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# Coping with post-hurricane mental distress: The role of neighborhood green space

**Dongying Li**[1,*], **Galen Newman**[1], **Tiantian Zhang**[2], **Rui Zhu**[1], **Jennifer Horney**[3]

[1]Department of Landscape Architecture and Urban Planning, Texas A&M University, Langford A 337, TAMU 3137, TX, 77843, USA

[2]Department of Landscape Architecture, School of Architecture, Soochow University, No.1 Shizi Street, Suzhou, 215006, China

[3]Epidemiology Program, University of Delaware, 100 Discovery Blvd, Newark, DE, 19713, USA

## Abstract

**Background:** Although increases in the prevalence of mental distress have been reported after natural disasters, less is known about the role the environment may play in mitigating posttraumatic stress disorder (PTSD) in hurricane-impacted communities.

**Aim:** This study aims to investigate the extent to which concentration and perceived quality of neighborhood greenness are associated with lower levels of PTSD, along with potential mechanisms through which these effects occur.

**Methods:** We conducted a cross-sectional survey of individuals (N=272) from 30 Houston neighborhoods that were affected during Hurricane Harvey. Perceived quality of neighborhood green space was measured using a scale adapted from the Neighborhood Open Space (NOS) scale, and concentration of greenness was measured objectively using the normalized difference vegetation index (NDVI). Probable PTSD was measured using the Posttraumatic Stress Disorder Checklist for DSM-5 (PCL-5), and hurricane-related distress using the Impact of Event Scale (IES-R). Generalized linear mixed models were used to fit individual models. Based on the results, structural equation models were employed to test direct and indirect pathways simultaneously. Models were adjusted for neighborhood- and individual-level confounders.

**Results:** Greater perceived quality of neighborhood green space was significantly associated with lower likelihoods of probable PTSD and hurricane-related distress. The effects of perceived green space quality on hurricane-related distress were mediated by higher levels of emotional resilience. Social cohesion, although significantly correlated with PTSD and distress, did not mediate the effect of perceived green space quality on either. Neighborhood NDVI was significantly associated with hurricane-related distress, but not with PTSD.

**Conclusion:** We conclude that living in neighborhoods with greater perceived quality of green space was associated with lower levels of post-hurricane distress, with mediation especially through the emotional resilience pathway. These findings suggest that in disaster recovery policy

*Corresponding Author: Dongying Li, dli@arch.tamu.edu.

frameworks, more attention should be paid to the benefits of high-quality neighborhood green infrastructure.

**Keywords**

Disaster recovery; Post-traumatic stress disorder; Green space; Emotional resilience; Social cohesion

## 1. Introduction

Hurricane Harvey was the wettest tropical cyclone to impact the continental U.S. More than 60 inches of rain fell between Aug. 25 and Aug. 29, 2017, affecting approximately 12 million residents of Houston, TX and the U.S. Gulf Coast with catastrophic flooding. At the peak, all 22 watersheds in Harris County, home to the City of Houston, were underwater (Harris County Flood Control District, 2018). More than 20 rainfall gauges registered seven-day readings topping 40 inches. Across Harris County more than 154,000 structures were flooded, 37,000 people needed temporary shelter, and 22,000 people were rescued from floodwaters (Harris County Flood Control District, 2018; Jonkman et al., 2018). Throughout the Houston metropolitan area, over 70 fatalities were reported (Sebastian et al., 2017). While much is known about the immediate effects of the hurricane on displacement and short-term morbidity (Norris et al., 2010; Taioli et al., 2018), our understanding of the long-term mental health consequences of Hurricane Harvey remains limited.

Exposure to a severe natural disaster such as a hurricane is associated with increases in stress, anxiety disorders, depression, and posttraumatic stress disorder (PTSD) (Goldmann and Galea, 2014; Lowe et al., 2015). In the aftermath of hurricanes, increases in the prevalence of mental health sequelae have been observed across diverse populations (Neria and Shultz, 2012). Accordingly, factors that may mitigate the mental health consequences of hurricanes (e.g., public health programs and regenerated urban centers and landscaping) need to be identified to inform interventions and programs to reduce the mental health consequences of hurricanes (Shultz and Galea, 2017).

One promising approach to mitigating post-disaster distress is related to the salutogenic effects of green space. For example, exposure to nature and green space has consistently been associated with increased coping skills among disadvantaged populations (Roe et al., 2013; Ward Thompson et al., 2012). Green space may also serve as a treatment for populations who have experienced traumatic events (Poulsen, 2017; Poulsen et al., 2016). However, while urban policies increasingly promote green infrastructure for stormwater mitigation in vulnerable coastal communities (I. Karaye et al., 2019a; Newman et al., 2020), these policies neglect the potential for green infrastructure to improve mental health, missing opportunities to further improve community resilience and enhance disaster preparedness through multi-functional environmental interventions.

In this study, we examine the extent to which concentration of greenness and perceived quality of neighborhood green space are associated with lower levels of post-hurricane stress and investigate the potential mechanisms through which this effect occurs. This study contributes to the literature by exploring the potential mental health benefits of access to and

quality of green space in the aftermath of one of the most extensive flooding events in recent years. We also draw on established theories to investigate the presence and magnitude of indirect pathways through which green space may affect mental health.

### 1.1. Post-hurricane PTSD and distress

Hurricanes are large-scale traumatic events that have been associated with psychological consequences, including increasing rates of PTSD, subclinical PTSD, anxiety, stress, depression, and emotional and mood disturbances (Manne et al., 1998; Yarvis and Schiess, 2008). In communities affected by Hurricane Katrina, elevated incidences of anxiety-mood disorders, PTSD, and suicidal thoughts were reported (Galea et al., 2007; Kessler et al., 2008a). Several studies have called attention to the mental health impacts of Hurricane Harvey (Shah et al., 2018; Shultz and Galea, 2017). Three weeks post-Hurricane Harvey, probable PTSD was reported by 46% of participants in heavily affected areas (Schwartz et al., 2018). Additionally, Gulf Coast area residents exposed to Hurricane Harvey reported poorer mental health than the U.S. average 3–15 months after Harvey; however self-reported mental component scores were higher among those with higher perceptions of surge risks (I. M. Karaye et al., 2019b).

Research on PTSD has traditionally focused on transient, short-term trauma, but recent evidence has highlighted the prevalence of delayed-onset PTSD, and long-term mental health issues. For example, in an assessment conducted between 14 months and 14 years after a hurricane, Smid et al. (2012) found that 29% of participants experienced delayed-onset PTSD. Among residents of the New Orleans metropolitan area, the prevalence of PTSD was significantly higher (20% versus 11.8%) one year after Hurricane Katrina (Kessler et al., 2008a). Although trauma-related stress and other symptoms may decrease in prevalence over time, this may not be the case among disadvantaged communities and lower-income populations (Chen et al., 2015; Paxson et al., 2012). For example, in a sample of minority youth affected by Hurricane Katrina, PTSD symptoms peaked between 24 and 30 months post-disaster (Weems et al., 2010).

### 1.2. Factors related to post-hurricane PTSD and distress

Besides hurricane exposure, other factors have been shown to be associated with post-disaster post-traumatic symptoms, such as demographic and socioeconomic (SES) factors. Decline in SES following Hurricane Katrina was associated with major depressive disorders, even after adjusting for disaster exposure (Joseph et al., 2014). Larger SES disparities, financial losses, and post-disaster social stressors were also associated with post-Katrina mental health (Galea et al., 2008; Kessler et al., 2008b; Sastry and VanLandingham, 2009).

Another individual-level factor related to the severity of PTSD symptoms is emotional resilience. Emotional resilience, otherwise labeled psychological resilience or resilience, is rooted in positive psychology and defined as the self-adjustment and recovery from stress and restoration of well-being and positive emotions (Bonanno, 2004; Karaırmak, 2010; Seligman and Csikszentmihalyi, 2000). After Hurricane Katrina, the likelihood of being resilient to PTSD varied across levels of disaster exposure, race, age, and marital status (Harville et al., 2010). For mothers of small children, trait resilience mitigated some of the

negative effects of hurricane exposure when mothers were exposed to multiple disasters (Harville et al., 2011). These studies suggest emotional resilience as a potential protective factor of post-disaster mental health.

Community context can also be an important determinant of recovery trajectory from disaster-induced trauma. After a disaster, individuals rely on multi-level support structures for resources, coping strategies and skills, and psychological well-being (Jose et al., 2019; Walsh, 2011). Unlike many types of personal life-event-induced trauma, a hurricane is a shared adversity which people in the neighborhood experience together (Norris et al., 2011). Therefore, social support is critical. For residents exposed to Hurricane Sandy or Katrina, greater social cohesion was linked to lower reported PTSD symptoms (Heid et al., 2017; Lê et al., 2013). The setting impacts behavior and social relationships (Barker, 1968; Heft, 2001); however, less is known about the neighborhood environmental characteristics that support social cohesion and the collective recovery process.

