



Puerto Rican Farmers' Obstacles Toward Recovery and Adaptation Strategies After Hurricane Maria: A Mixed-Methods Approach to Understanding Adaptive Capacity

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Farmers across the globe are experiencing compounding shocks that make evident the need to better understand potential drivers and barriers to strengthen adaptive capacity. This is especially true in the context of a disaster, where a disruption in the natural and built environment hinders livelihood strategies and exposes the underlying dynamics that perpetuate vulnerability to natural hazards. As such, the interconnections of structural and individual attributes must be considered when evaluating adaptive capacity. This paper uses a convergent mixed-methods approach to assess Puerto Rican farmers' actual and intended adoption of adaptation practices, in light of the obstacles they faced toward recovery after 2017's category four Hurricane Maria, to contribute to better understanding adaptive capacity. This study uses data from 405 farmers across Puerto Rico (87% response rate), surveyed 8 months after Maria by agricultural agents of the Extension Service of the University of Puerto Rico at Mayagüez. Quantitative data was assessed through negative binomial regressions (actual adoption) and generalized linear models (intended adoption), while qualitative data (reported obstacles) were analyzed through thematic analysis. This study found that almost half of farmers adopted an adaptation practice after Maria, and that in many cases, broader structures, such as systems of governance, farmers' social networks, and infrastructure, affect adaptive capacity more than individual perceptions of capacity. Future adaptation strategies and interventions, especially in the context of disaster, should consider the extent to which structural factors hinder individuals' ability to prepare for, respond, and recover from the impacts of these shocks. Our results show that there might be opportunity to enact new systems in light of catastrophic events, but this does not solely depend on individual actions. The mixed-methods approach used can inform future studies in better assessing adaptive capacity from a standpoint that incorporates individual and structural components.

Keywords: climate change, islands and archipelagos, food systems, farmers' decision-making, disaster and climate risk reduction

INTRODUCTION

Farmers across the globe are facing multiple compounding shocks, such as devastating hurricanes and severe droughts. These impacts are likely to become more frequent or intense in a changing climate (IPCC, 2014; Zhang et al., 2020), and thus it is increasingly important to understand the barriers and drivers to strengthen farmers' adaptive capacity—the available resources or assets to mitigate, prepare for, counter, and recover from impacts (Brooks and Adger, 2005; Gallopín, 2006; López-Marrero, 2010; Wisner et al., 2012; Cinner et al., 2018; Barnes et al., 2020; Phillips et al., 2020). Since farmers are embedded within social-ecological systems, it is important to recognize that adaptive capacity is comprised of various determinants that may extend beyond the individual to the institutional or systemic levels: political regulations, poverty, vulnerability to extreme events, and others (Reed et al., 2013; Shinbrot et al., 2019; Doran et al., 2020). Hence, when evaluating adaptive capacity, its determinants must be considered across scales (Adger, 2006; López-Marrero, 2010).

This assertion is especially true in the context of a disaster, where a disruption of the built and natural environments, as well as to day-to-day livelihood activities, reflects what resources and abilities people have available to manage the situation (Quarantelli, 1992; Wisner et al., 2004, 2012; Adger, 2006; Clay et al., 2018). Disasters are social-historical products that highlight people's vulnerability to natural hazards, which to a great extent is driven by people's exposure and sensitivity to those shocks, as well as their adaptive capacity (Brooks and Adger, 2005; Gallopín, 2006; Smit and Wandel, 2006; Ribot, 2014). Decreasing exposure and sensitivity to natural hazards—the rate of being subject to impacts, and the degree of change due to impacts, respectively—is difficult in places that due to geophysical and geographical conditions experience a higher prevalence of natural hazards (Gallopín, 2006; Smit and Wandel, 2006; López-Marrero, 2010; López-Marrero and Wisner, 2012). Thus, focusing on strengthening adaptive capacity is a crucial step in decreasing vulnerability.

As such, to better understand the adaptive capacity of farmers in a disaster context from both the individual and societal level, this paper uses a mixed-methods convergent design (Creswell and Plano-Clark, 2018) to examine the intended and actual adoption of adaptation practices and strategies of Puerto Rican farmers in the aftermath of Hurricane Maria, in light of the obstacles they faced to post-hurricane recovery. Hurricane Maria was the strongest category four hurricane to hit Puerto Rico in 89 years, and the first one to make a direct impact in 19 years (Castro Rivera et al., 2018; Bang et al., 2019). The hurricane made landfall in September 20, 2017, and it triggered a disaster that made visible how social and political dynamics in Puerto Rico exacerbate vulnerability to natural hazards (Moulton and Machado, 2019; Bonilla, 2020). Almost 3,000 deaths are attributed to the lack of access to electricity, water, healthcare, and other basic needs after Maria's passage (Santos-Burgoa et al., 2018; Bonilla, 2020).

Prior to Maria, agriculture in Puerto Rico was experiencing advancements in production and its recognition as an important sector in a place where around 85% of food is imported (Comas-Pagán, 2014; Irizarry-Ruiz, 2016; Álvarez-Berríos et al.,

2018). Hurricane Maria changed this trajectory; the Puerto Rico Department of Agriculture reported that 80% of agricultural infrastructure and production were lost due to the winds and rains of Hurricane Maria, which made landfall just 2 weeks after category five Hurricane Irma impacted the territory. Both storms were part of the 2017 Atlantic hurricane season, which surpassed meteorological standards and was the costliest season in record (Bang et al., 2019). Both hurricanes affected many islands in the Caribbean, making evident that improving adaptive capacity among island systems is key to furthering adaptation.

Island states and territories are known to face additional vulnerabilities to climate change because of characteristics, such as exposure to sea-level rise and constant shocks, coupled with their small economies and territories, isolation, and dependence on imports (Graham, 2012; IPCC, 2014; Scobie, 2018; Kim and Bui, 2019). The 2017 hurricane season made evident those underlying conditions, including Caribbean governance structures that reflect neocolonial relationships (Bang et al., 2019; Borges-Méndez and Caron, 2019; Bonilla, 2020), and perpetuate the vulnerability of social-ecological systems (Quarantelli, 1992; Ribot, 2014). Given the importance of local agriculture for island food security in the context of response and recovery from shocks, understanding farmers' adaptation to climate change in light of a disaster—the set of decisions and processes that allow them to secure agricultural production while safeguarding their livelihoods (Brooks and Adger, 2005; Jezeer et al., 2019; Shinbrot et al., 2019)—may provide us with a clearer picture of the interplay between individual and structural factors in adaptive capacity.

The adoption of agricultural practices and management strategies, such as farm diversification of products and energy sources, amongst others, allow farmers to offset impacts in a changing climate and are key to adaptations that can support livelihood outcomes such as food security (Caswell et al., 2016; Akhter and Erenstein, 2017; Niles and Salerno, 2018; Fernandez and Méndez, 2019; Anderzén et al., 2020). These actions can allow farming systems to either return to the prior state before the event (i.e., “bounce back”), or to transform into new systems that are better suited to changing climatic circumstances (i.e., “bounce forward”) (Payne et al., 2021). Either option, whether incremental (e.g., adopting cover crops) or transformative (e.g., changing from monoculture to diverse farming) is dependent on farmers' adaptive capacity—resources or assets farmers have access to, which play a key role in such decisions (Holt-Giménez, 2002; Caswell et al., 2016; Barnes et al., 2020; Wilson et al., 2020).

