Puerto Rican farmers' psychological awareness of climate change, and adaptation perceptions
after Hurricane Maria

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Abstract

Strengthening farmers' adaptive capacity is important for decreasing their vulnerability to natural hazards in this changing climate, and for safeguarding local food systems. One key step in strengthening adaptive capacity is understanding the relationship between farmers' experience with natural hazards and their perceptions of climate change, and its role in farmers' decision making around climate change adaptation. Here we explore Puerto Rican farmers' psychological distance of climate change after experiencing category 4 Hurricane Maria, in order to intersect the roles of experience, perceptions, and motivation for farmers' decision-making around climate change adaptation. Farmers throughout Puerto Rico were surveyed by Extension Services' agents (n = 405, 87% response rate) in 2018, eight months after Hurricane Maria. A structural equation model was used to evaluate how reported experience with past events and direct damages by Hurricane Maria related to farmers' psychological distance of climate change, and the association of these variables to farmers' motivation to adapt to climate change. We found that farmers psychological distance of climate change is both near and far, since they show a broad awareness to climate change's impacts both locally and globally in different dimensions (temporal, geographical, and social). Reported experience and direct damages by the hurricane were not linked to their psychological distance of climate change, and these did not relate to their motivation to adapt. These results suggest that using extreme events as a driver for climate belief and action may no longer be relevant, especially in a context where there is a high level of climate change belief and continued threat of extreme events. Thus, broadening analysis beyond individual perceptions as drivers of climate adaptation to how structural dynamics are linked to adaptive capacity could provide better understanding. This study is among the first to study the

role of climate change experience and perceptions on farmers' climate change adaption after an extreme weather event in an island-archipelago setting.

Introduction

Farmers across the globe are at the forefront of climate change-related impacts, and are thus important actors in safeguarding our food systems [1,2]. Natural hazards, such as hurricanes and droughts, have made farming more difficult due to an increased frequency, and, in many cases, negatively affected farmers' livelihoods [3,4]. This is notably true of those who farm in the tropics, especially farmers in island states and territories, who are more vulnerable to the impacts of natural hazards given islands' unique characteristics, such as small territories and economies, dependence on imports, and disproportionate exposure to sea-level rise and extreme weather events [5–8].

Exposure, sensitivity, and adaptive capacity are three main determinants of vulnerability to natural hazards [9,10]. Farmers in small island states and territories, most of which are located in the tropics, farm in regions that are often disproportionately exposed and sensitive to natural hazards [10–12]. Exposure refers to islands being situated in regions prone to extreme weather events (e.g. Atlantic's 'Hurricane Belt'), and sensitivity relates to the degree to which such hazards change physical systems (e.g. farms) [9,12–14]. As such, strengthening adaptive capacity —defined as the set of abilities and resources individuals and populations have to anticipate, withstand, cope with, and recover from a hazard, and the potential or abilities they have to modify the system in order to be more resistant to impacts [11,15,16]—is key in decreasing vulnerability to natural hazards. This paper utilizes the psychological distance of

climate change as its framework to explore Puerto Rican farmers' experience with Hurricane Maria, and their perceptions of climate change adaptation to understand potential drivers and barriers for adopting behaviors that strengthen adaptive capacity. This framework, which has been primarily used in non-island settings, allow us to intersect experience, perceptions, and their association to adaptation [17–19]. Focusing on Puerto Rico fills a current gap on food systems research in small island states and territories focused on exposure and sensitivity to natural hazards. Furthermore, it gives us the ability to generate novel information for scholarship focused on Puerto Rico as well.

Adaptive capacity is complex, and involves many diverse and interrelated determinants [11,12]. In the case of farmers, the adoption of new adaptation technologies and practices, as well as the access to institutional resources and networks of support, are important for strengthening adaptive capacity [3,4,20–22]. Research in the Caribbean and Central America—areas exposed to Atlantic hurricanes—have shown that farm and farmers' characteristics, as well as their access to diverse markets and sources of support are important in reducing vulnerability to natural hazards [3,23–26]. Nevertheless, given the heterogeneity of islands' sociopolitical systems, context-specific research is important to better understand adaptive capacity [12,27]. This is evident in the Caribbean, given the region's neocolonial dynamics, where many islands' sovereignty resides on continental countries [28–30]. This is the case of Puerto Rico as an Unincorporated Territory of the United States. Studying Puerto Rican farmers' climate change adaptation could reflect broader sociopolitical structures' roles in the process of strengthening adaptive capacity.

Understanding the role of perceptions and beliefs as determinants of adaptive capacity is key to determining effective strategies [11,31]. As such, it is important to understand to what extent

beliefs and perceptions play a role in farmers' decision-making processes around climate change adaptation. Climate change adaptation occurs at different scales [20,32], and it is contextualized, highlighting that understanding the degree to which cognitive beliefs impact individuals' decision-making and willingness to act is important in assessing adaptive capacity [13,17,31,33]. While existing research demonstrates a link between climate perceptions and beliefs, and climate change adaptation amongst the general public [34], and farmers [17], there are varied results [33,35,36]. Importantly, most research focused on perceptions about climate and the role of cognitive beliefs in climate adaptation is from high-income countries [33]. There is limited evidence of this topic from small island developing states and territories, whose unique exposure and sensitivity to climate change and extreme events may influence how residents perceive climate change and their adaptive capacity.

To contribute to fill the current gaps in the literature, we examine survey results from 405 Puerto Rican farmers following Hurricane Maria, a category four hurricane, which impacted Puerto Rico in September 2017. We examine farmers' perceptions and beliefs about climate change, its potential links to their experience with the hurricane, as well as the extent to which these perceptions and beliefs influence their motivation to adapt to climate change using the theoretical framework of the psychological distance of climate change—simply put, how near or far people perceive climate change to be from themselves in various contexts [19,34,37,38]. This work can expand our understanding of the role of cognitive beliefs and perceived psychological distance for prompting adaptation behaviors amongst individuals beyond high-income and continental countries.