### 1.3. The role of neighborhood greenness

Over the past decade, a growing body of research has identified mental health benefits of green space, including positive mood, less stress and anxiety, less aggression, and improved life satisfaction and psychological well-being (Bratman et al., 2012; Craig and Prescott, 2017; Gascon et al., 2015). Recent studies have reported on the role of access to nature in mitigating symptoms of several mental disorders defined in the Diagnostic and Statistical Manual of Mental Disorders (DSM-5), including depressive disorder (Bezold et al., 2018), anxiety disorders (Mackay and Neill, 2010), attention deficit disorder (Kuo and Faber Taylor, 2004), and autism (Li et al., 2019). Although only one research has examined the effects of neighborhood contextual greenness on PTSD quantitatively (Block et al., 2019), nature therapies have helped veterans with PTSD by increasing self-efficacy, feelings of calmness and security, and reducing symptoms (Poulsen et al., 2015, 2016).

Two foundational theories may explain why exposure to green space can benefit those recovering from traumatic stress: Attention Restoration Theory (ART) and Stress Reduction Theory (SRT). ART suggests that exposure to green space restores the cognitive resources that support executive functioning (R. Kaplan et al., 1998; S. Kaplan, 1995), which is required for the majority of daily tasks, including coping, planning, and carrying out actions. Similarly, SRT posits that contact with green space supports recovery from physio-psychological stress by inducing pronounced activity of the parasympathetic nervous system and positive-toned emotions (Ulrich et al., 1991). The benefits of higher density of greenness and better-perceived quality have both been recognized (Engemann et al., 2019; Van Dillen et al., 2012), although recent studies have emphasized that human-environment transaction and affective dimensions are critical to mental benefits, rather than the physical characteristics alone (Scopelliti and Giuliani, 2004; Tillmann et al., 2018). For example, studies showed the quality of the neighborhood green space and street greenness was more important than the quantity (Feng and Astell-Burt, 2018; Francis et al., 2012; Van Dillen et al., 2012). Drawing upon these theories, we hypothesize that concentration of greenness and perceived quality of neighborhood green space may be related to post-disaster PTSD directly and through two indirect pathways.

The emotional resilience pathway. Building upon SRT, many studies have demonstrated that exposure to natural scenes can buffer the impacts of stressful events and promote positive emotions (Roe et al., 2017; Ward Thompson et al., 2016). Emotional resilience has been reported to be related to coping and protect against mental health disorders (Denny et al., 2004; Gloria and Steinhardt, 2016). Although evidence on adults is lacking, the effects of nature on emotional resilience have been discussed for child populations. For example, attending a forest school or living in a greener neighborhood are shown to be positive factors for emotional resilience among children (Blackwell, 2015; Flouri et al., 2014).

The social cohesion pathway. Another possible mechanism through which community green space helps relieve stress is by enhancing community ties and social cohesion. The use of outdoor common space strengthens social ties and sense of community (Holtan et al., 2015; Kaźmierczak, 2013; Kweon et al., 1998), which predict PTSD recovery (Glass et al., 2009). Community green spaces can potentially facilitate recovery through strengthened social cohesion.

The central hypothesis of this study is that greater concentration of greenness and perceived quality of green space are related to lower levels of PTSD after Hurricane Harvey. These relationships are mediated by stronger emotional resilience and social cohesion. The conceptual framework of this study is illustrated in Fig. 1.

## 2. Methods

### 2.1. Sampling and survey mode

To test our hypothesis, we conducted a survey using a multi-stage sampling approach in Houston neighborhoods 24–28 months after Hurricane Harvey impacted the area (Fig. 2). First, we identified block groups that a) had a building inundation rate of more than 50% during Hurricane Harvey and (b) had at least one block consisting primarily of residential units. Using the Harvey max inundation data from Harris County Flood Control District, this process ensured that we sampled the neighborhoods where residents were heavily impacted during Hurricane Harvey. This yielded 89 block groups (representing the top impacted 6.7% of all block groups with centroids in the City of Houston). Next, we drew from that list a sample of 30 block groups based on percent Hispanic population and median household income to ensure representativeness of the socio-demographic conditions of all block groups enduring severe loss during Hurricane Harvey. These 30 block groups were treated as clusters. The average population represented by the 30 block groups was 1601. Then, we employed address-based sampling (ABS) in the 30 block groups using computerized delivery sequence files, with sampling probability proportional to the number of households in each block group. The ABS sampling ensured good coverage of households, distinguished between residential and business locations, and provided opportunities for geo-referenced data management and geospatial analysis. An initial sample of 4850 addresses was selected, and individuals from households were not randomly selected due to challenges related to tracking and verification.

Between August 2019 and December 2019, a mailed survey packet and two postcard reminders were sent to each sampled household. The survey packet included an information

sheet, survey booklet, and postage paid return envelope. Between November and December 2019, block groups that showed lower than average response rates were randomly selected to be visited by the researchers. Selected households were given survey packets face-to-face and invited to participate. Participants were eligible if they had lived at their current address since June 2017. Only one person (18+ years old) from each household was allowed to participate. Eligible participants could choose between a paper survey and an electronic web survey. Both English and Spanish versions of the survey were provided. Ethical approval for the study was given by the Human Research Protection Program at [name of university removed for blind review]. A total of 272 valid responses were received (209 mail and 63 online). Among the 4850 mailed packets, 431 (8.89%) were returned by USPS due to address undeliverable (recently deserted or demolished) or vacant. Our eligibility criteria required that a participant had lived in the current address since June 2017. According to the residency history (year householder moved into unit) from the ACS 5-year estimate, 15.20% of occupied housing units showed a less than 2-year residency. Based on these data, we estimated that there were 3747 () eligible households, and the response rate was 7.3%.

## 2.2. Measures

**Probable PTSD.—**Probable PTSD was assessed using the Posttraumatic Stress Disorder Checklist for DSM-5 (PCL-5) (Blevins et al., 2015; Weathers et al., 2013). Developed in the 1990s at the National Center for PTSD, PCL (Weathers et al., 1993) is one of the mostly widely used self-report scales for PTSD. PCL-5 was updated to reflect changes in the DSM-5 (Association, 2013) and has demonstrated strong reliability and validity (Blevins et al., 2015). The scale includes 20 items, each using a 5-point scale, concerning how much participants have been bothered by individual PTSD symptoms over the past month. Two methods for determining PTSD from PCL-5 responses have been proposed (Weathers et al., 2013): using a numeric cutoff on the summary score or scores based on the DSM-5 symptom clusters. We adopted the second method for its close alignment with the official definition of PTSD (Blevins et al., 2015).

**Hurricane-Related Distress.—**We used the Impact of Event Scale (IES-R), which consists of 22 questions (Creamer et al., 2003; Horowitz et al., 1979) that measure subjective response to a specific traumatic event and has been used in research on hurricanes and other disasters (Fussell and Lowe, 2014; Paxson et al., 2012). The scale asks respondents to “indicate how distressing each difficulty has been for you with respect to Hurricane Harvey”. It includes three subscales: intrusion (e.g. undesired memories, flashbacks, and nightmares), avoidance (e.g. avoiding prompts related to the trauma), and hyperarousal (e.g. irritability, aggression, and difficulty concentrating). For the three subscales, summary scores were calculated and used as the outcome measures following existing studies (Morris and Deterding, 2016; Shevlin and McGuigan, 2003).

**Hurricane Exposure.—**To assess hurricane exposure, we adapted a questionnaire used in a study examining mental health recovery after Hurricane Andrew (Norris et al., 1999; Xiong et al., 2010). Participants indicated which stressors they experienced in relation to Hurricane Harvey: feeling that one’s life was in danger, experiencing illness or injury to self or a family member, walking through floodwaters, severe home damage, not

having electricity for more than one week, having a loved one die, or seeing someone die. These items represent the most traumatic experiences related to a hurricane and are well in line with the stressor definitions of DSM-5 PTSD, which include direct exposure to or witnessing death, injury, or other life-threatening conditions (American Psychiatric Association, 2013). We used the total count of stressors each participant experienced to represent severity of hurricane exposure.

**Perceived Quality of Neighborhood green space.—**We measured perceived neighborhood greenness using self-report to capture the quality of the environment most relevant to participants. We adapted the Neighborhood Open Space (NOS) Scale (Sugiyama and Thompson, 2008; Ward Thompson and Aspinall, 2011) by removing the items less relevant to our study area such as beach and attractive water area, and items not related to green space. Our scale consisted of nine questions that cover access (accessible green space), amenities (good facilities, trees and plants, relaxing), safety (free from crime, safe after dark), and potential for activities (child activity, chatting and social activity) measured on a 5-point scale (Appendix I; Table SI). We conducted a pretest with 31 adult participants using this nine-item scale, and the data yielded a one-component model based on eigenvalue greater than 1 (Kaiser, 1960), with all nine items loaded > 0.4 onto the primary component. Based on our final survey data, a confirmatory factor analysis showed satisfactory item loadings (between 0.61 and 0.84) and fit indices (CFI > 0.9, RMSEA < 0.08) onto a one-component latent variable of perceived quality of neighborhood green space (Appendix I; Fig. SI). Therefore, a mean summary score was calculated. The Cronbach's alpha of the nine-item scale was 0.879.

