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Intersectional and Entangled Risks: An Empirical Analysis of Disasters and Landfills

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Landfills are environmental hazards linked to harms, such as the production of greenhouse gases and the accumulation of toxins in natural and human systems. Although environmental justice research has established such unwanted land uses as hazardous waste sites occur in poor communities and communities of color, less is known about the relationship between landfills and gender. As a driver of global climate change, there is also limited research into the relationships among disasters, landfills, and climate-related risks. To fill this gap, the current study uses an intersectional approach to theorize and empirically analyze relationships among landfills, disasters, race, class, and gender. We employ negative binomial regression to analyze a unique U.S. dataset of landfill counts, total number of disasters, and socio-demographic characteristics, including the use of two-way interactions among race, sex, and socioeconomic status variables, and number of federally-declared disasters that influence landfill counts. Findings suggest that intersecting axes of social location (specifically gender and race) are not multiplicative when it comes to landfills or the environmental risks they pose, but we argue may be entangled—that is related in non-linear and complicated ways. Using intersectionality theory, we interpret the findings to indicate that women of color are agents of resistance enacting their own forms of power against dominant structural arrangements that produce and maintain environmental injustices. Conclusions and implications for environmental justice, intersectionality, and climate risks are further discussed.

Keywords: gender, intersectionality theory, environmental justice, environmental risk, landfills, climate impacts, social disparities in climate

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INTRODUCTION

One underexplored area of great concern are the risks related to disasters and landfills particularly to women and racially minoritized groups. As global climate change leads to more frequent and catastrophic disasters, these disasters generate exponentially more waste than in a typical year. Disasters create a dual risk to residents of both the immediate effects of the disaster itself and the potentially harmful effects of disaster-generated waste. Moreover, such risk is unevenly distributed, with landfills, the eventual home of such waste, disproportionately located in communities of color and poor communities across the U.S. (e.g., Mohai and Saha, 2015a,b; Cannon, 2020). But how do these disparities of climate related impacts affect communities across intersecting axes of social location including along lines of gender, race, and socioeconomic status? To answer this question, the current paper integrates environmental justice and intersectionality theories to develop a theoretical framework to analyze the factors that influence landfill counts. This theoretical integration informs a quantitative analysis of landfills across the United States by examining crucial socio-demographic characteristics, disasters, and other relevant variables garnered from prior research.

Previous scholarship has found disasters have an indirect relationship on communities through waste generation (McKinney et al., 2015) and that landfills themselves pose a risk to neighboring residents through the production of greenhouse gasses and the accumulation of toxins in human and natural systems (Elliott and Frickel, 2013). To build on this prior work, the current paper uses an intersectional approach (e.g., Crenshaw, 1989; Cho et al., 2013; Collins and Bilge, 2020)—that interlocking axes of social location exacerbates social inequalities—to quantitatively assess disparities related to disasters and landfills. Building on previous scholarship that uses quantitative methods to advance intersectionality theory of social inequality (McCall, 2005), this paper extends this framework to further our understanding of environmental injustice, in the form of landfills, and the disparate risks related to waste generation from disasters. In doing so, we consider best practices from prior research on the inclusion of measures of gender in our analyses.

To accomplish these aims, we first review relevant environmental justice research of waste, the environmental risks it poses, and disasters. Next, we engage with leading research into gender inequality, climate change, and intersectionality theory to inform promising practices of conceptualizing and empirically assessing unique effects of gender related to the environment. Finally, we apply an intersectional environmental justice approach to our empirical analysis of a unique dataset to yield insights into climate-related environmental risks to landfills.

LITERATURE REVIEW

Landfills, Climate Risks, and Disasters

Environmental justice scholarship has a rich tradition of analyzing the disproportionate siting of environmental hazards, in particular waste sites and their attendant risks, in poor communities and communities of color across the U.S. (e.g., UCC, 1987; Bullard, 1990; Saha and Mohai, 2005; Bullard et al., 2007; Elliott and Frickel, 2013; Taylor, 2014; Mohai and Saha, 2015a,b). To date, much of the environmental justice research into these disparities has focused on federally-regulated sites, such as hazardous waste landfills or other facilities recorded in the US EPA's Toxics Release Inventory. However, little research has investigated the effects of other landfills—construction and demolition (C&D), municipal, and industrial—that make up 93% of all landfills in the U.S. (Cannon, 2020). Much of the waste that our modern societies produce are not classified or regulated as hazardous waste though much of it may be hazardous posing significant risks to neighboring communities (EPA (United States Environmental Protection Agency), 2008). Research suggests that such waste sites pose risks to human and community health and well-being, such as poor air quality, water contamination, and other noxious outcomes (World Health Organization, 2007; Mattiello et al., 2013). Moreover, landfills themselves emit greenhouse gases (GHG, i.e., methane) contributing to the acceleration of the global climate emergency and associated-climate risks (EPA, 2006, 2013a). While hazardous waste is regulated federally, individual states are responsible for establishing criteria for how these other landfills operate and for monitoring compliance. As understudied sources of climate risks, these landfills are an important site for further investigation (Cannon, 2020).

An important gap in the literature are the relationships among climate change-related disasters, landfills, and environmental risks. The ongoing environmental risks, such as increased rates of cancer, poor air quality, increased asthma rates and increased rates of diabetes (Ma et al., 2007; Fazzo et al., 2008; Gensburg et al., 2009; Koshy et al., 2009) posed by both hazardous and non-hazardous landfills (i.e., C&D, industrial, and municipal) may be further exacerbated by disasters, whose frequency and severity are all but certain to increase with the ongoing and unfolding climate crisis (IPCC, 2018). To further understand the complex linkages among landfills, disasters, climate change, and environmental risk disparities, environmental justice scholarship has also begun to investigate how disaster impacts on such waste sites exacerbates these already existing socio-environmental inequalities (McKinney et al., 2015). In their research on this topic, McKinney et al. (2015) found that debris from disasters in more urban areas created a pipeline of waste to more rural areas across the Southeastern U.S.

Moreover, understanding the effects of disaster-generated waste is a necessary site of study given the importance of its quick and thorough removal post-disaster to a community's successful recovery (Luther, 2010; Brown et al., 2011). Waste, whether disaster-generated or not, contributes to a climate change-related positive feedback loop in which accumulation of waste in landfills increases the production of greenhouse gasses, which contribute to global climate change, which in turn generates more frequent and extreme disasters producing more landfill waste [EPA (United States Environmental Protection Agency), 2013; McKinney et al., 2015]. This positive feedback loop generates climate-related risks through GHG emissions, themselves; risks from increased disaster frequency and severity; and, through the debris produced by disasters. Although there are ongoing efforts to capture methane releases from some landfills (e.g., Spokas et al., 2006; Ghosh et al., 2019), these efforts are patchwork and produce "fugitive emissions" that escape capture (e.g., Mønster et al., 2019). Given these complex relationships, further research is needed to uncover the key linkages among disasters, waste, and socio-demographic characteristics that produce climate change-related environmental risk disparities.