Theoretical framework

Construal Level Theory states that humans imagine the past and future through abstract constructs, since we are embedded in the here and now [37,38]. Psychological distance, a component of the aforementioned theory, is a subjective experience that uses the self as a reference point [37,38]. Psychological distance is measured in four components: temporal, social, geographical, and uncertainty of the distance or issue. The more distant, we perceive an issue or event to be across these dimensions, the more we rely on abstract constructs to make sense of it. In contrast, things we perceive as closer are more concrete. For example, as an event gets closer in time (e.g. conference presentation), the awareness of the dynamics involved become more concrete (e.g. transportation to the venue, nervousness, time management, and other variables). Thus, Construal Level Theory explains that we use mental constructs to build understanding of what transcends the here and now.

Applied in the realm of climate change communication and adaptation research, the psychological distance of climate change [19] refers to how near or far people (e.g. farmers) perceive climate change to be from themselves across the four dimensions: temporal (when climate change will or is occurring), geographical (where it happens), social (to whom it happens), and the hypothetical or uncertainty dimension (certainty of whether it occurs or not). Theoretically, this posits that individuals who are psychologically close to climate change are prone to perceive higher risks to hazards, and a greater motivation to act to adapt or mitigate climate change. Nonetheless, this assumption has not been consistent in research [35,36].

Research on the psychological distance of climate change

The aforementioned hypothesis has been the basis for many existing studies on the psychological distance of climate change (e.g. understanding how psychological distance affects the propensity for individuals to take action to mitigate or adapt to climate change). The current body of research focused on the psychological distance of climate change is both experimental [39,40], and observational [34,41]. More specifically, scholarship has explored (1) the interrelatedness of the different dimensions, (2) the role of experiencing extreme weather events on individuals' psychological distance of climate change, and (3) the degree to which psychological distance of climate change affects behavior. Overall, evidence indicates inconsistent outcomes related to the psychological distance of climate change and its capacity to prompt action, as well as the understanding of how experiences with extreme events affects psychological distance, and the relatedness of the four dimensions varies [36]. These results may suggest that context matters; a natural hazard (e.g. hurricane), for example, can be experienced and perceived differently depending on context (e.g. sociodemographic characteristics, beliefs, adaptive capacity) [9,10]. Some studies support that the four dimensions of the psychological distance of climate change are interrelated. Moreover, studies suggest that being psychologically close impacts behavior. For example, Spence and colleagues (2011, 2012) demonstrated that experience with floods was linked to individuals' perceptions of climate change in the United Kingdom. Their studies showed that the four dimensions of the psychological distance of climate change were interrelated, and that reduced psychological distance related to promptness to climate change mitigation actions [19,34]. Similarly, but based in the United States, Singh et al. (2017) found

that the four dimensions were interrelated, and that those psychologically close expressed more support towards climate change adaptation policies. In that study, the temporal and uncertainty dimensions, by their own, did not have significant effect on policy support; however, those that expressed higher uncertainty over climate change and were socially distant, expressed less support towards policies [41]. Furthermore, research has shown that the dimensions, though often interrelated, depending on context, manifest differently [36]. Focused on New Zealand's farmers, Niles et al. (2015) applied the psychological distance of climate change framework in combination with Liebig's Law of the Minimum to assess adaptation behaviors, finding that decreasing psychological distance may prompt action from farmers. Farmers who perceived climate change impacts as geographically close, were more likely to feel more concern for climate change and motivation to adapt [17].

Research has also described how experience with extreme weather events relates to being psychologically close [17,34,36,41]. Acharibasam and Anuga (2018) found that farmers who had experienced extreme events were socially and geographically close, and that psychological distance mediated emotional regulation among farmers—the mental processes through which individuals decide how emotions are expressed and experienced [42]. Nevertheless, a recent meta-analysis performed by van Valkengoed and colleagues (2019) found that experience had small-to-moderate effects on climate change adaptation. Moreover, Larcom (2019) found that experience with a heatwave amongst the general population did not elicit adaptation behaviors in the United Kingdom, but did elevate concern [43]. Similarly, Albright and Crow (2019) found that direct flooding experience was not a predictor of concern for climate change amongst Colorado, United States, residents [44]. These more recent studies suggest that there may be a threshold of individual exposure to natural hazards and their potential to catalyze behavioral

change; indeed, as the rate of extreme events increases, it could be probable that such events may saturate in people's experiences and become "more normal".

The aforementioned studies also highlight the importance of context, but also bring attention to how psychological distance of climate change research is limited in its generalizability [35].

Furthermore, most research on the matter have used data on reported experience, and not on direct experience (e.g. material impacts such as damage). Zanoocco et al. (2018) performed case studies of residents whose communities were directly impacted by extreme events to understand the relationship between experience of extreme event and views of climate change. Applying Construal Level Theory perspectives of psychological distance, they found that geographical proximity to the event did not align with climate change views, but reported harm did [45]. This quote from Demski et al. (2017), as cited by Zanoocco et al. (2018), underscores the aforementioned: "Self-reported measures of experience that include: direct physical experience and material impacts of an event, well-defined in terms of personal effects and damage, are less susceptible to biased reporting, providing the best proxy available for objective experience" (p. 152) [45] .

This paper attempts to fill several gaps in the research by assessing the psychological distance of climate change amongst Puerto Rican farmers after experiencing Hurricane Maria. First, we will assess Puerto Rican farmers' psychological distance of climate change after experiencing an extreme weather event. To the best of our understanding, there is no study that looks at the relationship between actual experience with extreme events and its relationship with the psychological distance of climate change in small island developing states and territories. Second, we will assess the extent to which the experience with Maria (both reported experience with other extreme events, and direct damages caused by Hurricane Maria) relate to

psychological distance of climate change. As stated above, most research has looked on reported experience. Third, in order to increase our understanding on the degree to which cognitive beliefs play a role in climate change adaptation and therefore relate to individual adaptive capacity, we examine the relationship of psychological distance of climate change to farmers' adaptation perceptions.