**Concentration of neighborhood greenness.—**We used the Normalized Difference Vegetation Index (NDVI) as the objective measure of neighborhood greenness to compare with the results from perceived quality of green space. The NDVI value ranges between 0 (completely barren) and 1 (very dense green), with negative values set to non-green space. Multispectral orthophotography from the National Agriculture Imagery Program (2016) was used as the data source, which has a spatial resolution of 1 m. The mean NDVI value within a 1000 m buffer radius from each participant's residence was calculated by averaging across the buffer zone.

**Emotional Resilience.—**Participants' emotional resilience was measured using the ten-item unidimensional Connor-Davidson Resilience Scale-Brief (DC-RISC) (Campbell-Sills and Stein, 2007). A sum score was created for emotional resilience.

**Neighborhood Social Cohesion.—**We assessed perceived social cohesion with a scale used in previous research establishing links between neighborhood social cohesion and health outcomes (Mair et al., 2010; Sampson et al., 1999). The scale consists of five items that assess inter-personal relationships, such as whether people can be trusted and are willing to help each other (Appendix I; Table SI). A mean score was created for social cohesion.

**Covariates.—**Neighborhood socioeconomic disadvantage (NSES) was calculated using six variables extracted from American Community Survey (2017) five-year estimates at the block group level: low educational attainment (less than high school), unemployment,

poverty, receiving assistance, single-parent household, and median income. The higher the NSES value, the more socioeconomically disadvantaged the neighborhood. Individual-level control variables collected as part of the survey included age, gender, ethnicity, race, education, employment, marital status, household income, housing, and length of residency.

### 2.3. Statistical analyses

Descriptive statistics were generated to explore the distributions of the study variables. Correlation coefficients were calculated to assess bivariate relationships and identify potential problems with multicollinearity. Multivariate models were fitted to estimate odds ratios for probable PTSD and coefficients for hurricane-related distress. Continuous variables were tested for normality using a Shapiro-Wilk test and transformed as needed. The generalized linear mixed models predicted probable PTSD and hurricane-related distress by greenness by considering the clustering effects of individuals nested within neighborhoods (i.e., block group). Intraclass correlation coefficients (ICCs) were examined. The ICCs of the base models were between 0.093 and 0.249, which warranted the use of multi-level models. After performing exploratory plots to decide on the types of random effects in model specifications, we fitted mixed models with random intercepts. The models were adjusted for control variables that may impact PTSD, including hurricane exposure, individual-level demographics, socio-economic factors, and neighborhood socioeconomic disadvantage. Given the identification of a significant direct effect of greenness on probable PTSD, the hypothesized mediating variables were later entered into the model; resulting changes in coefficients suggested a possibility of mediation.

After fitting the individual models, a path analysis following the conceptual framework in Fig. 1 was used to statistically test the mediations and simultaneously assess the strengths of the direct and indirect effects. We examined the coefficients for direct, indirect, and total effects and determined model fit based on the relative fit index CFI and the absolute fit indices RMSEA and SMRM. We employed 95% bias-corrected confidence intervals based on bootstrapping as the basis for statistically significant mediating effects. All analyses were done using R packages.

## 3. Results

### 3.1. Characteristics of participants

Data were collected from 272 participants spanning 30 neighborhoods (Table 1). Nearly two-thirds (n = 177; 62%) of respondents were female. The median age of respondents was 55 (Range: 18–98). Caucasian participants made up 67% (n = 165) of the sample and African American participants made up about 10% (n = 27). Approximately 29% (n = 75) of respondents reported Hispanic ethnicity. Most respondents were well-educated – more than half (58%; n = 154) reported they had obtained a bachelor's degree or graduate degree – and about half had a household income of over $75,000 (50%; n = 124; compared to the median household income of $ $51,140 in the City of Houston). About half of the respondents were employed full-time (47%; n = 124), and 25% (n = 67) being full-time students or retired.

Participants' hurricane exposure and probable PTSD conditions are displayed in Fig. 3. Approximately 18% did not experience any of the seven hurricane-related stressors. Among those who reported at least one stressor, "walking through floodwaters" (58%) and "feeling your life was in danger" (41%) were most common, followed by "severe home damage" (36%) and "not having electricity for more than a week" (24%). Stressors related to morbidity or mortality were less common, with 16.2% reporting illness or injury to self or family and fewer than 4% having lost a loved one or seen someone pass away. About one quarter of participants reported evidence of probable PTSD.

### 3.2. Bivariate relationships between key variables

Table 2 displays a correlation matrix among key variables. Greater exposure to hurricane stressors was associated with higher levels of the summary score of hurricane-related distress ($r(270) = 0.462$) and all three subscales: intrusion ($r(270) = 0.425$), avoidance ($r(270) = 0.423$), and hyperarousal ($r(270) = 0.410$).

Positive factors related to lower levels of distress were emotional resilience, perceived quality of neighborhood green space, and social cohesion. Specifically, emotional resilience was significantly negatively related to distress ($r(270) = -0.311$), intrusion ($r(270) = -0.247$), avoidance ($r(270) = -0.254$), and hyperarousal ($r(270) = -0.365$). Meanwhile, perceived quality of green space was negatively correlated with distress ($r(270) = -0.179$), intrusion ($r(270) = -0.147$), and hyperarousal ($r(270) = -0.246$), although magnitudes varied across subscales. The strongest relationship was with hyperarousal. NDVI was significantly correlated to perceived quality of green space ($r(270) = 0.177$) and hyperarousal ($r(270) = -0.140$). Finally, social cohesion was significantly negatively associated with distress ($r(270) = -0.129$) and hyperarousal ($r(270) = -0.192$); but not related to avoidance ($r(270) = -0.112$) or intrusion ($r(270) = -0.065$).

### 3.3. Perceived quality of green space, probable PTSD and hurricane-related distress

Based on the results of the correlation, we fitted linear mixed models with random intercepts to predict emotional resilience and social cohesion (Table 3). In Model 1, perceived quality of greenness was a statistically significant correlate of emotional resilience ($\beta = 0.136$, 95% CI: 0.003, 0.270). Another factor that was predictive of emotional resilience was part-time versus full-time employment ($\beta = -0.651$, 95% CI: −1.224, −0.077). In Model 2, perceived quality of green space was also statistically significantly associated with social cohesion ($\beta = 0.341$, 95% CI: 0.228, 0.454). Several demographic and SES covariates were also related to social cohesion, including age, gender, income, and neighborhood disadvantage.

Is perceived quality of green space associated with probable PTSD? To answer this question, we fitted generalized linear mixed models with logit links (Table 4). Model 3 assessed the association between perceived quality of green space and the odds of probable PTSD after adjusting for hurricane exposure, individual-level demographics and SES, and neighborhood disadvantage. Greater exposure to Hurricane Harvey was associated with a higher likelihood of probable PTSD (OR = 1.425, 95% CI: 1.090, 1.863), while perceived quality of neighborhood green space correlated with lower odds of probable PTSD (OR = 0.610, 95%

CI: 0.422, 0.833). Among the covariates, students reported a decreased likelihood compared to full-time employees.

Are emotional resilience or social cohesion associated with probable PTSD? Models 4–5 included emotional resilience and social cohesion factors. In Model 4, stronger emotional resilience was related to lower likelihood of probable PTSD (OR = 0.403, 95% CI: 0.248, 0.653). Meanwhile, the OR of perceived quality of neighborhood green space increased from 0.610 to 0.649, and both the confidence interval moved closer to zero and level of significance dropped, suggesting a potential mediating effect of emotional resilience. In Model 5, however, the coefficient of social cohesion was not statistically significant (OR = 0.833, 95% CI: 0.533, 1.300), indicating no pathway from perceived quality of green space through social cohesion. Based on these results, direct and indirect paths were later statistically tested using a path model (see Fig. 4 below).

Is perceived quality of green space associated with hurricane-related distress? We fitted linear mixed models to predict the intrusion, avoidance, and hyperarousal subscales of hurricane-related distress. Table 5 shows that perceived quality was significantly associated with hyperarousal (Model 6, β = −0.137, 95% CI: −0.264, −0.010), but not with intrusion or avoidance (see Appendix II; Table SII). After entering emotional resilience into the model (Model 7), the effect of perceived quality of green space became statistically insignificant (β = −0.094, 95% CI: −0.217, 0.029), and emotional resilience instead demonstrated significant association with hyperarousal (β = −0.287, 95% CI: −0.410, −0.164). However, Model 8 showed social cohesion was not a significant correlate of hyperarousal (β = −0.0.009, 95% CI: −0.160, 0.142). These results suggest that the relationship between perceived quality of green space and hyperarousal might be mediated by emotional resilience, but not by social cohesion. Regarding the covariates, African Americans and the self-employed also showed higher hyperarousal compared to Caucasians and full-time employees. Direct and indirect paths were later tested using a path model (see Fig. 4 below).