Gender Inequality, Environmental Hazards, and Disasters

Another strand of environmental justice research has investigated the disproportionate impact of environmental injustice on women (for an overview of gender and environmental justice research, see Sze, 2017). Increasingly, gender has emerged as a key analytical focus in environmental justice research as scholars increasingly examine how environmental hazards can affect women differently than men (e.g., Rocheleau et al., 1996; Downey and Hawkins, 2008; Collins et al., 2011; Taylor, 2014; Sze, 2017; Perry and Gillespie, 2019). Researchers have also begun to analyze how gender intersects with other aspects of social life including age, immigration status/citizenship, and indigeneity to influence disproportionate exposure to environmental hazards (e.g., Merchant, 1980; Mies and Shiva, 1993; Linder et al., 2008; Collins et al., 2011; McKane et al., 2018; Goodling, 2019; Nirmal and Rocheleau, 2019; McKee, 2020). Research along these lines, using secondary data analysis, have employed female-headed primary households as an indicator of gender inequality, in which they have found gender inequality plays a role in cancer risks associated with air pollution (Collins et al., 2011) and that female-headed primary households tend to be overly represented in U.S. census tracts with high concentrations of air toxics (Downey and Hawkins, 2008).

A brief explanation on the use of the category women. I recognize "women" as an expansive category and one that may include non-gender binary, trans-women, intersex and other people who identify as women. Empirically, given the use of female-headed primary households from the American Community Survey as a measure of gender inequality, I acknowledge that whoever identified as female was counted in this measure. In this way, I fail to capture the other ways that people are discriminated by and experience oppression on the basis of gender. I also acknowledge that people may identify as female in the ACS who may not be identified as such on their personal identification documents since the ACS asks for self-reporting. However, for those whom female does not fit their identity they may not be counted in this measure. More work needs to be done to include the full range of identity and expression in census data collection efforts.

Gender also plays a role in disaster experiences and recovery. For instance, research suggests that gender inequalities are linked to barriers to access resources and decision making around healthcare services, education, finances, legal apparatuses and rights for women and girls (Sultana, 2010; Ajibade et al., 2013; Kimura and Katano, 2014). Research has also found that women are disproportionately impacted by natural hazards, disasters, and climate change (Enarson and Morrow, 1998; Fordham, 2003; Sultana, 2014; McKinney and Fulkerson, 2015; Gaillard et al., 2017). Thus, gender plays a unique role in both environmental hazards and disasters warranting further empirical analysis, while recent scholarship documents that intersectionality can be a powerful theory for understanding such impacts (Vinyeta et al., 2016).

Intersectionality Theory

To better assess the ways gender inequality contributes to environmental hazards and intersects with race and socioeconomic status, scholars have also begun to apply intersectionality theory to further understand relationships among gender, race, socioeconomic status, along with other socio-demographic characteristics, and environmental outcomes (Ducre, 2018; Malin and Ryder, 2018; Mollet and Faria, 2018; Sultana, 2021). Intersectionality, a critical theory and approach that grows out of Black feminist thought, seeks to identify and critique the ways various systems of power oppress specific kinds of people and how oppressed peoples can enact their own forms of power (e.g., Crenshaw, 1989; Collins, 1990; Cho et al., 2013; Collins and Bilge, 2020). In foundational texts, Crenshaw (1989) and Collins (1990) assert that it is the intersection of interlocking systems of domination vis-à-vis race, class, and gender that oppresses people, in general, and Black, Indigenous, and women of color, in particular. Moreover, intersectionality, in focusing on and valuing difference, seeks to uncover the complex array of identities (e.g., race, socioeconomic status, gender, sexual orientation, religious, etc.) that are produced structurally and culturally and occur simultaneously. Intersectionality research engages with the experiences and meanings of belonging to multiple social groups, examines power and inequality, and understands social categories as fluid, dynamic, and emergent from social contexts (Cole, 2009; Else-Quest and Hyde, 2016a). Intersectional feminist theorists call for the acknowledgment and investigation of structural power to illuminate how it operates to create multiple and wide-ranging disparities (Ducre, 2018; Mollett, 2018; Mollett and Faria, 2018; Nash, 2019).

Researchers have begun to use such intersectional approaches to further understanding and analysis of environmental disparities as it relates to disasters (e.g., Luft and Griffin, 2008; Ryder, 2017), urban ecology (e.g., Di Chiro, 2006; Braun, 2015), environmental risks (e.g., Olofsson et al., 2016), pollution (e.g., Sze, 2006), space (e.g., Mollett and Faria, 2018), and climate change (e.g., Kaijser and Kronsell, 2014; Sultana, 2021). Ducre (2018), argues for the inclusion of gender in environmental justice research, which has often been lacking and that it is necessary to cast women experiencing environmental injustices not just as victims but as agents of resistance.

Yet, even fewer studies have used intersectionality theory to investigate waste as a form of environmental injustice (Dillon, 2014; Vasudevan, 2019) or used quantitative methods (for exception see McKane et al., 2018) to test hypotheses derived from intersectionality theories applied to environmental justice outcomes. Of the research that exists, Vasudevan (2019) applies critical race theory, postcolonial studies, and feminist geopolitical approaches to understand how racial capitalism as a political and ecological undertaking across scales produces an intimate relationship between race and waste to make metal valuable. Finally, Dillon (2014) advances "waste formations" as a framework for understanding and analyzing socio-ecological transformations that produced and reproduced urban inequalities creating new geographies of waste. This dearth of research creates a gap in knowledge of how race, gender, and waste may be related to produce environmental risk disparities.

Empirical Approaches to Intersectionality

Just as there is a growing body of research bringing together intersectionality theory and environmental issues, increasingly scholars have begun to call for research to employ quantitative approaches to test hypotheses generated from such rich theorizations to further our understanding and analysis of interlocking systems of oppression and power arrangements that uphold such systems (McCall, 2005; Cho et al., 2013; Else-Quest and Hyde, 2016a). Notably, intersectional research offers generative potential for analytical understanding of complex inequities (Else-Quest and Hyde, 2016a). Although identity categories as represented by quantitative measures are always approximate, by broadening the intersectionality theoretical perspective using more and various types of methods (other than commonly used techniques such as ethnography, deconstruction, and genealogy), scholars can add to how we understand structural inequality and experiences of oppression (McCall, 2005). Following other intersectionality scholars (e.g., McCall, 2005; Cho et al., 2013; Else-Quest and Hyde, 2016), the term "social category" refers to socially constructed classes of gender, race, socioeconomic status, etc. "Group" is used for groups within a social category (i.e., women, men). "Location" refers to different intersections of groups belonging to multiple intersecting categories (i.e., Black women). This approach also represents an opportunity to extend best practices for the inclusion of gender and racial minority considerations into research using secondary data analysis. Although such methodologies have been critiqued (e.g., Browne and Misra, 2003; Stainback and Tomaskovic-Devey, 2009), they can be used strategically to further our knowledge of interlocking systems of oppression and social (e.g., McCall, 2005; Grabe et al., 2015; Else-Quest and Hyde, 2016b) and environmental inequality (McKane et al., 2018; Mollett and Faria, 2018).

Given these interlocking systems of oppression, it would be expected that membership in two disadvantaged social groups (i.e., Black and women) would exacerbate the chances of experiencing more disadvantage (Else-Quest and Hyde, 2016a,b). Mostly such insights have been garnered through theorizations and qualitative methods (e.g., Collins, 1990; Crenshaw, 1991; Collins, 1999; MacKinnon, 2013; Collins and Bilge, 2020). Applying an interpretive intersectional framework to environmental justice concerns can improve our understanding of environmental disparities for women, generally, and women from racial and ethnic minoritized groups, specifically.