The present study

This study focuses in Puerto Rico, an unincorporated territory of the United States that imports around 85% of the food it consumes, and that is going through a social-economic crisis because of its billion dollar debt and political situation [46–49]. In response to Puerto Rico's debt crisis in 2016, the United States' government created a Fiscal Management and Oversight Board that imposed austerity measures, and made visible Puerto Rico's lack of political agency as a territory of the United States [28,29]. Simultaneous and previous to this change, the agricultural sector in Puerto Rico was experiencing positive changes, such as a rise in new farmers, production increases, and increased awareness of food security [23,49–51]. Such agricultural gains were important since Puerto Rico, like the broader Caribbean, was experiencing a steady decline in farms since the 1990's due to trade liberalization, globalization, and other external forces [5,24,51,52]. Nevertheless, such gains were erased when both Hurricane Irma and Hurricane Maria, two of the strongest in the Atlantic's history, hit Puerto Rico in September 2017. The local Department of Agriculture (2018) reported that both hurricanes caused \$2 billion in total losses, with the majority of losses from Maria (\$228 million in production losses, and \$1.8

billion in agricultural infrastructure losses). Such damages significantly impacted Puerto Rican agriculture, which, according to the USDA, is comprised of many small-scale farmers with an average farm size of 59 acres (approximately 23 hectares) [53], who focus mostly on domestic markets, and who have an average annual income of less than \$20,000 [52]. Focusing this study on Puerto Rican farmers after experiencing a major storm, not only allow us to advance our understanding of the psychological distance of climate change, but provides us the opportunity to produce important applied knowledge around strengthening adaptive capacity to safeguard local agriculture and food access [17,18].

Objective, research questions, and hypotheses

Our study focuses on understanding how the psychological distance of climate change manifests in an island-archipelago setting, amongst a vulnerable population (farmers). Specifically, we intend to assess (1) the psychological distance of climate change amongst farmers in Puerto Rico, an unincorporated territory of the United States and Caribbean non-UN member Small Island Developing State after an extreme-weather event, (2) the extent to which psychological distance of climate change is related to experience and to (3) other cognitive beliefs such as motivation to adapt, perceived capacity (self-efficacy or perceived instrumentality), and perceived vulnerability. We ask: 1) How do farm and farmer characteristics, and direct experiences with extreme events i.e. reported damages) relate to the psychological distance of climate change? And, 2) in light of experiencing an extreme event, what is the role of psychological distance of climate change in motivating Puerto Rican farmers to adapt to climate

change? Following research on the psychological distance of climate change, we hypothesize that farmers' psychological distance of climate change will be driven by their experience (e.g. reported damages) with Hurricane Maria (H1). Furthermore, we predict that psychological distance of climate change will be related to perceived capacity, perceived vulnerability, and motivation to adapt (H2). Fig 1 shows our hypothesized model.

Fig 1. Hypothesized model. Farm and farmer characteristics' variables included as controls.

Methodology

Data gathering

Previous studies of on-farm management and climate change perceptions, and on the psychological distance of climate change [17,22,41,54] informed the development of a survey instrument, which was contextualized to Puerto Rico and the general objectives of the main

study. This study was carried out in collaboration with the Extension Service of the University of Puerto Rico at Mayagüez. Thus, feedback from Extension partners were also included in the survey's development. The survey was translated into Spanish, and piloted in February 2018 with a pool of Puerto Rican farmers (n = 31), and was shared amongst Extension agricultural agents—enumerators of the survey.

Surveys (n = 440) were randomly administered to farmers, according to the five regions the Extension Service divides Puerto Rico: Arecibo, Caguas, Mayagüez, Ponce, and San Juan. Survey deployment was based on Extension Services' recommendations to access a wide range of farmers, and because agricultural agents had an established presence. Surveys were administered between May and July 2018 in person. A total of 405 surveys were completed, resulting in an 87% response rate based on the American Association for Public Opinion calculator.

Assessing the psychological distance of climate change.

Eight questions were used to assess the four dimensions of the psychological distance of climate change (temporal, social, geographical, and uncertainty) (Table 1). The temporal dimension was assessed with one item, while the social and geographical dimensions were assessed with two each. Questions assessing the social and geographical dimensions were intended to separately assess local and distant concerns. Uncertainty was assessed through three statements. Variables were reversed where needed, in order to analyze ascending levels of the psychological distance of climate change. All items were included as a scale variable for the psychological distance of

climate change—Cronbach’s alpha = 0.74, which suggests good internal validity (55). “Strongly agree” and “agree” answers for dimensions’ statements were combined as “psychologically far” for ease of interpretation. The same was done for “psychologically close” with opposite answers. “Neutral” was kept separate.

Structural equation model

A structural equation model was built to explore the extent to which psychological distance of climate change relates to farmers’ experience with Hurricane Maria, and their motivation to adapt to climate change. Structural equation models allow quantitative analysis of the direct, indirect, and mediated interactions between variables, and the incorporation of latent constructs [56–58]. Fig 1 shows the hypothesized model. Two variables assessed experience: “reported past experience” and “reported hurricane damages”. Variables for perceived capacity and vulnerability were included. Those variables, alongside psychological distance of climate change, were included to grasp an understanding of the role of cognitive beliefs in the context of adaptive capacity. The structural equation model was deployed in Stata 15.1, using Maximum Likelihood with bootstrapping (1000 iterations) to control for Type I errors and increase statistical power [57,59]. The following Goodness-of-fit criteria were used: Chi-square (χ^2), Standardized Root Mean Square Residual (SRMR), Comparative fit index (CFI), Root mean square error of approximation (RMSEA) [58].