How does perceived quality of neighborhood green space play a role in mental health? Based on the hypothetical framework and the results from previous models, we assessed two final path models to test the statistical significance and compare the magnitude of the direct and indirect paths (Appendix III; Tables SIII-a and SIII-b). Both models showed satisfactory fit indices: CFI >0.9, RMSEA <0.08, and SRMR <0.08 (Bentler, 1990; Browne & Cudeck). Fig. 4 displays the standardized coefficients of the paths. For probable PTSD, perceived quality of green space had a statistically significant total effect (β=−0.181, 95% CI: −0.325, −0.038), direct effect (β = −0.168, 95% CI: −0.319, −0.016), and a marginally significant partial mediation through emotional resilience (β = −0.039, 95% CI: −0.079, 0.002). However, the indirect effect through cohesion was not statistically significant (β = 0.025, 95% CI: −0.032, 0.081). For hurricane-related distress, the findings were consistent with the individual linear mixed models. After accounting for all variables, the total effect of perceived quality of green space on hyperarousal was significant (β = −0.121, 95% CI: −0.242, −0.001) and transmitted through emotional resilience β = −0.041, 95% CI: −0.080, −0.003). Although perceived quality of greenness had a significant effect on cohesion β = 0.293, 95% CI: 0.175, 0.410), the path from cohesion to hyperarousal was insignificant, leading to an insignificant indirect effect (β = 0.022, 95% CI: −0.014, 0.059).

### 3.4. NDVI, probable PTSD, and hurricane-related distress

To examine whether the findings hold when using objectively measured neighborhood greenness rather than perceived quality of green space, we fitted models predicting probable PTSD and hurricane-related distress-subscales (Table 6), using NDVI measures, along with all covariates controlled in previous models. The results showed that NDVI was not associated with probable PTSD (OR = 0.818, 95% CI: −0.247, 2.707), but was significantly negatively related to hurricane-related distress (β = −0.155, 95% CI: −0.276, −0.034). Greater concentrations of vegetation in the neighborhood were linked to lower levels of hurricane-related hyperarousal symptoms. NDVI was not associated with emotional resilience or social cohesion, and therefore ruling out the possibility of mediation effects through emotional resilience or social cohesion.

## 4. Discussion

### 4.1. Findings and interpretations

Although much is known about the expected increases in the prevalence of mental distress after disasters, less is known about the role the environment may play in mitigating these mental health sequelae in hurricane-impacted communities. Prior studies have explored the potential positive effects of neighborhood greenness on mental health, including stress, anxiety, mood, and depression (Balseviciene et al., 2014; Li et al., 2018; Sarkar et al., 2018), however, this work is the first to examine evidence of the protective effects of greenness in the context of hurricane-related PTSD. To examine whether greater green space in Hurricane Harvey impacted Houston neighborhoods was associated with lower incidence of probable PTSD, a cross-sectional survey was used. After adjusting for hurricane exposure, demographics, and multi-level socioeconomic factors, we found a statistically significant association between perceived quality of neighborhood green space and the likelihood of having PTSD two years after the disaster event. Specifically, greater access to and quality of neighborhood green space lowered the likelihood of probable PTSD. Our findings are in concert with recent studies that examine nature and PTSD. For example, literature on nature therapy (Greer and Vin-Raviv, 2019; Nadeau, 2019; Poulsen, 2017; Poulsen et al., 2016) suggests that nature may serve both as a treatment strategy and an in-situ salutary factor for populations with PTSD.

However, we found that the concentration of neighborhood greenness was associated with hurricane-related distress, but not probable PTSD. The salient findings from perceived neighborhood green space, rather than objectively measured concentration of nature may be explained by findings that the restorative benefits of nature depend on the actual activity and affective states (Scopelliti and Giuliani, 2004). As such, if an individual is unaware of or unexcited about the green space and/or would not use it, the benefits are likely to be weaker. This is in line with findings that suggest perceived quality of green space contributes additionally to health and emotional well-being (Marselle et al., 2015; Van Dillen et al., 2012). Studies in the disaster recovery setting also demonstrated the importance of the perceptive aspect of human-nature connection: earthquake amplified residents' perceptions of the landscape and related emotions (Bowring, 2013), and the attachment to the natural

environment was associated with fewer self-reported symptoms of depression and PTSD after bushfires (Block et al., 2019).

When considering the mental health impacts of Hurricane Harvey, it should be noted that green space was not consistently related to all sub-dimensions of distress. Higher concentration of greenness and perceived quality were associated with lower hyperarousal (i.e. irritability, aggression, heightened startle reaction, difficulty concentrating, and having physical and physiological reactions). This may be explained by the Stress Recovery Theory (SRT), which states that after experiencing a stressor, the restorative characteristics of natural scenes can promote a more positively-toned emotional state by reducing physiological and psychological arousal (Ulrich et al., 1991). However, no associations were identified between greenness and intrusion or avoidance, which are related to the cognitive encoding of the stressor (Brewin, 2015) or to behavioral avoidant coping strategies (Dempsey et al., 2000). Notably, no theory suggests that these mechanisms are influenced by exposure to natural environments.

We found emotional resilience as a possible mechanism for the protective effects of perceived quality of neighborhood green space on probable PTSD, which adds to the evidence of the link between nearby nature and emotional resilience (Buchecker and Degenhardt, 2015; Flouri et al., 2014). Prior studies proposed that exposure to nature may protect one from future stressful events similar to how a vaccine provides an immunization benefit (Hartig et al., 1991; Parsons et al., 1998). More recent literature has also framed nature as a buffering or protective factor for stressful events (Van den Berg et al., 2010). This protective or immunity effect could manifest as emotional resilience. Literature on children also suggests that nature forms a protective contextual factor which can improve resilience (Chawla et al., 2014; Razani et al., 2019). Our findings expand the discussion of neighborhood green space and emotional resilience to adults.

Although perceived quality for green space was associated with social cohesion (Kweon et al., 1998), social cohesion was not related to probable PTSD in this study as it has in several prior studies (Gapen et al., 2011; Glass et al., 2009). It may be that the effects were accounted for by individual and neighborhood SES. Alternately, social cohesion and mental health may only have significant and salient relationships during specific time periods. For example, Weil at el. (2012) found that the most socially-involved people showed more stress right after Hurricane Katrina, but displayed faster recovery over time.

### 4.2. Policy implications

As the first study examining the mental health effects of perceived quality of neighborhood green space in a hurricane recovery context, this study suggests some implications for public health, disaster recovery, and planning policies, which should consider concentration and quality of green space as a potentially positive environmental factor contributing to resilience. Studies examining the neighborhood physical environment related to natural disasters (Berry et al., 2010; Freedy et al., 1993; Kõlves et al., 2013) frequently rely on the premise that exposure to environmental hazards is detrimental to health (pathogenesis). The current study instead explores environmental factors that may play a role in positive health outcomes (salutogenesis) and points out that access to restorative environments such

as green space should be a part of the health disparities discussions after disasters. If the exploratory results presented here are confirmed by future experimental studies, community green space as a low-cost public amenity can be utilized to reduce inequalities and promote mental well-being and preparedness for at-risk populations.

Recently, interest has surged in regional, city-wide, and community disaster recovery or resilience plans (Jabareen, 2013; Woodruff, 2016). However, while recognizing the ability of green infrastructure to retain, absorb, and cleanse stormwater, they may neglect to include potential health benefits (Desouza and Flanery, 2013) instead relying on a more narrow range of ecosystem benefits. To maximize the benefits of community green space in recovery and resiliency planning, we must recognize its health-related roles. The importance of perceived quality of green space is in line with the cultural ecosystem services framework, where the appraised condition of the green space may have strong ties with the aesthetic and recreational experiences of users.

