0.091	0.040	2.251	0.0^{***}					0.086	0.042	2.036	0.04^{*}
Belief in climate change	0.175	0.040	4.429	0.00^{***}					0.108	0.041	2.631	0.01^{**}
Causes of climate change	0.103	0.032	3.195	0.00^{***}					0.045	0.033	1.370	0.17
Timing of climate change (already occurring/future)	−0.015	0.068	−0.216	0.83					0.037	0.070	0.528	0.60
Perceived climate change risk on household	0.114	0.029	3.951	$<0.00^{***}$					0.108	0.029	3.708	$<0.00^{***}$
Knowledge on climate change effects	0.011	0.022	0.500	0.62					0.032	0.022	1.419	0.16
Knowledge of responses to climate change	0.087	0.018	4.850	$<0.00^{***}$					0.069	0.019	3.626	$<0.00^{***}$
Sociodemographic variables												
Gender (male/female)					0.169	0.035	4.840	$<0.00^{***}$	0.179	0.036	4.929	$<0.00^{***}$
Age					−0.429	0.053	−8.064	$<0.00^{***}$	−0.409	0.055	−7.485	$<0.00^{***}$
Level of Education					0.127	0.026	4.884	$<0.00^{***}$	0.121	0.026	4.640	$<0.00^{***}$
Household location (urban/rural)					−0.198	0.097	−2.053	0.04^{*}	−0.209	0.097	−2.153	0.03^{*}
Household size					−0.164	0.015	−10.828	$<0.00^{***}$	−0.146	0.015	−9.569	$<0.00^{***}$
Working members					0.015	0.011	1.404	0.16	0.022	0.011	2.027	0.04^{*}
Household income per month					0.064	0.014	4.504	$<0.00^{***}$	0.065	0.014	4.563	$<0.00^{***}$

Significant at $^{*}p<0.05$; $^{**}p\leq0.01$; $^{***}p<0.001$

implications for policy making and the communication of climate change in Mexico, as household-level mitigation can be an option to achieve substantial reductions in future emission pathways with proper support.

Appendix: Classification of actions

Type of action	Subtype	*n*	Description
Mitigation	Reduce energy use	187	Comprised efforts to reduce the consumption of energy. This was often perceived to be achieved by decreasing the amount of service used, for example turning off a light switch, unplugging electric appliances and hanging clothes to dry.
	Recycle	144	Included practices devoted to recycling materials such as plastic, paper and aluminum.
	Reduce water use	149	Described activities such as keeping showers short, fixing a dripping tap, turning the tap off while brushing teeth.
	Reduce consumption	65	Represented conscious efforts to reduce the consumption of resources and reduce the amount of waste disposed in landfills. This was indicated for example by buying less food to minimize food waste, buying less clothes throughout the year, carrying a water bottle, and taking bags to the supermarket to reduce the number of plastic bags being used.
	Reduce emissions from vehicles	34	Covered practices that were believed to reduce emissions produced by vehicles by carpooling, decreasing driving speed, and driving a fuel-efficient vehicle.
	Heat or cool home efficiently	31	Described practices that reduce the number of appliances needed in a home to make it feel comfortable, for instance by insulating walls and windows
	Plant trees	29	Described planting trees to remove CO_2 from the atmosphere.
	Upgrade light bulbs	24	Consisted of replacing standard light bulbs with incandescent light bulbs.
	Reduce gas use	16	Covered activities to reduce the consumption of natural gas in the household, for example by cutting the time of use of stove and space heating and taking a bath or washing clothes in cold water.
	Purchase eco-friendly products	11	Described buying environmentally friendly alternatives of common products.

Type of action	Subtype	*n*	Description
	Purchase energy efficient appliance	9	Respondents indicated purchasing energy efficient appliances like washing machines and fridges.
	Install solar panels	8	Respondents indicated installing solar panels in their households as a renewable energy source.
	Use public transport	6	Respondents described using public transport (metro or bus).
	Reduce meat consumption	3	Respondents reported actively reducing their family's overall intake of meat and ranged from reducing the times they eat meat in a week/month or going vegetarian.
Adaptation	Coping with extreme temperatures	28	Covered practices to stay cool in warm weather or to stay warm in cold temperatures. For the warm temperatures, examples included using fans or air conditioning, wearing adequate clothes for comfort, and drinking plenty of liquids to stay hydrated. As for the cold temperatures, respondents mentioned using heaters and multiple layers of clothes.
	Emergency preparedness	25	Encompassed practices related to preparing for or dealing with natural disasters. Actions included were having non-perishable food on hand, having a first-aid kit, staying informed, collecting water, and purchasing household insurance.
	Household maintenance	22	Covered home repairs activities such as clearing shrubs, inspecting roofs for damages, and waterproofing to prevent leakages or damage, especially in preparation for the rainy season.
	Adapting gardens	11	Considered practices where respondents described adapting their gardens to climate change, for example by using plants native to the region and using plants that require less water.
Civic actions	–	8	Considered practices where respondents indicated becoming an activist, spreading awareness on the issue, and educating children about climate change and its effects.
Other types of environmental actions	–	72	Included practices that are perceived but are effectively neither mitigation nor adaptation action; albeit are related to environmental issues. This category included practices such as suspending the use of hairsprays, the proper disposal of batteries, and avoiding littering the streets
Not specified	–	22	Represented times when the participant mentioned indeed taking action, however, did not go into detail into what they did, for example by writing down: "Yes, we do take action."

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