306 **Table 1: Survey variables used in this study.**

Category	Variable	Question/Statement	Measure
Climate change perceptions	Global climate	The global climate is changing.	5-point Likert scale—from strongly disagree to strongly agree
	Global temperature	Average global temperatures are increasing.	5-point Likert scale
	Anthropogenic causes	Human activities such as fossil fuel combustions are an important cause of climate change.	5-point Likert scale
Psychological Distance of Climate Change			
Temporal Dimension	Today	The effects of climate change are already being felt today.	5-point Likert scale
Social dimension	Farmers	Farmers like me are not likely to be affected negatively by climate change.	5-point Likert scale

Category	Variable	Question/Statement	Measure
	General public	People who aren't farmers are likely to be affected negatively by climate change.	5-point Likert scale
Geographical dimension	Local agriculture	Climate change does not presents more risk than benefits to agriculture in Puerto Rico.	5-point Likert scale
	Global agriculture	Climate change presents more risks than benefits to agriculture globally.	5-point Likert scale
Uncertainty dimension	Impact uncertainty	There is scientific uncertainty about the potential impacts of climate change on agriculture.	5-point Likert scale
	Cause uncertainty	There is scientific uncertainty about the causes of climate change.	5-point Likert scale
	Hurricane uncertainty	I am uncertain that the occurrence of strong hurricanes in the Atlantic is related to climate change.	5-point Likert scale

Category	Variable	Question/Statement	Measure
Cognitive beliefs	Motivation to adapt	I feel motivated to change my agricultural practices to prepare for future extreme weather events like Hurricane Maria.	5-point Likert scale
	Perceived self-capacity	I feel that I have the capacity to change my agricultural practices to prepare for future potential extreme weather events like Hurricane Maria.	5-point Likert scale
	Perceived vulnerability	I believe my farm is vulnerable to future extreme weather events like Hurricane Maria.	5-point Likert scale
Experience with extreme weather events	Reported experience	I have faced similar extreme weather events like Hurricane Maria in the past ten years.	5-point Likert scale
	Reported damages	How would you describe the damages, if any, caused by Hurricane Maria to your farm?	5-point Likert—from no damages to total loss
Farmer and farm characteristics*	Age	In which year you were born?	Continuous

Category	Variable	Question/Statement	Measure
	Bonafide ^a	Do you participate in the bonafide program of the Puerto Rico Department of Agriculture?	Binary—yes or no
	Education level	What is the highest level of education you have completed?	Ordinal—from elementary school to PhD degree
	Farm size	How many <i>cuerdas</i> ¹ of terrain do you manage in your farm?	Continuous
	Gender	What is your gender?	Binary—female or male
	Household income	What is your approximate household income, including all far and off-farm income?	Ordinal—from Less than \$20,000 to more than \$90,000

^aThe bonafide^a program of the Puerto Rico Department of Agriculture provides farmers with agricultural incentives, and benefits then with various tax exemptions.

Results

Participants and the impact of Hurricane María

Farmers had an average age of 54, and farmed an average of 58 *cuerdas* (approximately 56 acres). The great majority of respondents had attended college (67%) (Table 2). Table 3 contrasts farmers' demographics and farm characteristics with those reported in Puerto Rico's 2017 Agricultural Census [53]. Respondents generally were similar to average census statistics, with the exception of having higher rates of formal higher education and somewhat higher percentage of income from farming. It is important to note that the recent census is not comparable to the previous one done in 2012 [53]. Moreover the 2017 census, performed in 2018, had a lower response rate, and USDA reported some difficulty in performing the census given post Hurricane Maria conditions [53,60]. Farmer respondents were distributed throughout Puerto Rico with 15% in the Arecibo region, 22% in the Caguas region, 19% in the Mayagüez region, 25% in the Ponce region, and 22% in the San Juan region. (Percentages do not sum 100% because some farms extend beyond one municipality that border with another). The majority of farmers experienced damages from Hurricane María; 42.6% reported total loss of their farms, while 45.6% reported significant damages (Fig 2). The majority of farmers (55.1%) disagreed and strongly disagreed (hereafter disagreed) that they had faced similar events to Hurricane Maria.

333 **Table 2: Mean statistics of control variables.**

Variable	Scale	Frequency (%)	Mean $\pm$ SD	n
Age	Continuous	-	54.0 $\pm$ 13.5	391
Bonafide	Yes	210 (52.8)	-	398
	No	188 (47.2)		
Education level	Elementary School	21 (5.2)	-	401
	Junior High School	13 (3.2)		
	Some High School	15 (3.7)		
	High School Diploma	82 (20.5)		
	Some College	42 (10.5)		
	Technical Degree	25 (6.2)		
	Associate Degree	41 (10.2)		
	Bachelor's Degree	109 (27.2)		
	Master's Degree	46 (11.5)		
	PhD	7 (1.8)		
Farm size	Continuous	-	58.1 $\pm$ 98.5	383
Gender	Female	55 (14.0)	-	395
	Male	340 (86.0)		
Household income	Less than \$20,000	138 (36.4)	-	379
	\$20,000 - \$40,999	125 (33.0)		
	\$41,000 - \$60,999	52 (13.7)		
	\$61,000 - \$80,999	36 (9.5)		

Variable	Scale	Frequency (%)	Mean $\pm$ SD	n
	More than \$90,000	28 (7.4)		

Table 3: Demographic variables of our study’s surveyed farmers in comparison to USDA 2017 Agricultural Census data for Puerto Rico.

Category	Present study	USDA 2017 Census data
Average farm size	58.1 <i>cuerdas</i> (majority farmed > 20 <i>cuerdas</i>)	59.3 <i>cuerdas</i> (majority farmed > 20 <i>cuerdas</i>)
Years farming	Majority > 10 years	Majority > 10 years
Average age	54	61
Gender	Great majority is male	Great majority is male
Education	Majority reported High School Diploma or more	Majority reported High School Diploma or less
Income from farming	> 50%	< 50%
Household income	Majority reported < \$20,000	Majority reported < \$20,000

Note: Data from the census is for farms’ principal operators. In Puerto Rico, this does not necessarily means that they are the sole owner of the farm. Neither the census or the local Department of Agriculture detail the number of Puerto Rican farmers who participate in the bonafide program; however, in a media report in 2019 (61), according to the Secretary of Agriculture, Carlos Flores, among Puerto Rico’s 17,000 farmers, 4,000 are part of the bonafide program; 24% in comparison to the 53% in our study. It is also important to note that the Secretary’s comment contrast with the number of farmers provided by the USDA census, which was conducted in 2018, and had a low response rate (53).