### 4.3. Limitations and directions for future studies

This study has several limitations. First, the onset and trajectory of PTSD involve complex temporal patterns that cannot be measured using a cross-sectional study design. A longitudinal study design with panel data collection and growth curve modeling may better reveal the development of PTSD and the influence of greenness. Second, probable PTSD and distress were measured using self-reported screening tools validated against clinical diagnoses. Future studies may include a review of clinical records to yield more accurate information. Pre-event mental health often is directly associated with post-disaster PTSD, and needs to be assessed in future studies. Third, our perceived neighborhood green space measure captures some aspects of attractiveness and affordances of green space, but may not cover all the qualitative dimensions of green space. It also does not distinguish views of surrounding nature from physically accessible nature in the neighborhood. Future studies can consider including more nuanced self-reported green space measures that account for different levels of exposure to and use of neighborhood green space. Fourth, while we attempted to increase the response rate and promote a balanced sample through face-to-face recruitment in low-response neighborhoods, the response was low and biased toward older, white, and medium-to-high SES populations. The response rates differed across block groups, leading to uneven coverage at the block group level, which might have contributed to the nonsignificant results related to the social cohesion measure. The frequently mentioned reasons for unit nonresponse included no interest in the study or incentive; difficult to find time to complete the survey; and burden from multiple Hurricane Harvey-related survey solicitations. More diverse survey modes that include telephone surveys or computer-assisted methods may be used in future surveys. Well-coordinated cross-institutional research efforts and commitments to give back to the communities that assist also need to be part of the study design. Future studies in areas with diverse demographic groups can also focus more on SES strata to compensate for the fact that the medium-to-high SES group have higher response rates than other populations. Finally, in our analysis of Hurricane Harvey exposure, all seven exposure factors (e.g., walking through floodwaters, severe home damage) were given equal consideration. Future studies can take into account the level of severity of the different stressors, as well as participants' history

of other hurricane exposures. This study did not consider those displaced due to Hurricane Harvey and did not return, who may have experienced the most adverse mental health effects. Future studies should adopt more flexible and diverse sampling approaches to gain access to this population.

## 5. Conclusion

Although prior studies have explored the potential positive effects of neighborhood greenness on mental health, including stress, anxiety, mood, and depression, the current study is the first to examine evidence of the protective effects of greenness in the context of hurricane-related PTSD. Living in neighborhoods with greater perceived quality of green space is associated with lower levels of post-hurricane distress, especially through the emotional resilience pathway. These findings suggest more attention should be paid to the benefits of perceived quality of neighborhood green infrastructure in the disaster recovery policy framework.

## Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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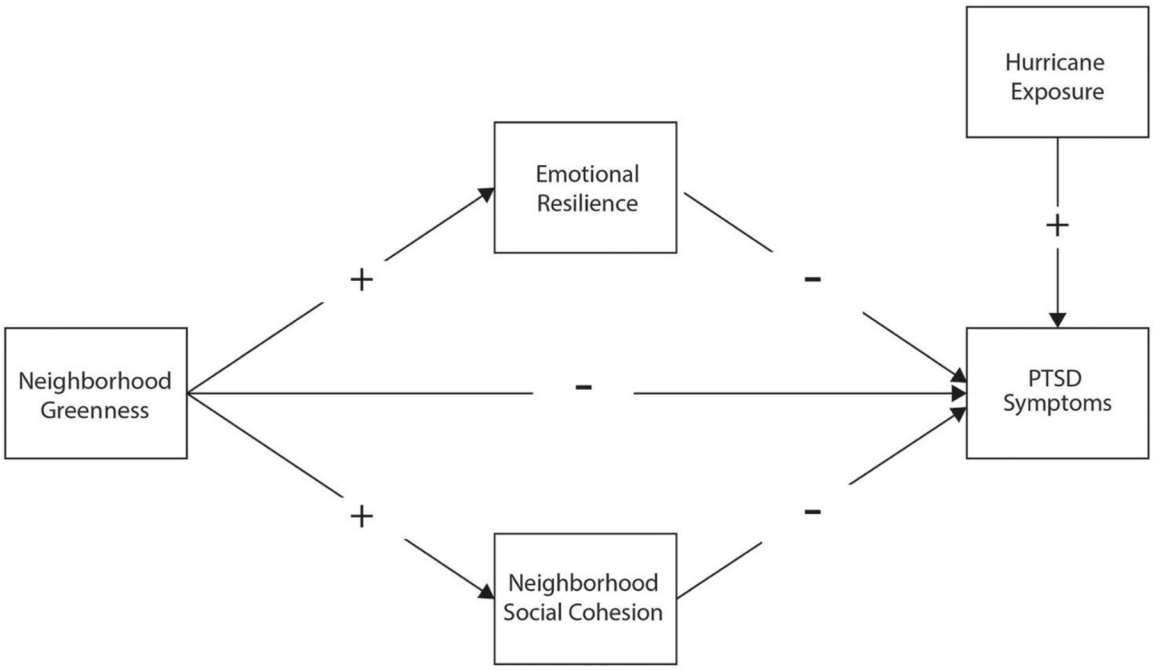