An intersectional quantitative approach emphasizes the *processes by which* categories (e.g., race, socioeconomic status, gender, etc.) are produced and reproduced by structural arrangements of power and are resisted (Cho et al., 2013; Else-Quest and Hyde, 2016a; Nash, 2019). Such an approach can help us to explore the nature and extent of configurations of social and environmental inequality. Therefore, primary focus is on the nature of relationships *among* social groups, the nature and extent of differences and inequalities, and how these relationships may be changing rather than on the definition of a particular social group (McCall, 2005, p. 1785). One analytical design suggested by scholars to get at these relationships among social groups is to use interaction effects to test between and within group configurations (McCall, 2005; Bauer, 2014; Else-Quest and Hyde, 2016b).

To this end, the current study uses a between-group design (i.e., *gender x race*) to test hypotheses derived from intersectionality theories using traditional quantitative approaches (i.e., negative binomial regression) with main and interactive effects. Statistical interactions between two or more categories are one way of considering multiplicative effects (Bauer, 2014; Else-Quest and Hyde, 2016a). Multiplicative effects begin to get at the premise articulated by intersectionality theory that inequality is more than the sum of its constitutive parts (e.g., Crenshaw, 1989; Collins, 1990). Importantly, as Cole (2009) warns interactive effects are not sufficient for an analysis to be intersectional, however using an intersectional framework to interpret such analyses offers insights into the production of injustices across social groups (e.g., McCall, 2005; Ducre, 2018; Mollett and Faria, 2018).

Statement of Purpose and Hypotheses

The current study aims to build on the research reviewed above to examine empirically intersectional effects of race, socioeconomic status, gender, and disasters on landfills, a measure of environmental hazards, and to test hypotheses derived from environmental justice and intersectionality theories to further understand climate risk disparities. To do this, we investigate the intercategorical complexity of race, gender, and socioeconomic status that contributes to inequality (McCall, 2005), broadly, and environmental risk disparities, specifically. Hypotheses are tested to ascertain whether there are complex differences and inequalities between groups with respect to measures of environmental inequality. Lastly, we employ an interpretive intersectional framework to quantitatively analyze environmental outcomes.

Based on the extant literature, the following hypotheses are tested:

H1: Counties with greater landfill counts, regardless of landfill type, contain a greater number of disasters compared to counties with fewer landfill counts, holding all other variables constant.

H2: Counties with greater landfill counts, regardless of landfill type, contain greater percentages of non-white residents and lower socioeconomic status compared to counties with fewer landfill counts, holding all other variables constant.

H3: Counties with greater landfill counts, regardless of landfill type, contain greater percentages of female-headed households compared to counties with fewer landfill counts, holding all other variables constant.

H4: There are complex differences within and between social groups with respect to predicting landfill counts.

H4-A: Counties with a greater percentage of non-white residents and low socioeconomic status, as measured by percent of families in poverty, will have multiplicative effects on landfill counts, regardless of landfill type, holding all other variables constant.

H4-B: Counties with a greater percentage of non-white residents and high gender inequality, as measured by percent of female-headed primary households, will have multiplicative effects on landfill counts, regardless of landfill type, holding all other variables constant.

H4-C: Counties with higher socioeconomic status, as measured by a greater percentage of percent of families in poverty, and gender inequality, measured as percent of female-headed primary households, will have multiplicative effects on landfill counts, regardless of landfill type, holding all other variables constant.

DATA AND METHODS

In this study, we theoretically specify and empirically analyze how disasters, socioeconomic, racial, and gender status contribute to unequal risks to environmental inequalities to evaluate the understudied effects of non-hazardous waste landfills across the U.S. Negative binomial regression was used to estimate models of a unique data set of social and environmental indicators for all counties of the 48 contiguous United States. A combination of data from several sources is necessary for this research. Data are reviewed below, followed by a discussion of the analytic technique.

Landfill Data, 2013

Waste generated from households and through industrial, construction and demolition processes must be disposed of somewhere. Location of landfills maintained by the state are recorded by each state's environmental regulatory agency (e.g., Environmental Management, Natural Resources, Environmental Quality, Environment and Natural Resources, etc.). There is a great deal of variance across landfill records with respect to fill size, accepted materials, and address given non-hazardous waste landfills are regulated and maintained at the state level. Moreover, given such variation across state records, data collection took an extensive amount of time (3 years) and necessitated going to each state's environmental agency to build a dataset of landfill by type and county. Collecting data from individual states, although more time-intensive, proved to be more accurate and thorough than using data from national databases, such as the Toxics Release Inventory (EPA, 2021), which often lacked the most current and complete data available. Furthermore, federal databases are not always comparable due to inconsistent data collection procedures across federal agencies. As such, this dataset represents the first of its kind to the author's knowledge. Hazardous waste landfill data since it is regulated and monitored at the federal level, were obtained from the U.S. Environmental Protection Agency. Landfills in the U.S. are typically in use for 50 years until they are capped or closed (South Carolina Department of Health Environmental Control, 2021). Because fill size is not recorded across landfills, we are unable to account for the differing sizes of landfills. Similar to much of the environmental justice literature into waste facilities (e.g., Mohai and Saha, 2015b), we treat all landfills as a measure of environmental inequality. All landfills that were listed as open in 2013 are used in the dataset for the 3,108 counties for which there were data.

Q19

Disaster Data, 2013

Disaster data are taken from the US Federal Emergency Management Agency (FEMA) for each county and include all federally declared disasters for the time period 1961–2011 (i.e., tropical storms, hurricanes, floods, tornadoes, earthquakes, fires, freezes, landslides, droughts, volcanoes, blizzards, water shortages, and tsunamis) (Federal Emergency Management Agency, 2013). These data are only if a disaster was declared by the U.S. President as a disaster according to the policies outlined in the Robert T. Stafford Disaster Relief and Emergency Assistance Act (1988). These data do not describe either the spatial or temporal dimensions of a disaster but the type of disaster, year, and county in which it occurred. To determine key relationships between disasters and landfills, we employ a total number of federally declared disasters from 1964–2011 (see McKinney et al., 2015) to test research hypotheses.

Q14

Urban Rural Continuum, 2013

To control for the urban-rural spectrum of counties, the rural/urban continuum coding (RUCC) from 2013 developed by the United States Department of Agriculture (USDA) is used. Nine classification codes designate counties by degree of urbanization and proximity to metro areas, with each county assigned one of the nine codes. This coding scheme allows researchers to use county data to move beyond metro and non-metro areas and into finer residential groups, particularly in analyzing trends of non-metro areas. Higher values (i.e., nine) represent more rural counties. Since the RUCC codes occur at the county level of analysis, this study uses the county as the level of analysis.

While county-level analyses may have the potential for errors related to aggregation, such geography is necessitated here due to the requirement of socio-demographically detailed C&D, industrial, and municipal landfill data. Moreover, given that no research has examined the effects of these landfills at the subnational scale, such level of aggregation is an important contribution to our understanding of the associations between social inequality and non-hazardous waste landfills. Lastly, counties are administrative units which are often responsible for regulating landfills. As such, they represent an important unit of study.