Fig 2: Farmer's past experience with events similar to Hurricane Maria (top) and reported hurricane damage (bottom).

Fig 3 shows results for farmers' perceptions around climate change and adaptation. An overwhelming majority of Puerto Rican farmers believe that the global climate is changing (86% strongly agree and agree; hereafter agreed), and that it has anthropogenic causes (91.4%). As well, 84.4% of Puerto Rican farmers agreed that they feel motivated to change their agricultural practices to better prepare for future extreme events. Though farmers perceive their farms to be vulnerable to future extreme weather events (93.5%), they understand themselves capable to adapt to climate change (79.0%).

Fig 3: Climate change perceptions and behavioral motivations among Puerto Rican farmers.

Puerto Rican farmers' psychological distance of climate change

We found that Puerto Rican farmers understand climate change as both a local and global phenomenon, being both psychologically close and psychologically distant across various measures. While we find evidence across all four dimensions of psychological distance for perceived “closeness”, we also find that farmers demonstrate awareness for climate change effects beyond Puerto Rico in all dimensions (psychologically far) (Fig 4).

Fig 4: Results for variables of the psychological distance of climate change. To ease understanding, answers were collapsed: “agree” and “strongly agreed” are shown as “psychologically far”, and “disagree” and “strongly disagree” are shown as “psychologically close”.

382 Respondents demonstrated a temporally close relationship to climate change with the majority
383 disagreeing (95.1%) that the effects of climate change are not being felt today. Regarding the
384 geographical dimension, Puerto Rican farmers perceive that climate change will both negatively
385 impact agriculture at both local and global scales (Fig 4). The majority disagreed (89.4%) that
386 climate change does not presents more risk than benefits to agriculture in Puerto Rico (e.g.
387 Puerto Rico's agriculture is at risk). Farmers also agreed (90.0%) with the statement focused on
388 the global scale, "Climate change presents more risks than benefits to agriculture globally". At
389 the social dimension, farmers expressed that climate change will both affect farmers (people like
390 them), and the general public (people not like them). The majority (92%) agreed that farmers like
391 them will likely be affected negatively by climate change (psychologically close); 89% agreed
392 that people who aren't farmers will also likely to be affected negatively by climate change
393 (psychologically far).

394 We found the greatest variability in the uncertainty dimensions of psychological distance of
395 climate change. Thirty nine percent (39%) of respondents agreed that there is scientific
396 uncertainty about the potential impacts of climate change on agriculture, 14% were neutral,
397 while 47% disagreed with the statement. The majority (60%) disagreed that there is scientific
398 uncertainty about the causes of climate change; 16% were neutral, and 24% agreed with the
399 statement. Regarding the statement related to feeling uncertain about the relationship between
400 climate change and occurrence of strong hurricanes in the Atlantic, 25% agreed, 13% were
401 neutral, and 63% disagreed. Furthermore, respondents overwhelmingly agreed that human
402 activities are an important cause of climate change 3.2% disagreed, 5.4% were neutral, and
403 91.4% agreed).

Structural equation model

The structural equation model (S1 table, S2 table, S3 table, and fig 5) demonstrates that four of the seven hypothesized pathways were statistically significant ($p < 0.05$); S1 table shows results for all variables, including control variables. Goodness-of-fit criteria suggests the model is acceptable: RMSEA = 0.059, CFI = 0.861, SRMR = 0.058. Furthermore, the model showed that for motivation to adapt, our main dependent variable, $R^2 = 0.410$.

Figure 5: Structural equation model results for the hypothesized model. Thick arrows show significance ($p < 0.05$). Standardize coefficients are also shown (b). The model controls for farmer and farm characteristics, including age, gender, household income, farm size, education, and bonafide. Goodness-of-fit criteria suggest an overall good fit: RMSEA = 0.059, CFI = 0.861, SRMR = 0.058. R^2 for motivation to adapt was 0.410. Results of indirect effects and total effects are in S2 table and S3 table, respectively.

The model shows that direct experience (reported hurricane damages) and reported past experience with extreme events are not significantly predictive of the psychological distance of

climate change amongst Puerto Rican farmers, a rejection of H1. Moreover, none of the control variables (age, gender, farm size, bonafide, education, and income) were linked to the psychological distance of climate change (S1 table). However, both perceived capacity and vulnerability are significantly negatively related to the psychological distance of climate change ($p < 0.05$) (H2). In other words, farmers that perceived climate change as more distant were more likely to report lower rates of perceived capacity ($b = -0.140$, $p = 0.017$), and were less likely to report higher rates of perceiving their farms as vulnerable to future extreme weather events ($b = -0.164$, $p = 0.011$). We find no significant direct relationship between psychological distance of climate change and motivation to adapt; however, both perceived capacity ($b = 0.578$, $p = 0.000$) and perceived vulnerability ($b = 0.256$, $p = 0.000$) were positively linked to motivation to adapt. We find no significant relationships between control variables and past experience with extreme events (S1 Table). Regarding reported hurricane damage, farmers who are participants of the bonafide program of the Puerto Rico Department of Agriculture were more likely ($b = 0.134$, $p = 0.034$) to report higher rates of damages to their farms due to Hurricane Maria. Furthermore, education level was negatively linked to reported damages by Hurricane Maria ($b = -0.177$, $p = 0.002$), meaning that, increasing levels of formal education were linked to reporting lower rates of damages.