**Fig. 1.**
Conceptual framework of direct and indirect paths predicting PTSD

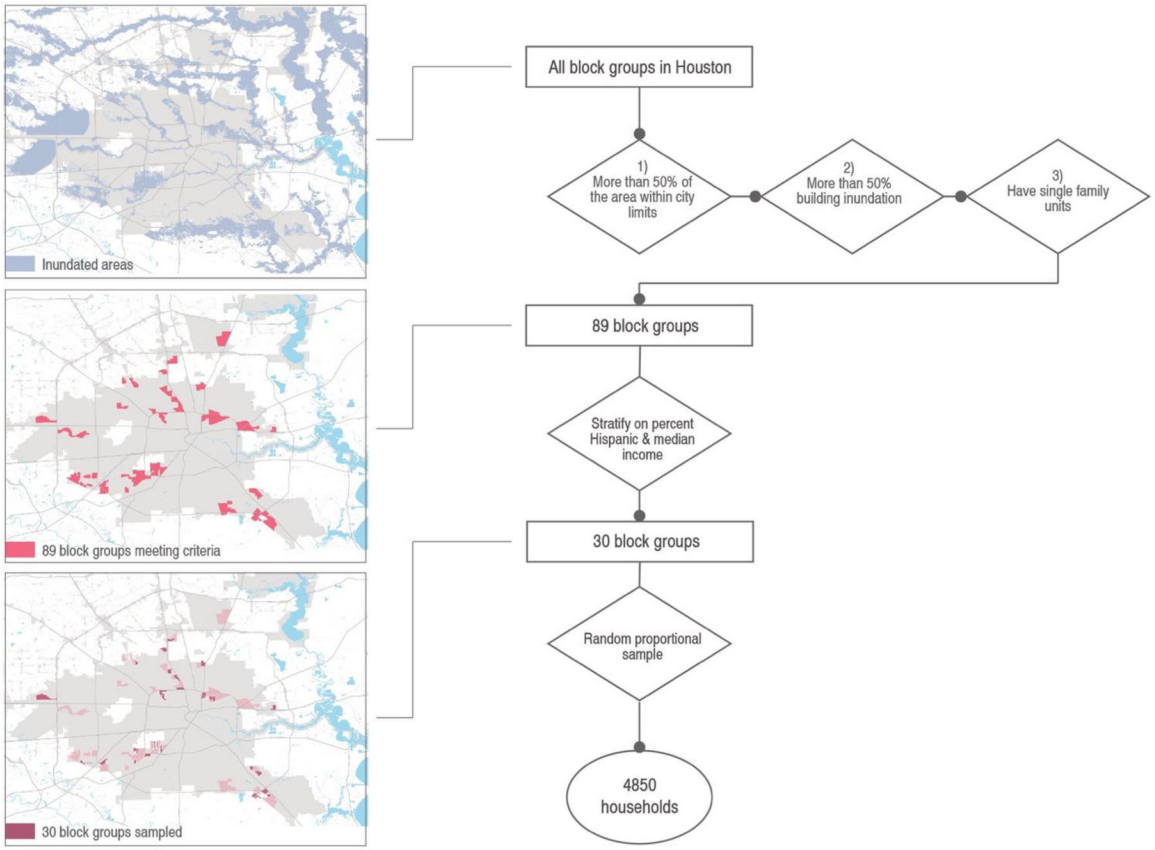


**Fig. 2.**
Sampling frame and neighborhoods sampled.

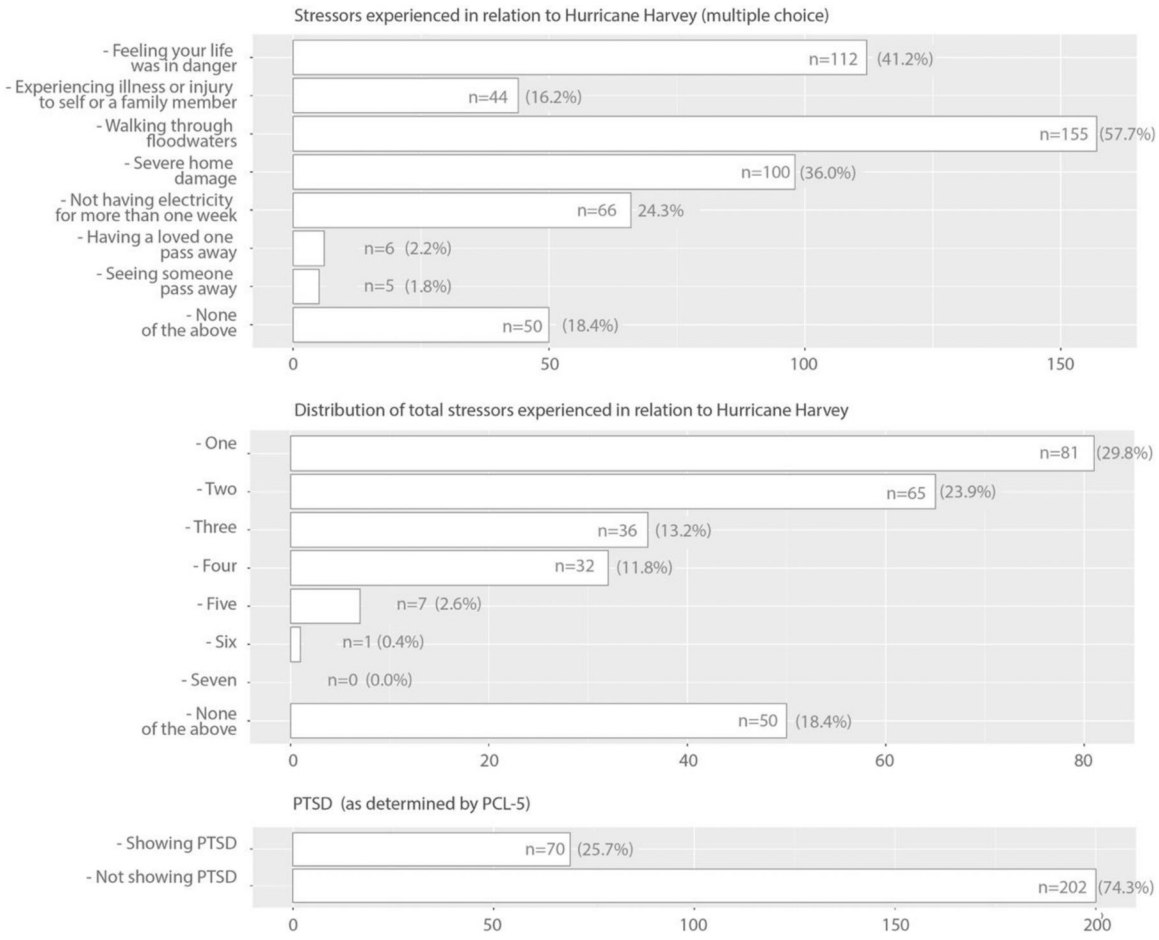


**Fig. 3.**
Participants' hurricane exposure and PTSD

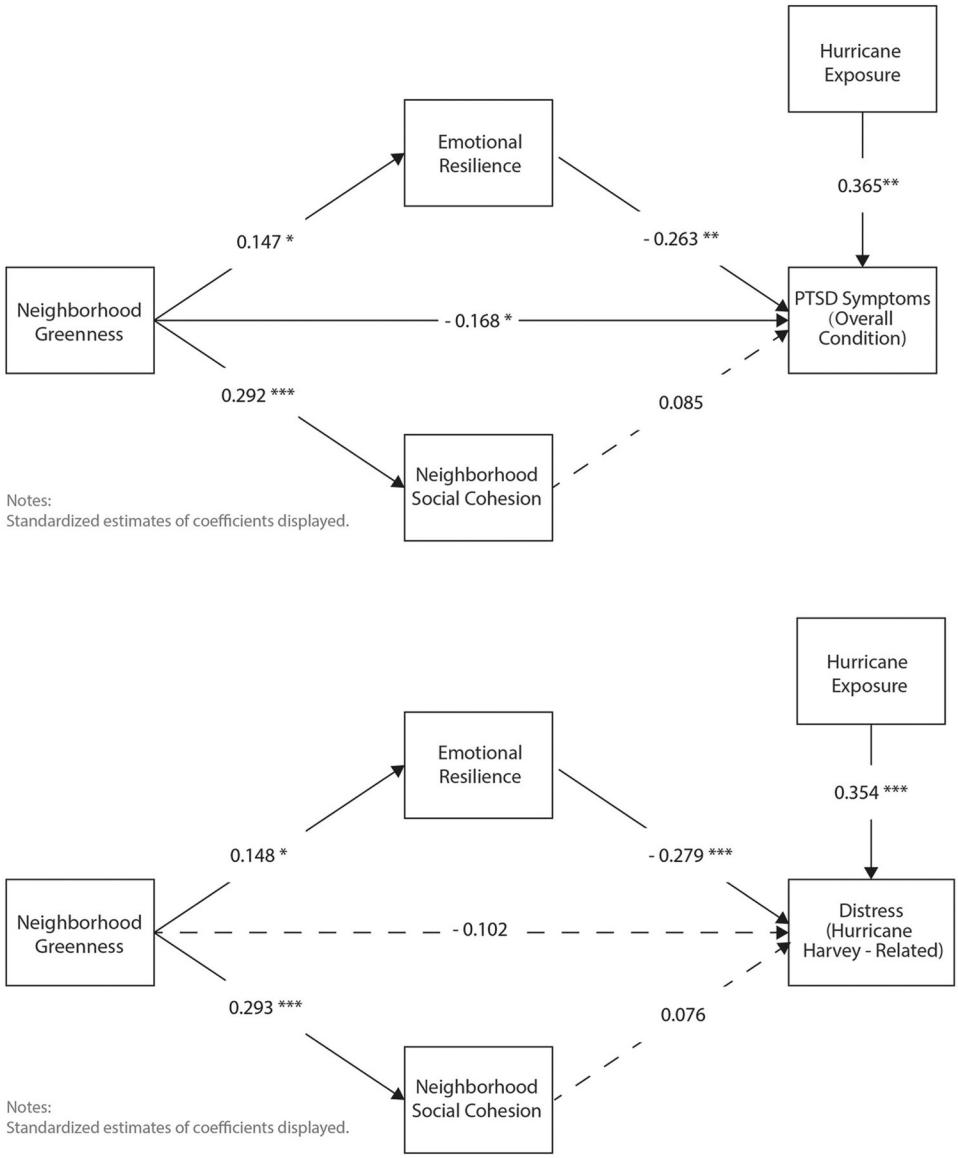


**Fig. 4.**

Final path model results showing direct and indirect paths between greenness and PTSD

**Table 1.**

Descriptive statistics of the sample.

| Statistic | N | Mean | St. Dev. | % |
|---|---|---|---|---|
| Age | 266 | 54.48 | 1.06 | |
| Gender | | | | |
| Male | 100 | | | 37.70% |
| Female | 165 | | | 62.30% |
| Ethnicity | | | | |
| Hispanic | 75 | | | 28.50% |
| Non-Hispanic | 188 | | | 71.50% |
| Race | | | | |
| Caucasian | 177 | | | 67.60% |
| African American | 27 | | | 10.30% |
| Asian | 16 | | | 6.10% |
| Native Hawaiian or Pacific Islander | 1 | | | 0.40% |
| American Indian or Alaskan Native | 4 | | | 1.50% |
| Other or Multi-racial | 37 | | | 14.10% |
| Education | | | | |
| Less than a high school diploma | 9 | | | 3.40% |
| High school degree or equivalent | 26 | | | 9.80% |
| Some college, no degree | 57 | | | 21.50% |
| Associate degree | 19 | | | 7.20% |
| Bachelor’s degree | 80 | | | 30.20% |
| Graduate degree | 74 | | | 27.90% |
| Employment | | | | |
| Employed full time | 124 | | | 46.60% |
| Employed part-time | 14 | | | 5.30% |
| Unemployed | 14 | | | 5.30% |
| Self-employed | 36 | | | 13.50% |
| Student or retired | 67 | | | 25.20% |
| Disabled | 11 | | | 4.10% |
| Income | | | | |
| Less than $20,000 | 23 | | | 9.30% |
| $20,000 to $34,999 | 24 | | | 9.70% |
| $35,000 to $49,999 | 32 | | | 13.00% |
| $50,000 to $74,999 | 44 | | | 17.80% |
| $75,000 to $99,999 | 34 | | | 13.80% |
| Over $100,000 | 90 | | | 36.40% |
| Marital Status | | | | |
| Married | 151 | | | 57.00% |
| Single | 65 | | | 24.50% |
| Divorced | 28 | | | 10.60% |

| Statistic | N | Mean | St. Dev. | % |
|---|---|---|---|---|
| Widowed | 17 | | | 6.40% |
| Separated | 4 | | | 1.50% |
| Year of residency | 264 | 25.74 | 7.62 | |

**Table 2.**

Bivariate correlations among continuous variables.