Adaptive capacity is multidimensional, and its determinants span from individual attributes, such as gender and financial assets, to material and governmental resources (Table 1). Approaching climate change adaptation by acknowledging adaptive capacity as a multidimensional component provides a framework to define what resources are needed to counter and recover from shocks in a given context (López-Marrero, 2010; López-Marrero and Yarnal, 2010; López-Marrero and Wisner, 2012). Understanding the role of how different capacities affect Puerto Rican farmers' actual and intended adoption of agricultural practices and management strategies after Maria, and their obstacles for recovery, can enable a more systematic assessment of the barriers and drivers to strengthen farmers'

TABLE 1 | Determinants of adaptive capacity as delineated by López-Marrero and Yarnal (2010).

Determinant of adaptive capacity	Description
Agricultural resources	Resources available to carry out current or post-hazard agricultural production (e.g., seeds, agricultural inputs, agricultural machinery, etc.).
Economic resources	The economic, and financial resources (e.g., monetary) farmers have (e.g., earned income, savings, credit, pensions, transfers from the state, insurance, etc.), and that are available (e.g., monetary aids) for adaptation or recovery.
Human resources	The skills (e.g., training), knowledge (e.g., formal education), and awareness (e.g., of adaptation options, the nature and evolution of hazards), experience, ability to work, and good health (e.g., food secured) that enable farmers to pursue adaptive strategies before hazards, and afterwards for recovery.
Institutions	The availability of critical institutions that promote and support adaptive strategies amongst farmers, along with the way they operate and are structured (e.g., transparent decision-making, institutional requirement).
Material resources and technology	The infrastructure (e.g., transport, drainage systems, housing, utilities) and the production equipment and materials available for adaptation and recovery; along with technological systems (e.g., communication systems, protective structures) available for adaptation and recovery.
Natural resources	The resources present in the physical environment (e.g., raw materials, biodiversity) and/or the services they provide (e.g., pollination) that are useful for adaptation.
Perception/cognition	The different views of nature people have, perceptions of hazards (e.g., likelihood of occurrence and potential damages), perceived effectiveness of past adaptive actions, perceived alternatives and perceived capacity to undertake them or act upon hazard exposure.
Political resources	Power, right, development of political capabilities or claims farmers can make on the state, institutions, or those more powerful than they are (e.g., unions, lobbying, access to legislature, etc.).
Social resources	The social resources (e.g., informal-horizontal networks, social mobilization, collective actions, and relations of trust, reciprocity, and exchange) upon which farmers can draw for adaptation and recovery.

Language was modified to focus on farmers (e.g., instead of using the word people); "agricultural resources" was added, and "food security" was added to "human resources." Table content is from López-Marrero (2010).

adaptive capacity, further providing us a better picture of how broader structures, beyond individual attributes, effect action (Rodríguez-Cruz and Niles, 2021).

Farmers' decision-making around climate change adaptation has been studied from various disciplinary perspectives (Prokopy et al., 2019; Ranjan et al., 2019; Foguesatto et al., 2020), with mixed conclusions on the extent to which adaptive capacities impact adaptation outcomes. For example, in contrast to studies in low and middle-income countries (e.g., Kassie et al., 2015), adoption of new behaviors among mainland US farmers is not highly dependent on natural and agricultural resources (e.g., land tenure, farm size, etc.) (Prokopy et al., 2019). Furthermore, social, governmental, and institutional resources, such as belonging to farmer networks, subsidies, and regulations, influence the degree to which farmers adopt new practices. For example, access to information sources through social or institutional networks of support that increase farmers' knowledge on what strategies benefit them, and how to carry them out, has been shown to be positive for farmers' adaptation (Dang et al., 2018; Bagagnan et al., 2019; Luu et al., 2019; Raza et al., 2019). Studies have also shown that psychological factors, such as perceived vulnerability and capacity, for example, play a role in farmers' adaptation decisions. Wang et al. (2019) found that perceived vulnerability and severity had an effect on Chinese farmer's intention to adopt pro-environmental practices, and Niles et al. (2016) found that perceived capacity linked to both intended and actual adoption of new practices among New Zealand farmers.

Though these studies have shown the importance of integrating different aspects of adaptive capacity, there is still a gap in triangulating the role of individual and structural aspects of adaptation behaviors (Foguesatto et al., 2020; Wilson

et al., 2020; Rodríguez-Cruz and Niles, 2021). Much of the literature has either focused on the intention to adopt or actual adoption, and has not considered both within the same population (Niles et al., 2016). Furthermore, adaptation literature has been limited in intersecting individual (intrapersonal) and societal (interpersonal) components. Here we address these gaps by focusing on Puerto Rican farmers during their recovery period from Hurricane Maria and examine the multiple facets of adaptive capacity and their relationship to intended and actual adaptation practice adoption. This paper intends to contribute to current conversations on how to understand and approach adaptive capacity in a way that analyzes multiple components. We do not aim to assess the efficacy of the practices and strategies toward adaptation. Rather, we aim to provide a different methodological perspective that can improve our assessment of what may be needed to improve adaptive capacity.

As such, we ask the following: (1) What obstacles did farmers experience that thwarted the recovery of their farms after Hurricane Maria, and what determinants of adaptive capacity are reflected within them? (2) What were farmers' actual and intended adoption of agricultural practices and management strategies after Hurricane Maria? (3) What determinants of adaptive capacity explain actual and intended adoption, and how do they compare? (4) How do farmers' reported obstacles to recovery post-Maria compare with intention to adopt and adoption of farm management practices and adaptation strategies??

The literature in the Caribbean and Central America, regions affected by Atlantic hurricanes, has shown that adaptation is highly dependent on structural (social, governmental, and

institutional) and income-related factors (economic, material and technological). Thus, we expect that variables reflecting these factors will be significant in both actual and intended adoption (H1). Furthermore, though research has shown that perceptual factors are not pivotal to Puerto Rican farmers' adoption of practices (Rodríguez-Cruz and Niles, 2021), we expect these factors to be related to intended practices (H2). Lastly, it is known that Hurricane Maria caused significant damage in Puerto Rico, and that subsequent recovery efforts failed to safeguard lives and wellbeing (Santos-Burgoa et al., 2018; Bonilla, 2020). Thus, we expect that farmers' self-reported obstacles will reflect the role of broader structures (governmental, institutional, and societal) in the recovery of their farms (H3), as well in the type of practices they actualized, and intended to carry out (H4).

MATERIALS AND METHODS

Survey Sample

A mixed-methods survey, informed by previous studies (Spence et al., 2011; Haden et al., 2012; Niles et al., 2015; Niles and Mueller, 2016; Singh et al., 2017), was developed in English, and translated to Spanish, to capture Puerto Rican farmers' perceptions and opinions around their experience with Hurricane Maria and climate change. The overall objectives of the main project focused on understanding farmers' adaptation and food security outcomes in light of farmers' recovery from Hurricane Maria (Rodríguez-Cruz and Niles, 2020). The study received approval by the Institutional Review Board of the University of Vermont in December 2017.