Given the novelty of these data and the use of RUCC data and FEMA disaster declaration summary data, the county level of analysis is an important first step to testing the research hypotheses elaborated above. The unit hazard coincidence method, wherein analysts investigate the relationship between sociodemographic characteristics of a unit (i.e., county) and the occurrence of a hazard in that unit (i.e., landfill), is used in this analysis. Although critiqued (e.g., Mohai and Saha, 2006), utilizing the unit hazard coincidence method is an important initial step in analyzing these novel data and may inform risk management policy given the administrative unit is often the level at which such decisions are made. Given the method and level of analysis, this research provides a generalized view of relationships being explored, more fine-grained data and analyses is needed to refine the results established here (see Limitations and Future Research for further discussion).

Sociodemographic Data, 2013

All sociodemographic data comes from the American Community Survey (ACS) 5-year estimate (2009–2013) to include data for all study areas regardless of population size (U.S. Census, 2021). Additionally, total population and population density, or people per square mile (Smith, 2009), are used

Q14

Q28 Q10

TABLE 1 | Summary statistics with multicollinearity measure, variance inflation factor (VIF), for all counties in the contiguous U.S.

	Mean	SD	Min	Max	VIF
Dependent variable					
Total non-hazardous landfill counts	1.52	2.09	0	18	-
Hazardous landfill counts	0.17	0.56	0	6	-
Independent and control variables					
Population density (sq. mile)	258.39	1,724.93	0.12	69,468.42	1.15
Total population	98,479.18	314,016.51	82	9,818,605	1.31
RUCC	4.99	2.7	1	9	1.57
Race					
% non-white	16.73	16.32	0.78	97.08	3.83
Socioeconomic					
% below poverty	11.97	5.53	0	40.19	2.77
Gender					
Percent female-headed primary households	11.33	4.28	1.68	38.01	6.38
N = 3,108					

as predictors in order to statistically control for variations in population size while controlling for the physical size of the county. Other independent variables found in the environmental justice literature (e.g., Mohai and Saha, 2015a) include percent non-white as a measure of racial minoritized groups and the socioeconomic variable, percent of families living below the poverty line. To ascertain a unique effect of gender on landfill counts, following research by Downey and Hawkins (2008) and Collins et al. (2011), percent of female-headed primary households is used as a measure of gender inequality. The census defines this measure as "primary families maintained by a female household with no husband present," (U.S. Census, 2021). This indicator is often used measure gender inequality in environmental research. Secondary data analysis is limited by the data collected and future data collection efforts should attempt to collect more information on the experiences and structural disadvantages that are uniquely related to gender to more fully account for gender-related disparities.

Analytical Approach

Negative binomial regression, a generalization of Poisson regression, was estimated to predict landfill counts (i.e., non-hazardous waste and hazardous waste) as a function of county-level socioeconomic characteristics, with a focus on associations among race, socioeconomic status, and gender inequality. Interactive effects were included to determine multiplicative effects of key independent variables to empirically test intersectionality theories of intersecting axes of oppression on an environmental justice outcome (i.e., landfill counts by county). These analyses follow a call by scholars to use quantitative analytic strategies (specifically non-additive linear modeling) to investigate whether or not and the extent to which intersectionality can be identified and analyzed at a level of analysis beyond the individual and to complement ongoing qualitative research into intersecting forms of oppression (McCall, 2005; Cho et al., 2013). Given the large sample size (i.e., 3,108 counties for which there were data) and this technique's flexibility for handling overdispersion (caused by an excess of "false" 0s), negative binomial regression was an optimal technique to predict landfill counts.

Negative binomial regression is preferable to zero-inflated or Poisson regression for several reasons. First, zero-inflated models are used to differentiate between "true" 0s and "false" 0s and given the rigorous methods of data collection from state sources, we assume all 0s are true. Second, negative binomial regression is the preferred model because the model is not under dispersed as determined by Pearson chi-square which estimates dispersion and is typically a rare problem. For instance, Pearson's chi-square > 1 indicates data are over dispersed and if it is < 1, data are under dispersed. Furthermore, dispersion parameter (α) was estimated from the data using maximum likelihood since they produced better fitting models than setting the dispersion parameter to 1 (Cameron and Trivedi, 1998). Several commonly used measures of goodness-of-fit were reported [i.e., the Pearson Chi-Square, Akaike information criteria (AIC), Bayesian information criterion (BIC), and the Likelihood Ratio Chi-Square] and within accepted ranges (Cameron, 2009). Taken together, these tests indicate the likelihood of the outcome happening given the set of independent variables. All models satisfied assumptions of negative binomial regression. Finally, the same models reported here were run using both Poisson regression and zero-inflated regression, the negative binomial regression models were the best fitted models.

DISCUSSION OF RESULTS

Summary statistics are reported in **Table 1**. A diagnostic bivariate correlation table is presented in **Table 2**. Negative binomial regression results are presented in **Table 3**. The distribution of landfills across the U.S. are presented in **Figure 1**.

Results are organized as follows. To test research hypotheses, two models, Models 1 and 2 respectively, were run with the

TABLE 2 | Bivariate correlation table of all measures included in regression models.

	1.	2.	3.	4.	5.	6.	7.	8.	9.
1. Total non-hazardous waste landfills	1.00								
2. Hazardous waste landfills	0.291**	1.00							
3. Population density	0.009	0.055**	1.00						
4. Total population	0.352**	0.256**	0.333**	1.00					
5. RUCC	−0.211**	−0.256**	−0.178**	−0.335**	1.00				
6. All disasters (1964–2011)	−0.003	0.054**	0.025	0.173**	−0.106**	1.00			
7. Percent non-white	0.169**	0.117**	0.162**	0.203**	−0.17**	−0.027	1.00		
8. Percent families below poverty	−0.021	−0.27	0.006	−0.05**	0.175**	0.008	0.532**	1.00	
9. Percent female-headed primary households	0.133**	0.124**	0.106**	0.133**	−0.24**	0.032	0.84**	0.702**	1.00

*$p < 0.05$; **$p < 0.01$.

same set of independent variables predicting total non-hazardous waste landfill counts (i.e., C&D, municipal, and industrial) and hazardous waste landfill counts. The variables included in interaction terms (i.e., percent non-white, percent female-headed primary households, percent living below the poverty line) are centered on the averages to improve interpretation of the non-interaction effects (see below Main effects) (Williams, 2015). Main effects of control and explanatory variables are reported first followed by a discussion of interactive effects. Incidence rate ratios for each variable are presented for ease of interpretation.