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|
| **1 Emotional Resilience** | – | | | | | | | | |
| **2 Hurricane-Related Distress** | −.311*** | – | | | | | | | |
| **3 Distress-Intrusion** | −.247*** | .937*** | – | | | | | | |
| **4 Distress-Avoidance** | −.254*** | .884*** | .720*** | – | | | | | |
| **5 Distress-Hyperarousal** | −.365*** | .906*** | .818*** | .684*** | – | | | | |
| **6 Hurricane Exposure** | −.214** | .462*** | .425*** | .423*** | .410*** | – | | | |
| **7 Perceived quality of neighborhood green space** | .166** | −.179** | −.147* | −.110+ | −.246*** | −.110+ | – | | |
| **8 NDVI** | 0.029 | −0.033 | −0.023 | 0.006 | −0.140* | 0.014 | 0.177* | – | |
| **9 Social cohesion** | .333** | −.129* | −.065 | −.112+ | −.192** | −.198** | .333*** | −0.027 | – |

Note:

+ $p < .1$

* $p < .05$

** $p < .01$

*** $p < .001$.

**Table 3.**

Associations between perceived quality of neighborhood green space and emotional resilience, social cohesion (N = 235, Group = 30).

| Variables | Model 1 | | | | | Model 2 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Emotional Resilience | | | | | Social Cohesion | | | | |
| | B | SE | t | 95% CI | | B | SE | t | 95% CI | |
| | | | | Lower | Upper | | | | Lower | Upper |
| (Intercept) | −0.191 | 0.379 | −0.505 | −0.934 | 0.552 | −1.018 | 0.321 | −3.169** | −1.648 | −0.388 |
| Individual level | | | | | | | | | | |
| Age | 0.001 | 0.005 | 0.160 | −0.009 | 0.010 | 0.011 | 0.004 | 2.599** | 0.003 | 0.019 |
| Gender (Female as reference) | 0.003 | 0.140 | 0.022 | −0.271 | 0.277 | −0.347 | 0.119 | −2.922** | −0.580 | −0.114 |
| Race (Caucasian as reference) | | | | | | | | | | |
| African American | 0.007 | 0.243 | 0.030 | −0.469 | 0.483 | 0.019 | 0.205 | 0.092 | −0.382 | 0.420 |
| Other | −0.116 | 0.164 | −0.708 | −0.436 | 0.205 | 0.000 | 0.139 | 0.001 | −0.272 | 0.272 |
| Hispanic (Non-Hispanic as reference) | −0.197 | 0.170 | −1.158 | −0.529 | 0.136 | 0.244 | 0.144 | 1.697+ | −0.038 | 0.527 |
| Employment (Employed full time as reference) | | | | | | | | | | |
| Employed part-time | −0.651 | 0.292 | −2.225* | −1.224 | −0.077 | 0.195 | 0.248 | 0.784 | −0.292 | 0.682 |
| Unemployed | 0.147 | 0.331 | 0.443 | −0.502 | 0.795 | −0.389 | 0.279 | −1.392 | −0.936 | 0.159 |
| Self-employed | −0.065 | 0.200 | −0.326 | −0.458 | 0.327 | −0.162 | 0.170 | −0.951 | −0.495 | 0.172 |
| Student or retired | 0.184 | 0.194 | 0.949 | −0.196 | 0.565 | 0.063 | 0.165 | 0.382 | −0.260 | 0.385 |
| Disabled, not able to work | −0.633 | 0.352 | −1.797+ | −1.324 | 0.058 | −0.348 | 0.298 | −1.168 | −0.931 | 0.236 |
| Income | 0.004 | 0.002 | 1.854+ | 0.000 | 0.009 | 0.006 | 0.002 | 2.843** | 0.002 | 0.009 |
| Marital Status (Married as reference) | | | | | | | | | | |
| Single | −0.028 | 0.162 | −0.170 | −0.344 | 0.289 | 0.221 | 0.138 | 1.604 | −0.049 | 0.491 |
| Divorced | −0.084 | 0.216 | −0.388 | −0.507 | 0.339 | −0.191 | 0.183 | −1.041 | −0.550 | 0.168 |
| Widowed | −0.115 | 0.304 | −0.378 | −0.711 | 0.481 | 0.063 | 0.259 | 0.245 | −0.443 | 0.570 |
| Separated | −0.656 | 0.507 | −1.295 | −1.650 | 0.337 | −0.655 | 0.431 | −1.521 | −1.499 | 0.189 |
| Perceived quality of neighborhood green space | 0.136 | 0.068 | 1.999* | 0.003 | 0.270 | 0.341 | 0.058 | 5.916*** | 0.228 | 0.454 |
| Neighborhood level | | | | | | | | | | |
| NSES | 0.255 | 0.144 | 1.771+ | −0.027 | 0.537 | −0.300 | 0.116 | −2.599* | −0.527 | −0.074 |
| Random Intercept | 0.250 | | | | | 0.172 | | | | |
| Residual | 0.935 | | | | | 0.798 | | | | |
| REML convergence | 673.7 | | | | | 601.7 | | | | |

Note:

+ $p < .1$

* $p < .05$

*** $p < .001$.

**Table 4.**

Generalized linear mixed model on probable PTSD (N = 233, Group = 30).

| Variables | Model 3 | | | | Model 4 | | | | Model 5 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Perceived Green Space Predicting PTSD | | | | Perceived Green Space + Emotional Resilience Predicting PTSD | | | | Perceived Green Space + Social Cohesion Predicting PTSD | | | |
| | OR | z | 95% CI | | OR | z | 95% CI | | OR | z | 95% CI | |
| | | | Lower | Upper | | | Lower | Upper | | | Lower | Upper |
| (Intercept) | 0.146 | −1.626 | 0.014 | 1.486 | 0.085 | −1.844 + | 0.006 | 1.168 | 0.131 | −1.699 + | 0.013 | 1.367 |
| **Individual level** | | | | | | | | | | | | |
| Age | 1.009 | 0.617 | 0.981 | 1.037 | 1.012 | 0.759 | 0.982 | 1.042 | 1.011 | 0.747 | 0.983 | 1.040 |
| Gender (Female as reference) | 0.985 | −0.038 | 0.451 | 2.153 | 1.039 | 0.089 | 0.443 | 2.438 | 0.913 | −0.221 | 0.410 | 2.036 |
| Race (Caucasian as reference) | | | | | | | | | | | | |
| African American | 2.292 | 1.365 | 0.697 | 7.539 | 2.585 | 1.411 | 0.691 | 9.669 | 2.347 | 1.408 | 0.716 | 7.697 |
| Other | 1.785 | 1.297 | 0.744 | 4.282 | 1.853 | 1.268 | 0.714 | 4.807 | 1.811 | 1.326 | 0.753 | 4.356 |
| Hispanic (Non-Hispanic as reference) | 0.683 | −0.798 | 0.268 | 1.743 | 0.517 | −1.204 | 0.177 | 1.513 | 0.724 | −0.667 | 0.281 | 1.870 |
| Employment (Employed full time as reference) | | | | | | | | | | | | |
| Employed part-time | 2.546 | 1.272 | 0.603 | 10.749 | 1.827 | 0.797 | 0.415 | 8.049 | 2.653 | 1.332 | 0.631 | 11.150 |
| Unemployed | 1.358 | 0.373 | 0.272 | 6.765 | 1.703 | 0.596 | 0.296 | 9.807 | 1.252 | 0.271 | 0.246 | 6.358 |
| Self-employed | 1.767 | 1.102 | 0.642 | 4.868 | 1.842 | 1.080 | 0.608 | 5.581 | 1.711 | 1.034 | 0.618 | 4.733 |
| Student or retired | 0.256 | −2.166 * | 0.075 | 0.879 | 0.256 | −2.005 * | 0.067 | 0.970 | 0.257 | −2.155 * | 0.075 | 0.884 |
| Disabled, not able to work | 5.075 | 1.689 + | 0.771 | 33.421 | 3.324 | 1.128 | 0.412 | 26.811 | 4.962 | 1.646 + | 0.736 | 33.429 |
| Income | 0.994 | −0.959 | 0.981 | 1.006 | 0.998 | −0.352 | 0.984 | 1.011 | 0.995 | −0.762 | 0.982 | 1.008 |
| Marital Status (Married as reference) | | | | | | | | | | | | |
| Single | 0.878 | −0.281 | 0.355 | 2.174 | 0.864 | −0.295 | 0.329 | 2.274 | 0.926 | −0.164 | 0.370 | 2.316 |
| Divorced | 0.897 | −0.176 | 0.267 | 3.009 | 0.758 | −0.407 | 0.200 | 2.871 | 0.884 | −0.199 | 0.263 | 2.976 |
| Widowed | 2.048 | 0.810 | 0.362 | 11.605 | 1.796 | 0.658 | 0.314 | 10.283 | 2.171 | 0.866 | 0.375 | 12.563 |
| Separated | 0.767 | −0.199 | 0.056 | 10.512 | 0.483 | −0.538 | 0.034 | 6.845 | 0.667 | −0.305 | 0.050 | 8.991 |
| Hurricane Exposure | 1.425 | 2.588** | 1.090 | 1.863 | 1.376 | 2.092 * | 1.020 | 1.857 | 1.410 | 2.483 * | 1.075 | 1.849 |
| Perceived quality of neighborhood green space | 0.610 | −2.618** | 0.422 | 0.883 | 0.649 | −2.086 * | 0.432 | 0.974 | 0.644 | −2.206 * | 0.435 | 0.952 |
| Emotional Resilience | | | | | 0.403 | −3.686 *** | 0.248 | 0.653 | | | | |
| Social Cohesion | | | | | | | | | 0.833 | −0.806 | 0.533 | 1.300 |
| **Neighborhood level** | | | | | | | | | | | | |

| Variables | Model 3 | | | | Model 4 | | | | Model 5 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Perceived Green Space Predicting PTSD | | | | Perceived Green Space + Emotional Resilience Predicting PTSD | | | | Perceived Green Space + Social Cohesion Predicting PTSD | | | |
| | OR | z | 95% CI | | OR | z | 95% CI | | OR | z | 95% CI | |
| | | | Lower | Upper | | | Lower | Upper | | | Lower | Upper |
| NSES | 0.954 | −0.1976 | 0.598 | 1.523 | 1.288 | 0.594 | 0.559 | 2.971 | 0.920 | −0.343 | 0.570 | 1.484 |
| Random Intercept | 1.408 | | | | 1.794 | | | | 1.401 | | | |

Note:

$^{+}p < .1$

$^{*}p < .05$

$^{***}p < .001$.