A pilot with a pool of diverse farmers ($n = 31$) was carried out in February 2018, and results were shared with partners at the Extension Service of the University of Puerto Rico at Mayagüez. The survey received minimal language and structure corrections.

Data used for the present study were a sub-set of survey questions (both closed response and open-ended), concerning farmers' demographics, questions that reflected adaptive capacity resources, adaptation perceptions, actual and intended practices, and reported obstacles. Some variables were converted (e.g., Likert scale to binary) to better group individuals, and because some had concentrated answers in two items (e.g., agree and strongly agree). **Table 2** shows independent variables used in this study, and **Table 3** shows agricultural practices and management strategies asked about in the survey.

The survey was deployed by local agricultural agents of the Extension Service who acted as enumerators of the survey, between May and July 2018, 8 months after Hurricane Maria. To access a diverse and substantial number of farmers, 440 surveys were distributed in the five regions that the Extension Service covers across Puerto Rico: Arecibo, Caguas, Mayagüez, Ponce, and San Juan. One hundred surveys were sent to each of the administrative offices of Caguas, Ponce, and San Juan; 70 were sent to each in Arecibo and Mayagüez, as per recommendation of Extension personnel. Agricultural agents then randomly surveyed farmers that were connected to Extension or had received services from it in municipalities of each region. This approach was recommended by Extension colleagues to access

a diverse range of farmers (e.g., mixed, banana, plantain, dairy, poultry, etc.) from across Puerto Rico.

Place and Population

Puerto Rico is the smaller of the Greater Antilles of the Caribbean. It is an unincorporated territory of the United States, with a population of ~3.3 million people (US Census Bureau, 2020). As most islands in the region, Puerto Rico has seen a decrease in farms and food production since the 1990s due to trade liberalization and unbalances, economic situations, influx of imports, and other external and internal factors that make local food production and access difficult (Weis, 2007; FAO, 2014; Lowitt et al., 2015; Irizarry-Ruiz, 2016). While it produced about 40% of its food needs in the 1980s, Puerto Rico currently only produces around 15% (Carro-Figueroa, 2002; Gould, 2015; Irizarry-Ruiz, 2016; Gould et al., 2017). The territory is also undergoing a social and political crisis due to high debt (Bueno, 2017; Félix and Holt-Giménez, 2017; Bonilla, 2020). Within that context, the agricultural sector was experiencing improvements in production, access to local markets, and other opportunities prior to Maria (Comas-Pagán, 2014; Irizarry-Ruiz, 2016; Gould et al., 2017). Governmental and community-based efforts were focused on supporting current and new farmers before 2017's hurricanes. These efforts were halted by the impacts of both hurricanes Irma and Maria. The Puerto Rico Department of Agriculture (2018) reports that these two hurricanes caused \$2 billion in damages, Maria being the most significant of the two in terms of agricultural losses (\$228 million in production losses, and \$1.8 billion in infrastructural losses). For example, reports indicate that the plantain sector suffered \$72 million in damages, while the banana sector suffered \$19 million. Other heavily affected sectors were coffee (\$18 million), dairy (\$14 million), and poultry (\$6 million).

Though both impacts decimated Puerto Rico's agricultural sector, farmers have experienced a significant quantity of natural hazards since 2017, such as intense storms, and severe droughts (Gould, 2015; Díaz et al., 2018; López-Marrero and Castro-Rivera, 2018, 2019; Rodríguez-Cruz and Niles, 2021). Even a category one hurricane can easily damage local agriculture. Many of Puerto Rico's high value crops, such as coffee, bananas, and plantains, are very susceptible to temperature change and moderate winds. Moreover, important farmland is located in coastal areas, which is susceptible to erosion, and seawater intrusion to aquifers (Díaz et al., 2018). US Congress' Fourth National Climate Assessment (2018) concluded that rainfall patterns will change, and water availability will likely decline for Puerto Rico, coinciding with rising temperatures that contribute to the occurrence of recurring droughts in the future. Those impacts are occurring simultaneously with stronger storms (Díaz et al., 2018).

Puerto Rico's farmers produce mainly for domestic markets, and work small to medium farms according to the USDA. Subsistence farming is not typical in Puerto Rico. The 2018 census states that most farmers in the territory (or principal operators) have a household income <\$20,000, significantly less than the US average, which exceeds \$60,000 (USDA ERS, 2020). Puerto Rico's average household income is \$20,539 (US

TABLE 2 | Independent variables used in quantitative models.

Determinant	Question/statement	Variable name	Scale	Rationale
Agricultural, natural	What agricultural products have you produced, currently produce or plan to produce in the future on your farm? Check all that apply.	Agricultural production	Aggregated count variable	This variable is a proxy for agricultural diversity, which has been shown to provide benefits (e.g., ecosystem services) that increase farms resistance to impacts, and supports recovery.
Agricultural, natural	How many <i>cuerdas</i> do you manage in your farm?	Farm size	Continuous	Farm size has been shown to be related to livelihood and adaptive capacity outcomes across regions.
Human	What is the highest level of education you have completed? Mark one	Education	Binary (1 = Some college or more; 0 = High school diploma or less)	Attaining formal education levels is related to livelihood and adaptive capacity outcomes through increasing household assets (e.g., higher income)
Human	What is your gender?	Gender	Binary (1 = Female; 0 = Male)	Farmers identified as females have been shown to face several constraints in achieving livelihood outcomes, such as food security.
Human	How many years have you been a farmer?	Years as farmer	Continuous	This variable was highly correlated with age. This variable was included because years farming may reflect traditional and local knowledge of farming. As well as farmers experiences with past events.
Physical, political, institutional, governmental	In what municipality your farm is located?	Metropolitan	Dummy (1 = Farm in metropolitan municipality; 0 = Not metropolitan)	Puerto Rican municipalities are categorized by the <i>Junta de Planificación</i> as metropolitan based on location (near big cities or coast) and population size. Metropolitan municipalities have higher access to physical assets (e.g., roads) and governmental and institutional agencies.
Physical, institutional, governmental	-	Extension region	Categorical (dummy)	A categorical variable based upon reported municipalities where farms are located. This variable was created to group farmers based on the Extension office that gives them service.
Economic, governmental	Are you a "bona fide" farmer of the Department of Agriculture?	Bona fide	Binary (1 = Yes; 0 = No)	To be bona fide, 51% or more of farmers' income must come from agriculture. This certification provides farmers with economic benefits (e.g., exemptions, incentives, etc.) and formal recognition by the Puerto Rico Department of Agriculture.
Economic	What is your approximate household income, including all far and off-farm income?	Household income	Binary (0 = <\$20,00; 1 = \$20,000 or more)	Household income has been a key variable in reflecting people's adaptive capacity. It is assumed that a higher income relates to access to other assets and higher wellbeing.
Economic	How do you sell your products? Check all that apply	Access to markets	Aggregated count variable	Having a diversity of ways to sell products may be beneficial for farmers' adaptive capacity in that it allows them to have more opportunities in selling their products.
Social, institutional	Which of the following organizations and institutions, if any, have you received information from related to adapting to climate-related impacts?	Contact scale	Aggregated count variable	Farmers were asked about the organizations and institutions that have provided them with information on climate change adaptation. This variable allows us to proxy social networks and access to diverse sources of support, which aid in adaptive capacity.
Perception/cognition	I feel that I have the capacity to change my agricultural practices to adapt to future potential extreme weather events like Hurricane Maria.	Perceived capacity	Binary (1 = Strongly agree, 0 = agree and below)	Perceived capacity composes diverse tested behavioral theories, such as the Theory of Planned Behavior. Individuals' perceived capacity to change a behavior or assume a new one has been shown to preclude actual behavior. Nevertheless, its role on behavior change varies. Furthermore, perceived capacity can reflect access to external assets that may motivate the individual to change or assume new behavior.
Perception/cognition	I believe my farm is vulnerable to future extreme weather events like Hurricane Maria.	Perceived vulnerability	Binary (1 = Strongly agree, 0 = agree and below)	Perceived vulnerability or risk can be a motivator for individuals to enact change that reduces that vulnerability or risk. Moreover, the perception of vulnerability can be useful to understand an individual's social-ecological context.
Vulnerability context	How would you describe the damages, if any, caused by Hurricane Maria to your farm?	Hurricane damage	Binary (1 = Total loss, 0 = Significant loss or other damages)	This variable is used as a proxy that reflects farmers' exposure and sensitivity to Hurricane Maria. Direct damage from a natural hazards can also reflect the severity of the impact.