Control Variables

Control variables, population density and total population, were in the expected direction for both models. Specifically, greater population density and total population are positively associated with landfill counts regardless of landfill type (Smith, 2009). For rurality as Model 1 indicates, consistent with previous research (Cannon, 2020), more urban counties are positively associated with a greater number of non-hazardous waste landfills. One driver of this relationship may be the expansive building boom in urban areas given the relative cheap credit available after the 2008 Great Recession along with both private investment in development and public priorities to fund housing. Moreover, we would expect a greater number of non-hazardous waste landfills near urban areas given the large populations concentrated in those areas. Model 2 also indicates that a greater number of hazardous waste landfills is positively associated with more urban areas. This finding is surprising given hazardous waste landfills often take waste from oil processes and other energy production activities that tend to occur outside of urban areas (EPA (United States Environmental Protection Agency), 2020). Taken together, with the expected rise in population size in urban areas, we may expect an increase in non-hazardous waste landfills contributing to climate change through carbon emissions and posing additional climate-related risks for an increased population. With the continued dominant fossil fuel energy system, we may similarly expect an increase in hazardous waste landfills, which take mostly waste from extractive and refinement of oil and natural gas processes, with their attendant risks. Below, statistically significant estimates of main effects of independent variables are reported, followed by interactive effects.

Main Effects

For Model 1, total number of disasters from 1964–2011 is negatively associated with non-hazardous waste landfill counts. This finding does not support Hypothesis 1—that counties with a greater number of non-hazardous waste landfills contain a greater number of federally declared disasters—but does support prior research that investigated the relationship between disasters and landfills in the Southeastern U.S. (McKinney et al., 2015). McKinney et al. (2015) theorized that there was waste displacement from areas that experienced disasters to other areas, extending the impacts and risks of disasters beyond immediately affected areas through waste transfer. This finding may similarly support what Dillon (2014) has referred to as "waste formations" in which waste is displaced to newly "waste-able spaces." These results can help inform how we think about climate-related risks from landfills and disasters and the downstream impacts for communities through such waste formations, waste generation and transfer. In Model 2, the relationship between disasters and hazardous waste landfills was not statistically significant.

Conditional Effects

For models that include interactive effects between two continuous variables, non-interaction effects (often referred to as main effects) are typically interpreted to ensure main effects and interactive effects are not confounded (Jaccard et al., 1990; Aiken and West, 1991). In such models, main effects represent conditional relationships—that is the main effect of one variable (i.e., percent families living below the poverty line) is in fact the effect of that variable when the other predictors used in the interaction terms equal zero (Williams, 2015). Put another way, the main effect of a variable on the outcome is conditioned by the other variable in the interaction term. For this reason, we have centered the variables—that is we subtracted the mean from each case—included in the interaction terms. This technique improves interpretability of our analyses such that we can interpret the non-interaction effects of each variable included in an interaction term as its average instead of as zero (Williams, 2015).

The conditional effect of race in Model 1 indicates a positive association with a greater number of non-hazardous waste landfills for counties with average percentages of female-headed primary households and families in poverty. This result supports

TABLE 3 | Negative binomial regression examining main and interactive effects of socio-demographic variables on counties with counts of non-hazardous and hazardous waste landfills.

	Model 1	Model 2
Independent variables	Non-hazardous	Hazardous
Population density (sq. mile)	1.00*** (5.46×10^{-5})	1.00 (6.65×10^{-5})
Total population[a]	1.01*** (0.0012)	1.01*** (0.0024)
Rurality		
RUCC code	0.95*** (0.0113)	0.77*** (0.0328)
Disasters		
Total disasters 1964–2011	0.98*** (0.0045)	0.998 (0.0126)
Socioeconomic		
% below poverty (centered)	0.96*** (0.007)	0.96† (0.208)
Race		
% non-white (centered)	1.01*** (0.0031)	0.995 (0.0076)
Gender		
% female-headed primary households (centered)	1.03* (0.0135)	1.23*** (0.0381)
Interactive effects		
Race*Gender	0.999* (0.0004)	0.998† (0.0012)
Gender*SES	1.00 (0.0014)	0.98*** (0.0058)
Race*SES	1.00 (0.0004)	1.003* (0.0014)
Constant	2.17* (0.0736)	0.4*** (0.1909)
Goodness-of-fit		
Likelihood Ratio Chi-Square (df)	433.43(10)***	487.61(10)***
Pearson Chi-Square (Value/df)	1.17	1.05
AIC	9,994.95	2,480.41
BIC	10,067.32	2,552.67
$N = 3{,}108$		

$^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$, $^{\dagger}p < 0.1$.
[a] Total population is reported in the hundreds of thousands.
Exponentiated coefficients (i.e., incidence rate ratio) are reported with standard errors in parentheses.

Hypothesis 2—that counties with greater non-hazardous waste landfills contain greater percentages of non-white residents compared to counties with fewer landfills—and is expected given prior research into environmental inequalities across other kinds of waste containment (e.g., Bullard et al., 2007; Smith, 2009; Pais et al., 2014; Mohai and Saha, 2015a,b).

The conditional effect of socioeconomic status in Model 1 and Model 2 both indicate a negative association with a greater number of non-hazardous waste landfills and hazardous waste landfills, respectively, for counties with average percentages of non-white residents and female-headed primary households. This result, which does not support hypothesis 2, is somewhat surprising given environmental justice research into toxic waste that indicates it tends to be concentrated in poorer areas in the U.S. (e.g., Downey, 2005; Mohai and Saha, 2015b), but does offer some support for Kosmicki and Long's (Kosmicki and Long, 2016) finding that nuclear power plants tend to occur in census tracts with higher median household incomes than coal hosting tracts in the U.S. This finding suggests the continued need to study different forms of environmental injustices and waste containment to better understand key relationships among environmental and social inequality.

The conditional effect of gender in Models 1 and 2 both indicate there is a positive association between a greater number of non-hazardous waste landfills and hazardous waste landfills, respectively, and percent female-headed primary households for counties with average percentages of non-white residents and families in poverty. This result supports hypothesis 3—that counties with greater counts of non-hazardous waste landfills are positively associated with gender inequality—and adds to the growing body of research that uses empirical analyses with indicators of gender inequality to investigate environmental hazards (Downey and Hawkins, 2008; Collins et al., 2011). It also could demonstrate that risks related to the landfills are often born by women.

One possible explanation for this finding may be that women, on average, make less money than men (81.6 cents to a man's dollar in the U.S.) (Gharehgozli and Atal, 2020), while accounting for more workers in the U.S. workforce (Kelly, 2020), they subsequently may have less time to mount a political resistance to unwanted land uses such as landfills and their potentially pernicious effects. Research has further shown that women experience time shortages due to the gender wage gap since they have to work more hours or more jobs to increase their wages (e.g., Hyde et al., 2020). Such an explanation advances the path of political least resistance theory in environmental justice research (e.g., Bullard, 1990; Downey, 2005) by including gender disparities.