Discussion

This study examined Puerto Rican farmer's psychological distance of climate change, and its relationship to reported damages following Hurricane Maria and experience with past extreme

weather events, in order to better understand potential drivers and barriers to strengthen adaptive capacity. We expand the current literature to utilize psychological distance of climate change beyond continental and high-income countries, and to understand how farmers' psychological distance of climate change relates to other cognitive beliefs in a vulnerable island-archipelago setting. We found that Puerto Rican farmers recognize climate change as a local and global issue (fig 4). Hence, they are neither psychologically close nor far, but psychologically aware of climate change's impacts across multiple time frames, geographies, and social constructs. We also found that neither reported experience with extreme weather events, nor the direct damages effected by Maria were linked to farmers' psychological distance of climate change. Furthermore, farmers overwhelmingly perceived themselves self-capable and motivated to adapt to climate change. Nevertheless, motivation was not directly linked to their psychological distance of climate change.

Studies have used psychological distance to climate change to better understand whether this framing can prompt individual mitigation or adaptation actions. Moreover, the trend in the literature is that reduced psychological distance—mainly through experience with extreme weather events—will correlate with action [17–19,35,36,39,41]. Our results provide a different picture—we found that Puerto Rican farmers cannot be characterized as psychologically close or psychologically distant to climate change, but are psychologically aware of the impacts related to climate change at different scales. Furthermore, we showed that direct experience with extreme weather events may not be the principal link to reduce psychological distance to climate change (Fig 5). As well, psychological distance did not have a direct effect on motivation to adapt, but it did have an indirect effect on it through perceived self-capacity and vulnerability (S2 table and S3 table).

These results show that Puerto Rican farmers recognize climate change as being both near and far, which indicates that in the Caribbean context, where climate change is recognized as happening [62], a psychological distance framing may not be relevant. Our results on overall climate change perceptions, and farmers psychological distance of climate change, align with a study by the Puerto Rican Department of Natural Resources that state that Puerto Ricans believe in, are aware of, and are concerned about climate change [63]. Puerto Rican farmers, overwhelming, understand that the climate is changing. This awareness of climate change as a threat is strong in Latin America and the Caribbean [62], where farmers and non-farmers are aware of the impacts related to climate change [64–66]. Surveyed farmers understand that climate change is happening now (temporal), that it will affect farmers and non-farmers (social), and that it will affect local and global agriculture (geographical). This could suggest that when a threshold for climate change belief is passed, individuals recognize it as a problem that goes beyond their own self-interest. Furthermore, it could be that there is an understanding of the interactions (e.g. feedback loops) and interconnectedness amongst scales in and beyond a place, and indicates that there may be a saturation point for the psychological distance of climate change framing. In other words, when enough people recognize the problem, both locally and globally, it may longer catalyze action. This should be further studied.

Our respondents were heavily affected by Hurricane María; 42.6% reported total loss, while 45.6% reported significant losses. Given the absolute prevalence of damage across our population, these outcomes may relate to the fact that we find no relationship of reported damage to psychological distance. As such, these results suggest that there may also be a threshold for level of damage and frequency of extreme events that may then fail to impact psychological distance. When a group of people consistently face extreme events, especially ones that are

wholly devastating, they could no longer think about such events as being close and driving climate change perceptions.

Our structural equation model showed that farmers who are bonafide participants in the Puerto Rico Department of Agriculture (52.8%) were more likely to report higher rates of damages ($R^2 = .050$). To participate in that program, 50% or more of farmers' income must come from agriculture. Farmers who are bonafide are exempted from some state and municipal taxes, and have access to other agricultural incentives. In our study, those that were bonafide had an average farm size of 85 *cuerdas*, and 76% of their income came from agriculture. This could point to the relationship of structural determinants' (e.g. policy structures) to climate change's effects on farmers. We did not have variables looking at type of agricultural incentives, or access to governmental, community-based resources or assets; future studies could look at how policy structures, coupled with federal laws and Puerto Rico's context as a US territory, impact farmers' adaptive capacity. Furthermore, another line of research could focus on the extent to which dependence on Puerto Rico Department of Agriculture incentives relate to on-farm management and farm systems. This is timely given that Puerto Rico's recent incentives code, Law 60 of 2019, changed various regulations that have been in place for over 30 years [67]. Furthermore, given that farmers overwhelmingly reported feeling self-capable and motivated to adapt—variables that have been shown positively linked to decision-making around climate change adaptation [33]—future research and practitioners could focus on actual adaptation of agricultural practices (beyond intentions and cognitive factors), and those drivers and barriers at broader levels (e.g. community, institutional, regional, national) to strengthen adaptive capacity. The structural equation model (Fig 5) shows that perceiving climate change to be psychologically distant is linked to reporting lower rates of perceived self-capacity and perceived

vulnerability to extreme weather events. This aligns with the psychological distance of climate change assumptions on how one's awareness relates to our promptness to act to mitigate or adapt to climate change. Nevertheless, farmers' psychological distance of climate change (and other variables in the model) does not explain much of the variability in both perceived self-capacity ($R^2 = 0.019$) and vulnerability ($R^2 = 0.026$). This further suggests that in areas constantly affected by extreme weather events, other variables beyond the ones explored here may be more relevant in explaining and fostering adaptation. Farmers in Latin America, the Caribbean, and Africa have expressed concern for climate change at different scales, but such perceptions are poorly linked to actual climate change adaptation [42,65,66,68]. Puerto Rican farmers overwhelmingly feel motivated to adapt to climate change, and that is positively linked to perceived self-capacity and perceived vulnerability. Nonetheless, taking into account the damage caused by Hurricane María and its aftermath, as well as the poor subsequent recovery efforts, our findings suggest that to strengthen farmers' adaptive capacity we must look at other determinants beyond the individual level.

In small island developing states and territories, where climate change impacts are already being felt to a greater extent than in high-income continental countries, cognitive beliefs nor psychological distance to climate change may be strong components of adaptive capacity.