Each variable is categorized to reflect an adaptive capacity determinant.

TABLE 3 | Categorized agricultural practices and management strategies to adapt to future extreme weather events like Hurricane Maria asked to farmers.

Category	Practice or management strategy	KR-20	α
Market oriented and capital-intensive growth practices and strategies	Acquire new insurance or improve current insurance	0.6471	0.6551
	Acquire solar panels		
	Apply more synthetic inputs		
	Expand agricultural land		
	Improve irrigation systems		
	Increase tillage		
Ecological transition practices	Seek new agricultural markets	0.8005	0.6725
	Crop rotations		
	Decrease tillage		
	Diversify crops		
	Integrated pest management		
	Switch from a perennial to an annual crop		
Natural design practices	Switch from an annual to a perennial crop	0.8338	0.8460
	Collect rainwater for irrigation		
	Contouring		
	Plant native species		
	Plant trees to reduce erosion		
	Use compost		
	Use mulch		

Frequencies and reliability measures are shown: Kuder-Richardson Formula 20 for actual adoption's binary variables (KR-20), and Cronbach's alpha for intended adoption's Likert-scale variables (α).

Census Bureau, 2020). The USDA defines a Puerto Rican farm as a location where \$500 or more of agricultural products are produced or sold. Between 2012 and 2018, Puerto Rico saw a decrease in farms (USDA NASS, 2020). There were 13,159 farms in 2012—when the last census was carried out—, with 8,230 farms reported in the current census (USDA NASS, 2020). Today, most farms are <100 *cuerdas* (Puerto Rico's traditional land measure) or 97 acres (an average of 59.3 *cuerdas*), and are mostly family or individual farms. There are large farms that run extensive monocultures, but many of the small-medium farms produce a diverse array of agricultural products (Álvarez-Febles and Félix, 2020). It is important to note that many other farms, such as community-supported agriculture projects and others, are not counted in the census or are not directly linked to the Puerto Rico Department of Agriculture.

Qualitative Analysis

The survey asked farmers to state at least three obstacles faced during the recovery of that their farming operations. Farmers' responses to this open-ended question were analyzed using double coding through thematic analysis with *a priori* codes (Creswell, 2014, 2016). Responses were translated from Spanish into English by the first author, and then transcribed to a Microsoft Word document, which was uploaded to NVivo v.12 (QSR International, 2019). Given the purposes of this study, an *a priori* coding frame, accompanied by code definitions, was used to categorize the reported obstacles into nine nodes (or themes) following the nine determinants of adaptive capacity adapted from López-Marrero (2010) shown in **Table 1**. Authors LARC and MM (coders) first agreed upon the codes and

coded the first 10 responses together. In order to establish transparency and consistency within the coding (O'Connor and Joffe, 2020), intercoder reliability (ICR) was evaluated following a first round of coding by quantifying the degree of consensus using percentage of agreement. More than 90% is considered highly reliable (Lavrakas, 2008). Two nodes, *agricultural resources* and *economic resources*, did not score more than 90% agreement after the first round of coding. Thus, after the coders discussed divergences and reached consensus, a second round of coding was undertaken. The second assessment successfully achieved more than 90% ICR in all nodes (**Supplementary Table 1**). Codes with the highest frequency within each theme, and quantification of such themes to identify coverage and percentages, were evaluated using Nvivo 12's hierarchy chart wizard and word cloud function.

Quantitative Analysis

The survey asked farmers to state the agricultural practices and management strategies that they were considering adopting in the future or that they had adopted since Hurricane Maria (~8 months prior to the survey) in a close-ended question with pre-coded responses. The responses included a list of practices which list of practices was developed based upon conversations and recommendations from colleagues at the Extension Service and at the University of Vermont with expertise in agriculture and climate change. The survey asked, "Which of these agricultural practices and management strategies, if any, might you adopt in the near future to adapt to future extreme events like Hurricane Maria?" (**Table 3**). Hereafter, these practices and strategies will be referred to as "adaptation practices." The 22 practices were

TABLE 4 | Descriptive statistics of independent variables.

Variable	Scale	Frequency (%)	Mean \pm SD	n
Contact scale	Continuous	–	2.3 \pm 2.1	398
Agricultural production	Continuous	–	2.2 \pm 2.0	402
Bona fide	Yes	210 (52.8)	–	398
	No	188 (47.2)		
Education	High school diploma or less	131 (32.7)	–	401
	Some college or more	270 (63.3)		
Farm size	Continuous	–	58.1 \pm 98.5	383
Gender	Female	55 (14.0)	–	395
	Male	340 (86.0)		
Income	<\$20,000	138 (36.4)		379
	More than \$20,000	241 (63.6)		
Markets	Continuous	–	1.2 \pm 1.0	401
Metropolitan	Metropolitan	229 (58.0)	–	398
	Non-metropolitan	169 (42.0)		
Perceived capacity	High perceived capacity	192 (50.4)	–	381
	Low perceived capacity	189 (49.6)		
Perceived vulnerability	High perceived vulnerability	264 (66.5)	–	397
	Low perceived vulnerability	133 (33.5)		
Region	Arecibo	57 (14.3)	–	398
	Caguas	88 (22.1)		
	Mayagüez	76 (19.1)		
	Ponce	92 (23.1)		
	San Juan	85 (21.4)		
Damage	Total loss	229 (57.4)	–	399
	Significant loss	170 (42.6)		
Years farming	Continuous	–	20.5 \pm 15.3	392

Frequency and percentages of responses, as well as mean and standard deviation (SD) are included.

included as a list in a table. The first column stated, “Currently in use” (binary, yes or no), and the subsequent columns represented a 5-point Likert scale for adoption (from very unlikely to very likely). The binary column was used to assess actual adoption, and the Likert scale to assess intended adoption. The list was also intended to include practices recommended for adaptation or for conservation of natural resources, as well as other conventional or common practices in Puerto Rico and the contiguous United States. It is important to note that the objective was to assess what practices or strategies farmers understand to be helpful for adaptation, and not to evaluate if those decisions are adaptive or maladaptive. Variables that had $n < 20$ were excluded from the analysis (e.g., “stop farming” and “forage conservation”), since they represented $<5\%$ of total respondents.