All models were fitted with a mixed model with a logit link.

**Table 5.**

Linear mixed model on hurricane-related distress – hyperarousal subscale (N = 235, Group = 30).

| Variables | Model 6 | | | | | Model 7 | | | | | Model 8 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Perceived Green Space Predicting Hyperarousal | | | | | Perceived Green Space + Emotional Resilience Predicting Hyperarousal | | | | | Perceived Green Space + Social Cohesion Predicting Hyperarousal | | | | |
| | B | SE | T | 95% CI | | B | SE | T | 95% CI | | B | SE | t | 95% CI | |
| | | | | Lower | Upper | | | | Lower | Upper | | | | Lower | Upper |
| (Intercept) | −0.604 | 0.375 | −1.612 | −1.339 | 0.131 | −0.567 | 0.359 | −1.579 | −1.272 | 0.137 | −0.612 | 0.383 | −1.600 | −1.363 | 0.138 |
| **Individual level** | | | | | | | | | | | | | | | |
| Age | 0.003 | 0.005 | 0.621 | −0.006 | 0.012 | 0.003 | 0.005 | 0.631 | −0.006 | 0.012 | 0.003 | 0.005 | 0.630 | −0.006 | 0.012 |
| Gender (Female as reference) | −0.249 | 0.135 | −1.848 + | −0.513 | 0.015 | −0.242 | 0.129 | −1.884 + | −0.495 | 0.010 | −0.252 | 0.137 | −1.834 + | −0.521 | 0.017 |
| Race (Caucasian as reference) | | | | | | | | | | | | | | | |
| African American | 0.481 | 0.229 | 2.103 * | 0.033 | 0.930 | 0.499 | 0.222 | 2.248 * | 0.064 | 0.934 | 0.482 | 0.229 | 2.099 * | 0.032 | 0.931 |
| Other | −0.078 | 0.157 | −0.493 | −0.386 | 0.231 | −0.115 | 0.150 | −0.765 | −0.409 | 0.179 | −0.078 | 0.158 | −0.492 | −0.387 | 0.231 |
| Hispanic (Non-Hispanic as reference) | 0.200 | 0.163 | 1.228 | −0.119 | 0.518 | 0.133 | 0.156 | 0.850 | −0.173 | 0.438 | 0.202 | 0.164 | 1.230 | −0.120 | 0.524 |
| Employment (Full time as reference) | | | | | | | | | | | | | | | |
| Employed part-time | 0.196 | 0.282 | 0.692 | −0.358 | 0.749 | 0.025 | 0.272 | 0.090 | −0.508 | 0.557 | 0.198 | 0.284 | 0.697 | −0.358 | 0.754 |
| Unemployed | 0.150 | 0.312 | 0.480 | −0.462 | 0.762 | 0.138 | 0.302 | 0.458 | −0.453 | 0.730 | 0.146 | 0.314 | 0.465 | −0.470 | 0.762 |
| Self-employed | 0.449 | 0.192 | 2.332 * | 0.072 | 0.826 | 0.435 | 0.184 | 2.366 * | 0.075 | 0.794 | 0.447 | 0.193 | 2.316 * | 0.069 | 0.826 |
| Student or retired | 0.028 | 0.185 | 0.152 | −0.335 | 0.391 | 0.076 | 0.178 | 0.424 | −0.273 | 0.425 | 0.028 | 0.186 | 0.153 | −0.335 | 0.392 |
| Disabled, not able to work | 0.337 | 0.334 | 1.008 | −0.318 | 0.991 | 0.155 | 0.324 | 0.478 | −0.480 | 0.790 | 0.333 | 0.336 | 0.992 | −0.325 | 0.992 |
| Income | −0.001 | 0.002 | −0.317 | −0.005 | 0.004 | 0.001 | 0.002 | 0.250 | −0.004 | 0.005 | −0.001 | 0.002 | −0.289 | −0.005 | 0.004 |
| Marital Status (Married as reference) | | | | | | | | | | | | | | | |
| Single | 0.067 | 0.156 | 0.429 | −0.240 | 0.374 | 0.049 | 0.148 | 0.327 | −0.242 | 0.340 | 0.069 | 0.158 | 0.437 | −0.240 | 0.378 |
| Divorced | −0.176 | 0.208 | −0.847 | −0.584 | 0.232 | −0.194 | 0.199 | −0.977 | −0.584 | 0.195 | −0.178 | 0.209 | −0.850 | −0.587 | 0.232 |
| Widowed | −0.406 | 0.294 | −1.383 | −0.982 | 0.170 | −0.413 | 0.279 | −1.478 | −0.960 | 0.135 | −0.405 | 0.294 | −1.377 | −0.982 | 0.172 |
| Separated | 0.345 | 0.491 | 0.703 | −0.617 | 1.308 | 0.194 | 0.470 | 0.412 | −0.728 | 1.115 | 0.340 | 0.494 | 0.688 | −0.628 | 1.309 |
| Hurricane Exposure | 0.234 | 0.048 | 4.902 *** | 0.140 | 0.328 | 0.196 | 0.047 | 4.197 *** | 0.105 | 0.288 | 0.233 | 0.048 | 4.849 *** | 0.139 | 0.328 |
| Perceived quality of neighborhood green space | −0.137 | 0.065 | −2.116 * | −0.264 | −0.010 | −0.094 | 0.063 | −1.498 | −0.217 | 0.029 | −0.134 | 0.070 | −1.914 + | −0.271 | 0.003 |
| Emotional Resilience | | | | | | −0.287 | 0.063 | −4.588 *** | −0.410 | −0.164 | | | | | |
| Social Cohesion | | | | | | | | | | | −0.009 | 0.077 | −0.117 | −0.160 | 0.142 |
| **Neighborhood level** | | | | | | | | | | | | | | | |

| Variables | Model 6 | | | | | Model 7 | | | | | Model 8 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Perceived Green Space Predicting Hyperarousal | | | | | Perceived Green Space + Emotional Resilience Predicting Hyperarousal | | | | | Perceived Green Space + Social Cohesion Predicting Hyperarousal | | | | |
| | B | SE | T | 95% CI | | B | SE | T | 95% CI | | B | SE | t | 95% CI | |
| | | | | Lower | Upper | | | | Lower | Upper | | | | Lower | Upper |
| NSES | −0.025 | 0.119 | −0.208 | −0.258 | 0.208 | 0.050 | 0.127 | 0.394 | −0.199 | 0.299 | −0.027 | 0.121 | −0.225 | −0.265 | 0.211 |
| Random Intercept | 0.099 | | | | | 0.194 | | | | | 0.100 | | | | |
| Residual | 0.910 | | | | | 0.860 | | | | | 0.912 | | | | |
| REML convergence | 657.1 | | | | | 641.0 | | | | | 660.3 | | | | |

Note:

$^{+}p < .1$

$^{*}p < .05$

$^{***}p < .001$.

**Table 6.**

Comparative analyses conducted with neighborhood NDVI as the explanatory variable (N = 235, Group = 30).

| Variables | Emotional Resilience | | | | | Social Cohesion | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | B | SE | t | 95% CI | | B | SE | t | 95% CI | |
| | | | | Lower | Upper | | | | Lower | Upper |
| Neighborhood NDVI | 0.016 | 0.075 | 0.208 | −0.132 | 0.163 | −0.061 | 0.069 | −0.880 | −0.196 | 0.075 |
| **Variables** | **Probable PTSD** | | | | | **Hurricane-Related Distress - Hyperarousal** | | | | |
| | **OR** | | **z** | **95% CI** | | **B** | **SE** | **t** | **95% CI** | |
| | | | | **Lower** | **Upper** | | | | **Lower** | **Upper** |
| Neighborhood NDVI | 0.818 | | −0.328 | −0.247 | 2.707 | −0.155 | 0.062 | −2.503* | −0.276 | −0.034 |

Note:

*$p < .05$.

All models specified as the models that use perceived quality of neighborhood green space as the explanatory variable (i.e., controlled for age, gender, race, ethnicity, employment, income, and marital status, neighborhood-level N.