And yet, much environmental justice research has shown the importance of women, generally, and Black, Indigenous, and women of color, in particular, in advancing environmental justice movements (e.g., Bullard, 1993a,b; Taylor, 2000; Cole and Foster, 2001; Schlosberg, 2003, 2004; Bell and Braun, 2010; Mann, 2011; McGregor, 2015; Martinez-Alier et al., 2016; Pulido and De Lara, 2018; Perkins, 2021). Although, Black, Indigenous, and women of color earn less money and have less time, they are key organizers in fighting environmental injustices in their communities. A key insight of intersectionality theory is that women of color are not just survivors or victims of environmental injustices they also enact resistance to the systems of oppression that perpetrate these injustices (Ducre, 2018). Taking an intersectional approach to environmental justice, it is likely that although women of color experience greater risks from landfills, they also tend to organize resistance for healthier environments, a benefit that extends beyond their immediate communities. This insight is aligned with Ducre's (2018, p. 33) argument regarding Black women's liberation and its possible wide-ranging effects, when she writes "their [Black women] liberation from oppression and rights to clean air and water would ensure that all others would

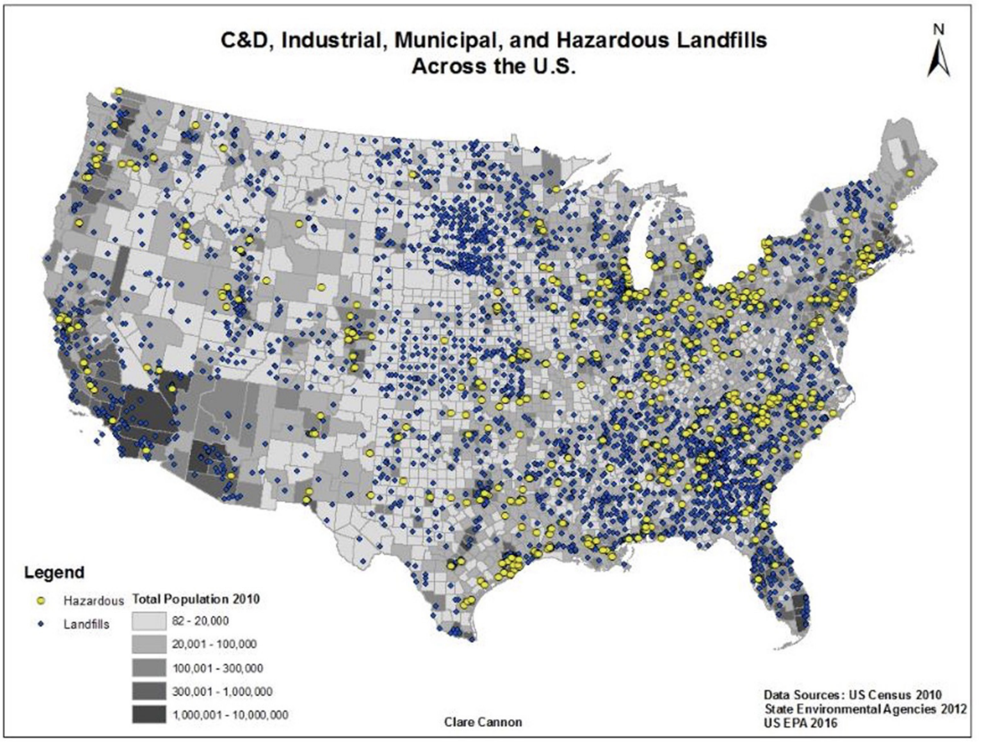

FIGURE 1 |

have access to the same." Similarly, given our analyses suggest there are downstream consequences from disasters on landfills in areas not immediately impacted by such disasters, future research may discover that these sites of resistance also have downstream impacts.

It could also be the case that since women tend to make less money than men, they have less choice in where they can afford to live (e.g., Gotham, 2014). Previous environmental justice research has argued that environmental inequalities are disproportionately located in racial minority neighborhoods because racial housing discrimination constrains residential choices of racial minorities and confines them to neighborhoods with high levels of environmental hazards (Bullard, 1993a,b; Mohai and Saha, 2006; Pais et al., 2014). Following this research and applying an intersectional interpretive framework, one explanation could be that Black, Indigenous, and women of color's housing choice is further constrained for a multitude of factors both related directly to gender as well as intersecting systems that affect women's residential choices (i.e., discriminatory practices, both overt and covert, related to racial, gender, and socioeconomic statuses, including the gender wage gap). Just as women of color are fighting for healthier environments to reduce risks and environmental injustices, women of color are also leaders in the movement for affordable housing (i.e., Moms 4 Housing). Such insights suggest that just as experiences of injustices are intersectional so is the resistance to them. More research is necessary to understand both why female-headed primary households are disproportionately located in areas with landfills and how women are organizing to fight these injustices. Given the current and existential threat due to the climate crisis, future research should particularly focus on the role of women of color within social mobilizations confronting climate change.

Interactive Effects

To test hypotheses elucidated above drawn from intersectionality and environmental justice scholarship, three two-way interaction terms—*race x gender, gender x socioeconomic status, and socioeconomic status x race*—were included in both models with respective environmental outcomes, non-hazardous and hazardous waste landfill counts (see **Table 3**). Results of statistically significant interactions are graphed in **Figures 1**, **2** for Models 1 and 2, respectively, and elaborated below.

Model 1 indicates that as the effect of percent of non-white residents of a county increases there is a corresponding increase in the number of non-hazardous waste landfills, but that effect decreases as percent of female-headed primary households increases (see **Figure 2**). Model 2 indicates that as the percentage of female-headed primary households increases there is a corresponding increase in the number of hazardous waste landfills, but that effect decreases as percentage of non-white residents increases (**Figure 3A**). Taken together, these findings do not support hypothesis 4-A that interactions between gender and race have a multiplicative effect on landfills.

This finding is unexpected given research into both environmental hazards (Downey and Hawkins, 2008; Collins

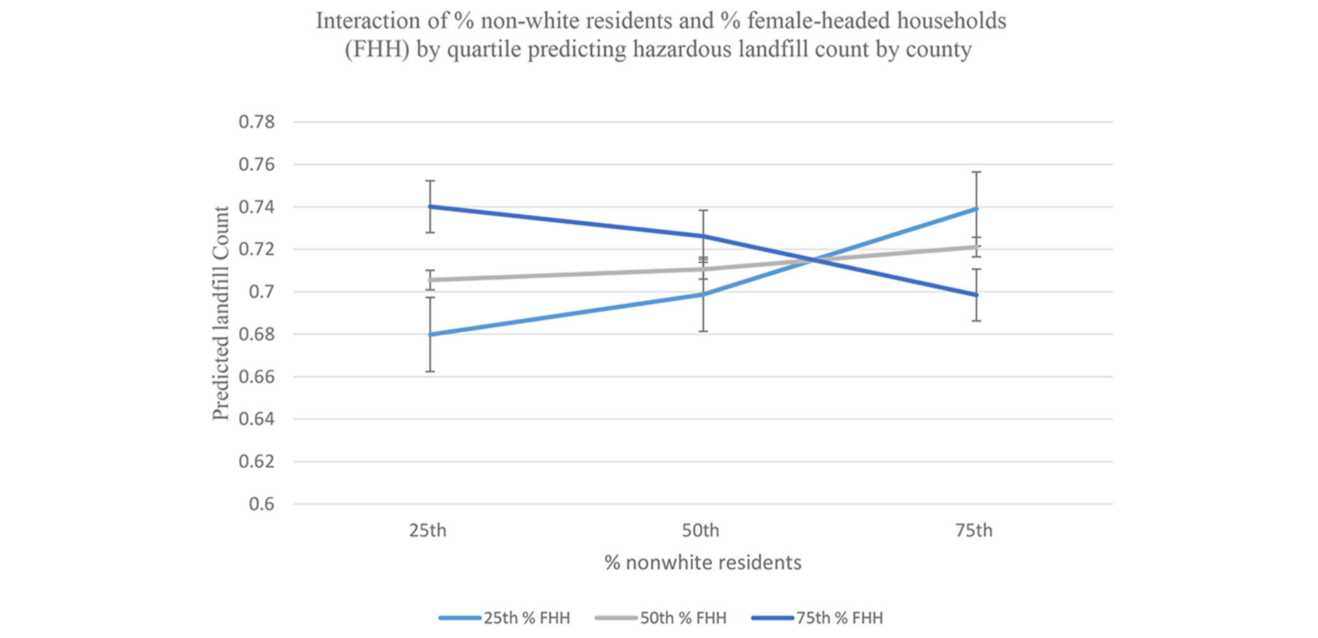

FIGURE 2 | Graph indicating statistically significant interaction of percent non-white residents and percent female- headed primary households by quartile predicting non-hazardous waste landfill count by county from Model 1. Please note error bars represent 95% confidence interval.