Farmers in Latin America [65,66], and the Caribbean [68,69] have been noted to lack institutional structures of support. In Puerto Rico, Perfecto and colleagues (2019) found that social capital and support networks were pivotal for Puerto Rican coffee farmers' recovery after Hurricane María, and that their agroecological practices, such as agroforestry, and other management styles were not sufficient for farms to be resilient and resistant within the catastrophic context of Hurricane Maria [70]. Hurricane María affected all of Puerto Rico,

causing 2,975 deaths [71], and decimated the archipelago's agriculture. As such, we argue that reasons and circumstances beyond the self (cognitive beliefs) deserve more attention to better understand Puerto Rican farmers' decision-making, and increase their adaptive capacity. Taken together, these results show that the psychological distance of climate change may not be an appropriate framework to understand cognitive beliefs' role in adaptive capacity, especially in an island setting, but potentially increasingly as climate change beliefs become saturated towards acknowledgement of the issue. We understand we are reaching a point where climate change-related conversations and perceptions are widely accepted. Future research could further generate understanding on that. Farmers in island and disadvantaged areas, who are at the forefront of constant climate change-related impacts, might have already gotten to a point where experiencing climate change is not the most important driver of concern nor motivation to adapt to climate change. Caribbean farmers face institutional barriers to better adapt to climate change [6,23,24,49,51], and are localized in a region that still today is subject to colonial relationships and power dynamics that increase their vulnerability to natural hazards [28–30]. It is important to understand the degree to which psychological awareness (not distance) of climate change relates to other cognitive beliefs and decision-making, but this cannot be done through ignoring the circumstances in which farmers are embedded. Climate change adaptation cannot be reduced to something that is dependent on the individual because then we could be contributing on the assertion that the genesis of vulnerability lies on the individual [72]. Vulnerability to natural hazards is a systemic issue, and farmers adaptation to climate change, as a decision-making process, is subject to structural interactions that cannot be overlooked.

Limitations

We note some limitations in this study. First, to the best of our knowledge, there is no previous study looking at Puerto Rican or Caribbean farmers' psychological distance of climate change before and after an extreme weather event. We lack information on the issue before Hurricane Maria or other events. This limits our ability to understand if their psychological awareness is driven by experience. Nonetheless, Extension Service's internal data before Hurricane Maria showed that farmers were aware of climate change's impacts at different scales. Second, farmers surveyed showed higher percentage of income from farming than that reported in census data [53], and we had an overrepresentation of bonafide farmers. Nevertheless, most of the demographic factors of surveyed farmers here align with those of the latest agricultural census for Puerto Rico (table 3). Furthermore, given that most farmers surveyed for this study receive information from, or are linked to the Extension Service, this might suggest that they have higher access to information and resources, which may affect their understanding of climate change and other related issues. As research in island systems on this topic continues to grow, there is opportunity for broader engagement with farmers, including those not directly integrated with Cooperative Extension.

Conclusion

Farmers' adaptive capacity must be strengthened to decrease their vulnerability to natural hazards. In order to do so, cognitive beliefs must be considered given that climate change adaptation—a set of decisions at the individual level—is one key action to increase adaptive

capacity. Here we assessed Puerto Rican farmers' climate change adaptation perceptions after Hurricane Maria to understand the role of experience with extreme events on the psychological distance of climate change, and its relation to motivation to adapt. We found that Puerto Rican farmers are psychologically aware of climate change impacts at different levels—local to global—and that such awareness is not driven by their experience with extreme events. These findings contrast with research in continental and high-income countries that seeks to reduce psychological distance to climate change amongst individuals to prompt mitigation and adaptation actions. Furthermore, we expand literature cemented on the assumption that being psychologically close enacts change, and that such psychological distance is driven by experience. We showed that neither reported experience with extreme events, nor farmers' actual experienced damages by Hurricane Maria were determinants of farmers psychological distance of climate change. Furthermore, here we demonstrate that context matters, and that the adaptive capacity of individuals embedded in vulnerable contexts—farmers in an island disproportionately exposed and sensitive to climate change's impacts—is not highly dependable on individual actions. We suggest that variables, such as institutional frameworks of support, must be better understood. Furthermore, research on the psychological distance of climate change should consider that we might be arriving to a threshold where climate change perceptions are not significant drivers of change. Hence, we suggest that understanding peoples' "psychological awareness of climate change" and its relation to context could provide a more nuance comprehension of climate change adaptation than focusing on how being "close" or "far" enacts change.

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Supporting information

S1 Table. Structural equation model structural results for our hypothesized model.

Standardized coefficients (β), bootstrap standard error (SE), and significance level (p) are included.

S1 Table: Structural equation model structural results for our hypothesized model.

Standardized coefficients (β) of main and control variables, bootstrap standard error (SE), and significance level are included.

Relationship	<i>b</i>	SE	<i>p</i> =
Age → Reported experience	0.106	0.054	0.051
Farm size → Reported experience	0.007	0.059	0.901
Gender → Reported experience	0.017	0.057	0.771
Education → Reported experience	-0.103	0.062	0.094
Household income → Reported experience	0.069	0.056	0.219
Bonafide → Reported experience	-0.107	0.060	0.076
Age → Reported damages	-0.055	0.054	0.302
Farm size → Reported damages	-0.014	0.061	0.821
Gender → Reported damages	-0.011	0.052	0.839
Education → Reported damages	-0.177	0.059	0.002
Household income → Reported damages	-0.075	0.057	0.189
Bonafide → Reported damages	0.134	0.064	0.034
Reported experience → Psychological distance of climate change	0.027	0.058	0.636
Reported damages → Psychological distance of climate change	-0.020	0.060	0.742
Psychological distance of climate change → Perceived self-capacity	-0.140	0.059	0.017
Psychological distance of climate change → Perceived vulnerability	-0.164	0.065	0.011

Perceived self-capacity → Motivation to adapt	0.578	0.067	0.000
Psychological distance of climate change → Motivation to adapt	-0.023	0.045	0.603
Perceived vulnerability → Motivation to adapt	0.256	0.073	0.000

S2 Table. Structural equation model structural results for indirect effects of our

hypothesized model. Standardized coefficients (β), bootstrap standard error (SE), and

significance level (p) are included.