Actual Adoption

Actual adoption of agricultural and management strategies following Hurricane Maria was assessed through binary variables where farmers indicated “currently in use,” as noted above. We used Kuder-Richardson-20 Reliability Tests in Stata 15.1, which test internal consistency or scale reliability of binary items (Kuder and Richardson, 1937) and range from 0 to 1 in ascending reliability (Table 4). This test is similar to assessing Cronbach’s alpha, which evaluates internal consistency of scale variables

(Nunnally, 1978). Two categories had KR-20s > 0.80 , which are acceptable determining internal consistency or reliability of a group of items, and one had a coefficient > 0.60 , which is reasonable (Nunnally, 1978). Each groups’ variables were summed to create three new aggregate count variables for analysis: (1) Market oriented and capital-intensive growth, (2) Ecological transition practices, and (3) Natural design, as well as fourth aggregate count variable of all practices combined (Table 3). The first group had seven practices; the second and third groups were composed of six.

Model development considered distribution of the count variables. We implemented a Poisson regression to test the model, but model assumptions were not met on multiple factors (Likelihood ratio test showed over dispersed data: LR test of $\alpha = 0$: $\text{chibar}2(01) = 649.22$, $\text{Prob} \geq \text{chibar}2 = 0.000$, and the Poisson regression assumption of identical means and variances was not met). Instead, we used a negative binomial regression (nbreg) to fit over-dispersed data. We developed four nbreg models, with clustered errors for municipalities, utilizing Stata 15.1.

Intended Adoption

Intended adoption was evaluated through scale variables (5-point Likert) of the list of practices and management strategies. Three

TABLE 5 | Coding coverage—the percentage of content coded-for each set of adaptive capacity themes.

Theme	Coverage	Most prevalent references
Institutions	27.0%	Issues with the government, such as frustration with government bureaucracy, insufficient support from governmental institutions, and lack of general aid
Economic resources	26.2%	Loss of income, delayed insurance payment, cost of workforce, and financial assets (e.g., available cash)
Material resources and technology	26.1%	Access to electricity, machinery, and water; physical access to farms (e.g., because of fallen trees and landslides).
Agricultural resources	22.8%	Lack of seeds
Human resources	7.9%	Lack of laborers or human assistance to help with post-hurricane cleanup and reconstruction.
Political resources	5.5%	Negotiating with governmental agencies
Natural resources	4.3%	Pests, lack of flowers, erosion
Social resources	2.8%	Focused advice from specialized advisors.
Perception/cognition	0.1%	Feelings of abandonment

scale variables were created to understand likelihood of intended adoption, using the same categorization of actual adoption scales, with Cronbach alpha acceptable at >0.65 (Nunnally, 1978). As with all of the actual adoption variables, a single variable was created with all the intended adoption practices ($\alpha = 0.86$). We used generalized linear models with clustered errors around municipalities to account for spatial correlation (Nichols and Schaffer, 2007). Distribution of scale variables show similitude to both Gaussian and Gamma distributions. In order to choose the best family distribution to build the models, Akaike information criterion (AIC) and the Bayesian information criterion (BIC) were used to compare across generalized linear models with either Gaussian or Gamma distributions. The models yielded better fit with Gaussian distributions (**Supplementary Table 2**). Thus, the generalized linear models used Gaussian as the family choice, and “Identity” as the link choice.

RESULTS

Descriptive Statistics

A total of 405 farmers answered the survey through Extension enumerators, resulting in an 87% response rate. Farmer and farm characteristics, which were categorized under different adaptive capacity resources, varied across respondents (**Table 4**). On average, farmers surveyed had 58 *cuerdas* (56.3 acres or 23 hectares), were 54 years old, and had been farming for 20 years; results that align with census data for Puerto Rican farmers (USDA NASS, 2020). The majority of respondents were male (86%) and reported a household income of \$20,000 or more (64%), which also aligns with recent census data. Nevertheless, we had an overrepresentation of bona fide farmers (53%). Farmers reported being connected to an average of two organizations or institutions (min = 0, max = 11), that provide them support around climate change adaptation, and reported selling their products to one of the listed venues, on average (min = 1, max = 5).

Qualitative Analysis Results

While 345 farmers (90%) responded that they had faced significant obstacles toward recovery, only 333 provided

responses to the open-ended question. Farmers identified many obstacles to their recovery related to their adaptive capacity (agricultural resources, economic resources, human resources, institutions, material resources and technology, natural resources, perception/cognition, political resources and social resources) (**Table 1**). **Table 5** shows the coverage percentages of each of the identified themes, and also displays the most prevalent references within each theme. Obstacles most mentioned by farmers were related to institutions and institutional support (27.0%), material resources and technology (26.1%), economic resources (26.2%), and agricultural resources (24.3%). Obstacles that fell under themes of perception/cognition (0.07%), natural resources (2.6%), and social resources (4.3%) were the least mentioned. Within each theme, we also evaluated the most prevalent references within a theme.

In addition, from the cloud analysis, we can see that the top 10 words mentioned in farmer responses to our open-ended question regarding their top obstacles to recovery overall were: “lack,” “insurance,” “seeds,” “agricultural,” “electrical,” “energy,” “economic,” “aid,” “laborers,” and “water.” Many of these words reflected resources or structural components of a system (e.g., electricity, energy, aid) that are often related to institutional support.

Quantitative Analyses Results

Actual Adoption Results

Figure 1 shows farmers’ reported actual adoption and management practices. Overall, the top five practices implemented after Hurricane Maria were: integrated pest management ($n = 97$, 24.4%), crop rotation ($n = 84$, 21.2%), crop diversification ($n = 78$, 19.6%), contouring ($n = 68$, 17.1%), and composting ($n = 65$, 16.2%). We find that 49% of farmers adopted any new practices after Hurricane Maria.

Table 6 shows results with significance for the four models that evaluated the relationship between actual adoption outcomes and adaptive capacity resources or assets. **Supplementary Table 3** shows full model results. In the first model (actual adoption of all practices) we found that farmers with higher levels of education ($\beta = 0.5780$, IRR = 1.7824)