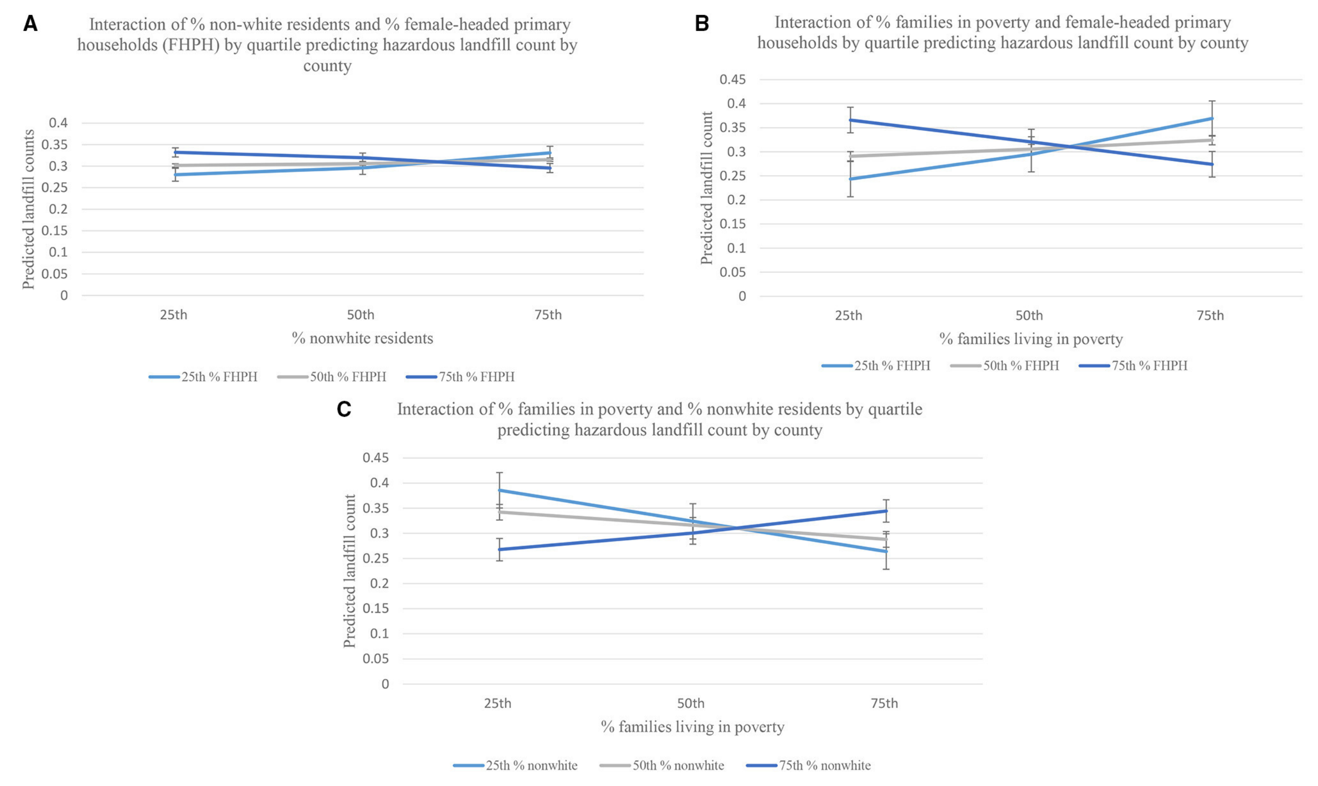

FIGURE 3 | Statistically significant interaction effects between percent non-white residents x percent female- headed primary households **(A)**, percent families in poverty x percent female-headed primary households **(B)**, and percent families living in poverty x percent non-white resident **(C)**, predicting hazardous waste landfill count by county.

et al., 2011) and intersectionality (McCall, 2005) that would suggest racial and gender inequality would have multiplicative effects on increased environmental hazards. This finding does not support hypothesis 4-B. Given these unexpected findings, models were re-run multiple times regionally to ascertain if there were differences across regions. For instance, the same models were run by US EPA region (i.e., Northeast, Southeast, West, and Midwest) and the same results held across each region. Models were also run by RUCC code. Counties were subsetted by metro, non-metro, and completely rural counties according to RUCC codes. The findings reported here also held across these different groupings (Results are available upon request). Considering this and drawing on more recent quantitative intersectional research that has found intersectional risks to be more than the sum of their parts (i.e., not multiplicative) (e.g., Evans et al., 2018), we argue that intersectional risks to environmental injustices may not be multiplicative so much as entangled.

Entanglement is understood both as a complicated or compromising relationship and as what Einstein referred to as "spooky action at a distance"—that two objects affect each other in hard to predict and non-linear ways over space and time (e.g., Gilder, 2009). To say the least, socially constructed categories of race and gender, not to mention data measures of these constructs (e.g., D'Ignazio and Klein, 2020), are complicated relationships in themselves and to each other that may put residents in compromising positions because of the ways that structural racism and heteropatriarchy play out across space and time (e.g., formal and informal practices of redlining). Rather than understanding the multiplicative ways that race and gender can and do disadvantage some, intersectional theory pushes us to think deeper about the arrangements of power that constrain people's lives and life chances. Applying an intersectional theoretical framework, we suggest that race and gender interlock in entangled ways and not just multiplicative ones. This may mean that though we would expect, for example, Black women to be doubly constrained by structural racism and heteropatriarchy, we also find that they have access to forms of power and resistance that push back on these forces and tells a more complicated story than one solely of multiple forms of oppressions and attendant injustices (e.g., Ducre, 2018). The non-linear findings suggest that just as structural arrangements of power that produce and maintain oppressions are complicated so are arrangements of resistance. The pressing social and environmental crises due to climate change are likely to both exacerbate the effects of such power arrangements as well as inspire opposition to it. Future research should investigate and test this suggestion particularly using qualitative methods to gain greater insights into the lived experiences of Black, Indigenous, and women of color in both their experiences of environmental injustice and forms of their resistance to it, especially as it relates to climate change risks.

In Model 2, the two-way interaction between gender inequality and poverty indicates that as the percentage of female headed primary households increases there is a corresponding increase in the number of hazardous waste landfills, but that effect declines as percentage of families in poverty increases (**Figure 3B**). This result does not support hypothesis 4-C that gender and income inequality would have multiplicative effects on environmental hazards.