Relationship	<i>b</i>	SE	<i>p</i> =
Age → Psychological distance of climate change	0.000	0.000	0.549
Farm size → Psychological distance of climate change	0.000	0.000	0.826
Gender → Psychological distance of climate change	0.001	0.004	0.741
Education → Psychological distance of climate change	0.000	0.004	0.957
Household income → Psychological distance of climate change	0.002	0.003	0.565
Bonafide → Psychological distance of climate change	-0.007	0.012	0.546
Reported experience → Perceived self-capacity	-0.003	0.006	0.628
Reported damages → Perceived self-capacity	0.004	0.013	0.738
Age → Perceived self-capacity	-0.000	0.000	0.531
Farm size → Perceived self-capacity	-0.000	0.000	0.531
Gender → Perceived self-capacity	-0.000	0.001	0.741
Education → Perceived self-capacity	-0.000	0.001	0.957
Household income → Perceived self-capacity	-0.000	0.001	0.548
Bonafide → Perceived self-capacity	0.002	0.003	0.526

Relationship	<i>b</i>	SE	<i>p</i> =
Reported experience → Perceived vulnerability	-0.002	0.005	0.639
Reported damages → Perceived vulnerability	0.004	0.012	0.737
Age → Perceived vulnerability	-0.000	0.000	0.545
Farm size → Perceived vulnerability	-0.000	0.000	0.545
Gender → Perceived vulnerability	-0.000	0.001	0.741
Education → Perceived vulnerability	-0.000	0.001	0.957
Household income → Perceived vulnerability	-0.000	0.000	0.555
Bonafide → Perceived vulnerability	0.002	0.003	0.534
Reported experience → Motivation to adapt	-0.002	0.005	0.635
Reported damages → Motivation to adapt	0.004	0.012	0.737
Age → Motivation to adapt	-0.000	0.000	0.540
Farm size → Motivation to adapt	-0.000	0.000	0.824
Gender → Motivation to adapt	-0.000	0.001	0.741
Education → Motivation to adapt	-0.000	0.001	0.957
Household income → Motivation to adapt	-0.000	0.001	0.552
Bonafide → Motivation to adapt	0.002	0.003	0.532
Psychological distance of climate change → Motivation to adapt	-0.180	0.072	0.013

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835 **S3 Table. Structural equation model structural results for total effects of our hypothesized**
836 **model.** Standardized coefficients (β), bootstrap standard error (SE), and significance level (p) are
837 included.

Relationship	<i>b</i>	SE	<i>p</i> =
Age → Reported experience	0.012	0.006	0.051
Farm size → Reported experience	0.000	0.001	0.901
Gender → Reported experience	0.074	0.255	0.771
Education → Reported experience	-0.067	0.040	0.095
Household income → Reported experience	0.085	0.069	0.219
Bonafide → Reported experience	-0.332	0.187	0.077
Age → Reported damages	-0.003	0.003	0.302
Farm size → Reported damages	-0.000	0.000	0.820
Gender → Reported damages	-0.021	0.104	0.839
Education → Reported damages	-0.052	0.018	0.003
Household income → Reported damages	-0.042	0.032	0.190
Bonafide → Reported damages	0.188	0.088	0.033
Reported experience → Psychological distance of climate change	0.011	0.025	0.636
Reported damages → Psychological distance of climate change	-0.019	0.057	0.742
Age → Psychological distance of climate change	0.000	0.000	0.549
Farm size → Psychological distance of climate change	0.000	0.000	0.826
Gender → Psychological distance of climate change	0.001	0.004	0.741
Education → Psychological distance of climate change	0.000	0.004	0.957

Relationship	<i>b</i>	SE	<i>p</i> =
Household income → Psychological distance of climate change	0.002	0.003	0.565
Bonafide → Psychological distance of climate change	-0.007	0.012	0.546
Reported experience → Perceived self-capacity	-0.003	0.006	0.628
Reported damages → Perceived self-capacity	0.004	0.013	0.738
Psychological distance of climate change → Perceived self-capacity	-0.232	0.101	0.022
Age → Perceived self-capacity	-0.000	0.000	0.531
Farm size → Perceived self-capacity	-0.000	0.000	0.824
Gender → Perceived self-capacity	-0.000	0.001	0.741
Education → Perceived self-capacity	-0.000	0.001	0.957
Household income → Perceived self-capacity	-0.000	0.001	0.548
Bonafide → Perceived self-capacity	0.002	0.003	0.526
Reported experience → Perceived vulnerability	-0.002	0.005	0.639
Reported damages → Perceived vulnerability	0.004	0.012	0.737
Psychological distance of climate change → Perceived vulnerability	-0.211	0.084	0.012
Age → Perceived vulnerability	-0.000	0.000	0.545
Farm size → Perceived vulnerability	-0.000	0.000	0.825
Gender → Perceived vulnerability	-0.000	0.001	0.741
Education → Perceived vulnerability	-0.000	0.001	0.957
Household income → Perceived vulnerability	-0.000	0.001	0.555
Bonafide → Perceived vulnerability	0.002	0.003	0.534
Reported experience → Motivation to adapt	-0.002	0.005	0.635

Relationship	<i>b</i>	SE	<i>p</i> =
Reported damages → Motivation to adapt	0.004	0.012	0.737
Psychological distance of climate change → Motivation to adapt	-0.214	0.091	0.018
Perceived self-capacity → Motivation to adapt	0.511	0.074	0.000
Perceived vulnerability → Motivation to adapt	0.291	0.084	0.001
Age → Motivation to adapt	-0.000	0.000	0.540
Farm size → Motivation to adapt	-0.000	0.000	0.824
Gender → Motivation to adapt	-0.000	0.001	0.741
Education → Motivation to adapt	-0.000	0.001	0.957
Household income → Motivation to adapt	-0.000	0.001	0.552
Bonafide → Motivation to adapt	0.002	0.003	0.532

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