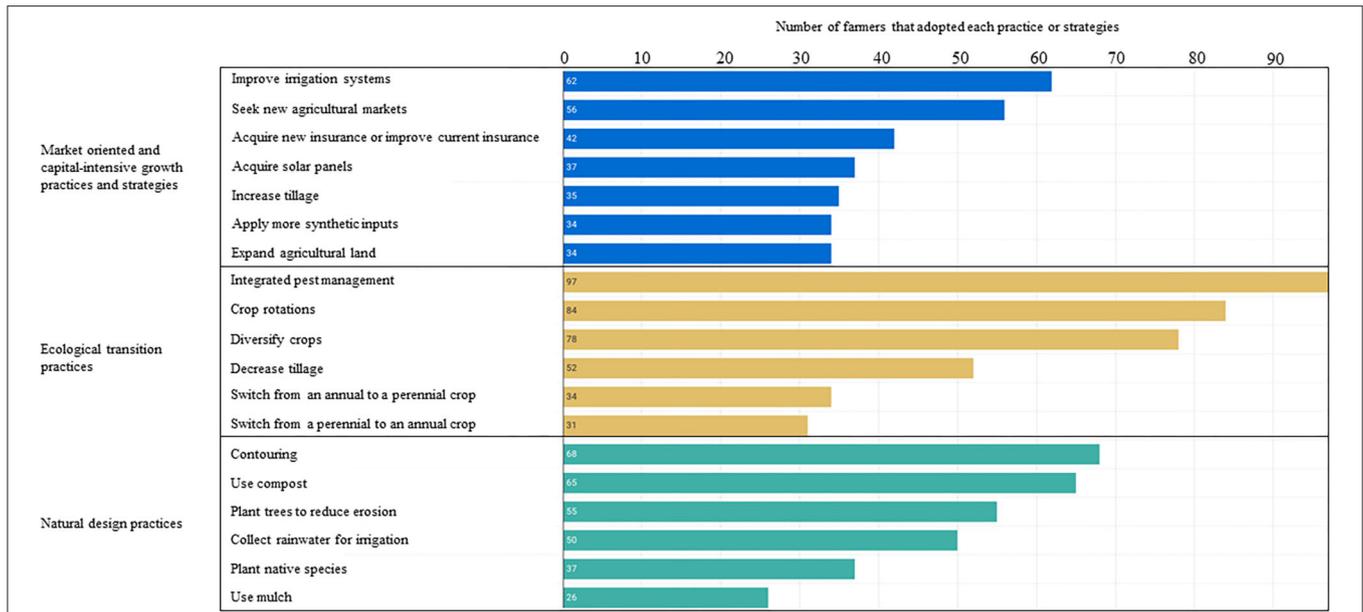


FIGURE 1 | Farmers' reported actual adoption of adaptation practices and strategies after Hurricane Maria.

TABLE 6 | Significant results for four separate negative binomial regression models predicting actual adoption of farm and management practices.

Models and dependent variables	Independent variables	β	p
Model 1: Actual adoption of all practices	Education*	0.5780	0.003
	Damages*	0.6665	0.001
Model 2: Actual adoption of market oriented and capital-intensive growth practices and strategies	Damages*	0.7343	0.000
Model 3: Actual adoption of ecological transition practices	Agricultural production*	0.1207	0.014
	Education*	0.5483	0.001
	Damages*	0.6467	0.002
Model 4: Actual adoption of natural design practices	Contact scale*	0.1453	0.013
	Education*	0.9138	0.000
	Farm size*	-0.0041	0.038

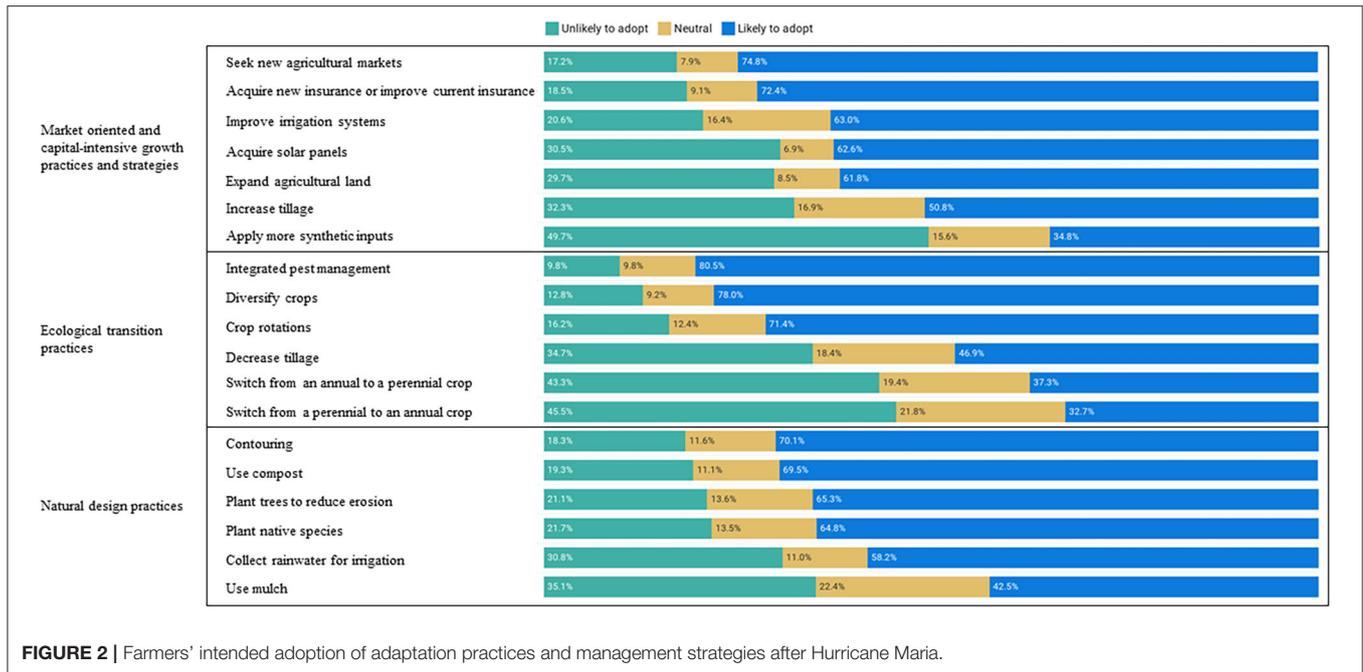
Supplementary Table 3 shows full results, including estimates (β), robust standard errors (SE), significance (p), 95% confidence intervals (CI), and incident rate ratios (IRR). * $p < 0.050$.

and those that reported total loss of their farms (infrastructure and production) due to hurricane winds, rain, and landslides ($\beta = 0.6665$, IRR = 1.9474), were more likely to report higher number of practices adopted after Hurricane Maria (Table 6). We expected that variables around structural and financial assets, such as social, agricultural, economic, and material resources would be significant. These results were not aligned with that expectation (H1).

In examining the specific types of market oriented and capital-intensive growth practices and strategies adopted (Model 2), we found that total farm loss (damages) was the only significant variable ($\beta = 0.7343$, IRR = 2.0840, $p < 0.05$) (Table 6). This result is counterintuitive because no variable related to economic or material resources was found significant (H1). In model 3, actual adoption

of ecological transition practices, we found that the number of agricultural products produced ($\beta = 0.1207$, IRR = 1.1282), farmers' levels of formal education ($\beta = 0.5483$, IRR = 1.7303), and reporting total loss of farms ($\beta = 0.6467$, IRR = 1.9093) were significant predictors of adoption ($p < 0.05$) (Table 6).

Finally, we found in the fourth model (Actual adoption of natural design practices) that the number of reported organization or institutions that have provided services to farmers (contact scale) ($\beta = 0.1453$, IRR = 1.1564), education ($\beta = 0.9138$, IRR = 2.4936), and farm size ($\beta = -0.0041$, IRR = 1.0000), were significantly correlated ($p < 0.05$) with conservation practice adoption after Hurricane Maria (Table 6). These results demonstrate that farms with higher number of contacts and higher education (or greater social and human



capital) were more linked to adoption, while larger farms were less likely to have adopted conservation practices.