Adding to the point above, it may be the case that the interlocking systems of oppression (i.e., heteropatriarchy and structural racism) that constrain women's life chances do so in non-linear ways. For instance, take the gender wage gap referenced above. When that gap is broken down further by race and ethnicity, it tells a more specific story that black women earn 66%, while Indigenous women make 60%, and Hispanic women earn 58% of a white man's pay for the same work (Hegewisch and Tesfaselassie, 2018; Asante Muhammad et al., 2019; Hegewisch and Barsi, 2020). It could be that this lack of wages not only constrains residential choice putting women of color in areas with more landfills and thus in areas with increased environmental risks as posited above, but also may inform relationships between gender, race, environmental justice, and resistance in ways not yet theorized or fully understood.

That is to suggest, gender, race, class, and environmental injustice—here in the form of environmental risks posed by landfills—are non-linear and may be entangled. For example, given environmental justice research we would expect that as the percent of non-white residents increases and the percent of female-headed primary households increases so does the number of landfills. However, we find that this effect decreases as the number of female-headed primary households increases. One explanation of this result could be that women, and in particular Black, Indigenous, and women of color, though they earn less money for the same work, are often the driving force behind organizing and coalition building to stop unwanted land uses (i.e., landfills) (e.g., Taylor, 2000; Cole and Foster, 2001; Bullard and Wright, 2012). Using an intersectional interpretive framework to understand these analyses, we argue that such findings could evidence sites of resistance and forms of power by Black, Indigenous, and women of color to environmental injustices and risks (Mann, 2011; Ducre, 2018; Perkins, 2021) which may explain the unexpected finding. Such an interpretation could have implications for climate risks both in how landfills contribute to global warming through methane emissions and in how landfills are not "climate ready"—that is they are not designed to withstand shocks anticipated from increased disaster frequency and severity due to the global climate crisis (e.g., Weber et al., 2011; Sinnathamby et al., 2014; Wille, 2018; Beaven et al., 2020).

Model 2 also shows that as percentage of non-white residents in a county increases there is a corresponding increase in the number of hazardous waste landfills in a county, especially as percentage of families in poverty increases (**Figure 3C**). This finding supports Hypothesis 4-A that membership in both a racial minoritized group and low socioeconomic status group has multiplicative effects on the likelihood of experiencing environmental inequality. It also may signal the complicated relationship among structural power arrangements in that there is a multiplicative effect of race and class on presence of environmental risks, confirming insights from previous environmental justice research (e.g., Brulle and Pellow, 2006; Mohai and Saha, 2015b; Cannon, 2020) and intersectionality research (e.g., McCall, 2005; Else-Quest and Hyde, 2016b). While belonging to two disadvantaged social groups exacerbates environmental injustices, there is still much to learn about the ways that gender, race, class, and environmental justice intersect to produce and reproduce both environmental risks and resistance. This finding also highlights the importance of including gender in theoretically developing and empirically analyzing environmental outcomes, an often-overlooked dimension in quantitative environmental justice scholarship, as it tells a more complicated story than one of just race and class.

To summarize, we find some support for the idea that intersecting social axes do not result in just multiplicative effects but that the linkages among race, class, gender, and waste are more complex. Applying an intersectional framework to environmental justice theories of waste distribution, such as the path of least political resistance and constrained housing choices referenced above, informs us not only of the complexities that gender brings to socio-environmental analysis that has thus far predominantly focused on race and class, but also generates novel insights into structural arrangements of power. In our intersectional reading, it is not simply that women of color most likely experience greater environmental injustices due to structural power arrangements that make intersecting identities matter, but that they most likely are actively resisting such injustices. Such insights have implications for climate-related risks not just from landfills but also for social mobilizations against major contributors to climate change (e.g., fossil fuel industries, industrial agriculture, regulatory and compliance failures). Additional research is needed to test the explanation presented here and to better articulate the complex relationships among waste, power, and resistance.

Limitations and Future Research

There are limitations to this study that suggest important areas for future research. First, the current study employs a cross-sectional analysis of secondary data (for critiques, see Mohai and Saha, 2015a). As such, this research is unable to determine causality, future research should include historic census data, municipality data, and landfill permitting dates. More data is needed at an even greater detailed level to focus on at-risk areas for disaster. Such finer grained data is necessary to more accurately identify and define key relationships among sociodemographic characteristics, disaster, and landfills especially for those most vulnerable to harmful impacts. Future research should consider using disaster data that include both spatial and temporal indicators to investigate relationships across time, space, and social inequality intersectionally. Moreover, future research should consider investigating the relationship between disaster type and social inequality. Secondly, the sub-national level scope and the county scale might affect estimated relationships (Baden et al., 2007). Similar to many geographic units of analysis, there are limitations in accounting for differences across the unit of analysis (i.e., counties) (Ringquist, 2005). For example, there may be more within-county variation for certain variables (i.e., percentages of non-white residents) than other variables (i.e., RUCC). Future research should further test the identified relationships here among sociodemographic characteristics, disasters, and landfills at a more fine-grained level of analysis (i.e., using census tracts, at-risk areas for disaster). Additionally, environmental justice research has shown the effectiveness of using distance-based methods (i.e., geographically weighted regression) to ascertain key relationships among race, class, and hazardous waste sites (Mohai and Saha, 2015a). This research has demonstrated the importance of including measures of gender inequality in environmental analyses. However, analyses are limited by the secondary data collected. Subsequently, additional data must be collected to more fully measure and account for gender inequality. Additionally, more research is needed to address other vulnerable groups to disaster including the elderly and children. Similarly, intersectional data should be collected to further test the findings and theories presented here. Finally, future research should employ qualitative approaches to further extend intersectionality theory within environmental justice and to advance our understanding of underlying mechanisms of general trends presented here (e.g., Malin and Ryder, 2018).

CONCLUSIONS

Quantitative environmental justice research into waste containment has rarely theoretically developed or analytically included measures of gender or gender inequality. This paper advances our understanding of intersectional environmental risks through an analysis of both non-hazardous and hazardous waste landfills, disasters, race, class, and gender across the U.S. In doing so, we highlight the risk disparities related to landfills. We advance intersectionality studies by empirically testing research hypotheses derived from intersectionality theory and applied to environmental outcomes. Doing so we improve understanding of disparate environmental impacts on women and racially minoritized groups and reflect on best practices for including gender and racial minority considerations into research design and analysis. We build on these insights to suggest that relationships among gender, race, class, and waste are entangled—that they are related in non-linear and spooky ways—and as such reflect the complicated ways that minoritized women are agents of power not just encountering environmental injustices but also fighting them. Our theory can inform policies related to risk management around landfills, as well-strategies of resistance to environmental injustices, especially in light of the pressing and existential challenges driven by global climate change, particularly for marginalized groups. This theory necessitates further testing and refinement through both quantitative and qualitative means. In sum, the theoretical framework and analysis presented here extends environmental justice research through a synthesis of intersectionality theory to develop a theoretical framework of intersectional entanglement to empirically analyze climate-related risk disparities in the U.S.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

AUTHOR CONTRIBUTIONS

The author confirms being the sole contributor of this work and has approved it for publication.

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