Intended Adoption Results

Figure 2 shows farmers' intended adoption practices and strategies, and Supplementary Table 4 shows the tabular results. Respondents' top reported practices and management strategies to adopt in the future (likely and very likely to adopt) were: integrated pest management (80.5%), diversification of crops (78.0%), seeking new agricultural markets (74.8%), acquiring new insurance or improving current insurance (72.4%), and crop rotations (71.4%). In general, intention to adopt results contrasted with those of actual adoption.

Four generalized linear models were carried out to assess intended adoption outcomes (Table 7). Full model results are shown in Supplementary Table 5, while significant results are shown in Table 7. We found no significant variables in Model 5 (Intended adoption across all practices and management strategies). In Model 6 (Intention to adopt market oriented and capital-intensive growth practices and strategies), perceived capacity significant ($\beta = 0.2343, p < 0.05$) was correlated with higher adoption intention (Table 7). In the 7th model (Intended adoption of ecological transition practices) being a bona fide farmer ($\beta = -0.3243, p < 0.05$) was negatively correlated with intention to adopt, meaning that those that reported being part of that program of the Puerto Rico Department of Agriculture, had lower intention rates to adopt such practices (Table 7). In the last model (8), exploring intended adoption of natural design, two variables were significant ($p < 0.05$). Producing a higher number of agricultural products (Agricultural production) was correlated with higher intention to adopt conservation practices ($\beta = 0.0902$) while reporting a total loss (damages) ($\beta = -0.2663$) was negatively correlated with intention to adopt those practices.

DISCUSSION

This paper assessed Puerto Rican farmers' actual and intended adoption of adaptation practices and management strategies in light of the obstacles they faced toward recovery after Hurricane Maria. It aimed to understand potential barriers and drivers for strengthening adaptive capacity through a mixed-methods approach, in order to provide a new approach to understanding adaptive capacity in a disaster context. We find that drivers for actual adoption vary from factors related to intended adoption of adaptation practices, and that almost half of all farmers in our survey had actually adopted a practice or strategy in the 8 months since Hurricane Maria. Furthermore, we find that the majority of farmers faced significant obstacles in their recovery, especially with institutional support, economic resources, and access to material resources and technology. Combining quantitative and qualitative data provided a richer understanding of how individual and structural factors intersect and reflect adaptive capacity.

Contrary to our expectations (H1), variables related to governmental, institutional, social, economic, and material resources were not the principal drivers for both actual and intended adoption. Instead, facing a total loss, and having a higher level of formal education were most related to actual adoption of adaptation practices. Furthermore, we did not find that perception factors were significantly related to intended adoption, rejecting H2. Instead, intention to adopt had varying factors across the different categories of practices and management strategies. Although variables used around the aforementioned resources were not significant, qualitative data analysis suggests that lack of broader structures of support, such as expected and timely aid, insurance payments, and access to services and supplies should be considered in farmers'

TABLE 7 | Significant results of generalized linear regression models for farmers intended adoption.

Dependent variables	Independent variables	β	p
Model 5: Intended adoption of all practices ^a			
Model 6: Intended adoption of market oriented and capital-intensive growth practices and strategies	Perceived capacity*	0.2343	0.048
Model 7: Intended adoption of ecological transition practices	Bona fide*	-0.3243	0.014
Intended adoption of natural design practices	Agricultural production*	0.0902	0.004
	Damages*	-0.2663	0.028

Full results are shown in **Supplementary Table 5**, including estimates (β), robust standard errors (SE), and 95% confidence intervals (CI) are shown.

* $p < 0.05$.

^aNo variable was found to be significant.

decision-making around adaptation and recovery (H3 and H4). These findings reflect how we might include other questions in future surveys exploring disaster recovery. Future studies should consider how variables often used to assess the determinants of adaptive capacity, such as the ones used in this study, might not provide the nuanced information specific to a disaster context.

One of the major drivers for actual adoption in all models, except for natural design practices (Model 4), was “total loss.” This contrasts with research in Central America with tropical agriculture farmers subjected to Atlantic hurricanes, where farmers’ adoption of new practices was not significantly driven by damage experiences from extreme weather events, likely because of pre-existing low adaptive capacity (Harvey et al., 2018). Nevertheless, experiencing risk or climate-related impacts has been found to be a precursor of adaptation (Salerno et al., 2019). Farmers in our study that reported total loss were more likely to report a higher number of practices adopted overall, and in the adoption of market oriented and capital-intensive growth practices and strategies, as well as higher adoption of ecological transition practices. These findings are critically important for considering opportunities to rethink agricultural systems, and provide evidence that farmers may be willing to reconsider transforming their farming systems after experiencing significant damages that change their farming landscapes.

The finding that higher levels of formal education were linked to all actual adoption models, except market oriented and capital-intensive growth practices and strategies (Model 2), suggests that human assets may open doors to access other resources important for recovery and adaptation, likely through enabling formation of ties that increase social and structural support (López-Marrero and Wisner, 2012; Kassie et al., 2015; Caswell et al., 2016; Shah et al., 2019). For example, Model 4 showed that education was positively linked to adoption of natural design practices, as well as access to information sources. These findings align with Caribbean research suggesting that farmers who have external support are likely to adopt practices that support the environment, while sustaining their production (Lowitt et al., 2015; Saint Ville et al., 2016; Paul et al., 2017). Research outside the Caribbean supports this as well (Bagagnan et al., 2019; Žurovec and Vedeld, 2019).

These results suggest that being able to adopt practices to adapt to climate change or re-envision agricultural systems may occur among farmers with higher levels of human capacity.

Future studies should focus on farm recovery processes after a significant shock that alters the working landscape to understand decision-making processes in rebuilding the system. Taken together, this suggests that total loss events, while catastrophic, do present opportunities for reinvention, if people have access to the necessary resources. These results further highlight the need for institutional support and capacity for farmers without formalized education, or social networks.

Our results also reflect other research showing that actual and intended adoption may not be driven by the same variables (Niles et al., 2016). While we expected (H2) to see perceived capacity be a notable factor predicting intended adoption as reflected in the Theory of Planned Behavior (Ajzen, 1991), as well as perceived vulnerability, we only find this significant in intention to adopt ecological transition practices (Model 6). These results further support that perceptual factors around climate change may not be pivotal in advancing adaptation in places where shocks are consistently experienced (Rodríguez-Cruz and Niles, 2021). On the other hand, being a “bona fide” farmer decreased likelihood of intending to adopt ecological transition practices (Model 7), which may help in increasing farmers likelihood of recovering their farms after a hurricane (Holt-Giménez, 2002; Rosset et al., 2011). This finding was counterintuitive since bona fide farmers are recognized officially by the government, which often provides them access to governmental and institutional resources. However, given the large number of farmers who reported institutional obstacles for recovery, it is possible that bona fide farmers did not receive benefits that might otherwise have been available.

Results from the qualitative analysis highlighted that most of the obstacles reported by farmers stemmed from mechanisms of support (e.g., insurance payments, governmental aid, etc.) that were not available for a significant period of time following Hurricane Maria, varying from several months up to a year. Farmers across all regions of Puerto Rico voiced the challenges they experienced when attempting to access governmental agencies, services, and materials and supplies needed to repair their farms and recover, physically and financially, from the effects of the hurricane. These were exacerbated by Puerto Rico experiencing the longest blackout in the modern history of the United States; communications were downed, and many regions of Puerto Rico only received restored power and water months after the hurricanes’ landfall (Masters and Houser, 2017; Bonilla,

2020). Farmers also noted these obstacles as the third most common. Furthermore, our analysis suggests that farmers also faced challenges when accessing social networks of support, likely further challenged by the lack of material resources and technology. Perfecto et al. (2019) assessed how coffee farms' management, whether incorporating agroforestry or performing an intensive style, related to the degree of damages experienced and farm recovery after Maria. The study found that coffee farmers' recovery after Maria was potentiated by assistance from their social and community networks of support. And that management style may come secondary in a catastrophic context (Perfecto et al., 2019). Nevertheless, our qualitative analysis suggests that farmers may have been constrained in accessing such networks, which likely affected their overall capacity for recovery. Furthermore, the analysis reflected farmers' disappointment on the state, and unmet expectations regarding aid in a catastrophic event.

The lack of institutional, economic, and social support likely affected the way that farmers perceived the practices necessary to adopt to overcome future challenges. We found that one of the top intended future practices was to acquire new agricultural insurance or improve current insurance. Agricultural insurance is one key risk management tool that farmers in the US use to offset climate-related impacts (Claassen et al., 2017; Reyes et al., 2020), but this insurance may not be aligned with needs of farmers, the impacts they face, or their farming systems. On the other hand, it could be that insurance dynamics (e.g., making payments, answering claims, etc.) might not be adequately equipped to deal with emergencies such as the one triggered by Hurricane Maria. Mainland US research has demonstrated regional differences in the role of insurance as a risk management tool (i.e., important in Midwest, less so in New England) (Mase et al., 2017; White et al., 2018). In Puerto Rico, agricultural insurance is mostly managed by the *Corporación de Seguros Agrícolas* (CSA) of the local Department of Agriculture. Obtaining payments from this insurance was specifically mentioned numerous times as an obstacle in our analysis. For example, one farmer noted, "I had about an acre of *yautía* insured, and the insurance paid after seven months. I could not recover any of the *yautía*." These results indicate that while insurance likely would have enabled increased capacity for farm recovery, it too faced many barriers, which prevented farmers from receiving the money from their insurance claims in a timely manner. This finding also suggests that in the aftermath of Maria, or in the context of disaster, where "normal" means of communication and accessing resources are disrupted, bureaucracy may not have the capacity to manage these challenges. Thus, there is an important need to improve agricultural insurance delivery in future disaster contexts, especially if more farmers intend to invest in these services.

Our study further suggests that broader structures, such as systems of governance, farmers' social networks, in relation to infrastructure, policy, and public health, play a significant role in farmers' adaptive capacity. Hurricane Maria, as a disaster, made evident that Puerto Rico's political and social characteristics must be taken into account when aiming to understand adaptive capacity.

We note several limitations of our study, all of which are important for future research. First, we did not ask farmers if they had insurance prior to Maria, so we do not know if their insurance adoption is new or additional. Nevertheless, the survey did ask farmers if they had insurance at the time (8 months after landfall), and 53% stated that they did. Most of them reported that their insurance was with the Corporation of Agricultural Insurance of the Puerto Rico Department of Agriculture. Much of this paper's qualitative data indicated that farmers had insurance at the time of Maria, and show the difficulties experienced in assessing the funds. Future research could look more deeply to the extent to which agricultural insurance in Puerto Rico relates to adaptive capacity outcomes. Second, we are assuming that reported actual adoption was indeed only adopted after Maria, and not just a continuation of practices prior to the hurricane. The table in which they reported actual adoption practices specified "currently in use," though we did not ask about pre-hurricane adoption. Nevertheless, the survey question asked about new practices for future adoption ("Which of these agricultural practices and management strategies, if any, might you adopt in the near future to adapt to future extreme events like Hurricane Maria?"). Thus, we assumed those reported practices were only actualized after Maria. Third, we did not include in the models the type of farming system (e.g., dairy, mixed, coffee, etc.), and instead use a proxy for diversity (number of products). This was done because many production systems in Puerto Rico are already diversified, making it challenging to assign farmers to a specific category. Furthermore, even within some categories (e.g., fruit/vegetable farmer), systems can vary significantly from annual to perennial. Lastly, we had an overrepresentation of bona fide farmers—53% in our study, while 24% overall in Puerto Rico as reported by past Secretary of Agriculture in 2019, Carlos Flores (Díaz Rolón, 2019)—, despite most other demographics consistent with census data. This may be the result of selection bias through Cooperative Extension, which may have stronger connections with bona fide farmer networks.

CONCLUSION

This study assessed how various determinants of adaptive capacity reflect on Puerto Rican farmers' actual and intended adoption of adaptation practices, in light of the obstacles they faced toward recovery after 2017's Hurricane Maria. Our results suggest that, in many cases, broader structures, such as systems of governance, farmers' social networks, and infrastructure, affect adaptive capacity more than individual perceptions or capacity assets. We find that experiencing a total loss, appears to provide a window of opportunity for reinventing agricultural systems, as evidenced by the fact that farmers who faced a total loss adopted the most actual adaptation practices. Importantly, farmers with higher education were also more likely to adopt more adaptation practices, suggesting that capacity to change farming systems after a total loss is related to human capital. These results suggest that catastrophic events like Hurricane Maria, while devastating, do provide opportunities for change and resilience; but being able to take advantage of those opportunities is related not only to the

human capital of an individual farmer, and their social networks, but the institutional and infrastructure capacities that are in place for recovery. Absent either, agricultural resilience may be challenging to achieve, or slow at best. Thus, working to improve both individual and structural factors that affect adaptive capacity are both likely to lend themselves toward greater adoption of adaptation practices, which would, in turn, improve resilience of farm systems under future shocks. Lastly, our study shows that a mixed-methods approach into understanding adaptive capacity provides nuanced information that might not be captured in quantitative model assessments alone. Future studies should further integrate qualitative and quantitative data to improve our understanding on the role of broader structural components in individual adaptive capacity outcomes.

DATA AVAILABILITY STATEMENT

The data sub-set used for this study can be available upon request to the corresponding author.

ETHICS STATEMENT

This study was approved on December 2017 by the Committees on Human Subjects Serving the University of Vermont and the UVM Medical Center at the Research Protections Office approved our study on 04-Dec- 2017. The study (CHRBSS: 18-0258) received Exemption Category 2. Consent was included in survey booklet, and was facilitated orally through enumerators. Written informed consent for participation was not required for this study in accordance with the national legislation and the institutional requirements.

AUTHOR CONTRIBUTIONS

LR-C: wrote manuscript draft, conceptualized study, quantitative analysis, qualitative analysis, and project liaison. MM: reviewed and edited manuscript, conceptualized study, and qualitative analysis. MTN: reviewed and edited manuscript, conceptualized study, quantitative analysis, and funding

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SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: <https://www.frontiersin.org/articles/10.3389/fsufs.2021.662918/full#supplementary-material>

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Conflict of Interest: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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