

Geospatial Analysis of Mental Health Outcomes Following the 2013 West, TX Fertilizer
Plant Explosion

By

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I dedicate this to my mom, step-father, and brother, who supported me throughout my educational journey. Thank you for supporting me and providing the motivation I needed to continue on despite any challenges I faced. Additionally, I would like to dedicate this to two of my friends, Kaylee Schilling and Jeff Martinez. Thank you for being there for me throughout this program.

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ABSTRACT

Natural and man-made disasters have increased in the frequency of occurrence and the extent of their impact on people, agriculture, and infrastructure over the previous 40 years (UN Office for Disaster Risk Reduction, 2020). Given the growing frequency of disasters occurring, it has become crucial in the field of public health to better understand the mechanisms behind how disasters impact health and well-being. This study examined the geospatial relationship associated with the Euclidean distance from the site of an explosion in the rural community of West, TX, and the adverse mental health outcomes the community faced in the years following the incident. Data for this analysis was collected via in-person and online surveys of residents of the City of West. The findings from this study found that the prevalence of potential PTSD in rural communities meets and potentially exceeds that of urban communities. Additionally, we found that adverse mental health was clustered closest to the disaster site, and that the density of potential prevalence tapered off as distance increased.

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CHAPTER I

INTRODUCTION

Natural and man-made disasters have increased in the frequency of occurrence and the extent of their impact on people, agriculture, and infrastructure over the previous 40 years (UN Office for Disaster Risk Reduction, 2020). It is estimated that approximately 400 natural disasters occur worldwide each year (Waldman, 2018). These disasters impart significant tolls by impacting the health of millions and resulting in substantial increases in mortality (Waldman, 2018).

From a public health perspective, disasters present unique challenges due to them frequently occurring with little notice, ultimately leaving people with little to no time to adequately prepare or evacuate. With little warning, physical injuries and death will generally happen within minutes of a disaster occurring (Galea, 2018). As the events of the disaster subside, community members will face additional challenges, including the disruption of daily activities, community clean-up, and tasks associated with rebuilding. Unfortunately, living through a disaster and the losses people experience will contribute to the potential development of mental health conditions such as depression, post-traumatic stress disorder (PTSD), and anxiety (Galea, 2018; Morganstein & Ursano, 2020). Therefore, it is crucial for community members, first responders, medical professionals, public health officials, and governmental organizations to understand the immediate and secondary impacts of disasters.

As previously mentioned, disasters occur worldwide and do not discriminate when it comes to locality or population size. The rural community of West, TX,

experienced a devastating disaster on April 17, 2013, after a fire began at the West Fertilizer Company plant, which was located in close proximity to a residential neighborhood and schools (Waco-McLennan County Public Health District [WMCPHD] & Texas Department of State Health Services [TXDSHS], 2014). At the time of the fire, approximately 40 to 60 tons of fertilizer grade ammonium nitrate was stored on-site (U.S. Chemical Safety and Hazard Investigation Board, 2016). The fire quickly spread throughout the fertilizer building and subsequently caused the detonation of approximately 30 tons of the ammonium nitrate (U.S. Chemical Safety and Hazard Investigation Board, 2016).

The explosion of such a significant amount of combustible materials resulted in several immediate impacts on life and property. During the evening of the explosion, 176 people sought medical treatment in area hospitals and medical facilities, and by the end of April 18th, 2013, a total of 232 patient visits had occurred (WMCPHD & TXDSHS, 2014). In total, the explosion fatally injured 15 individuals and was directly involved in the injuries of 252 additional people (WMCPHD & TXDSHS, 2014). Injuries sustained as a direct result of the explosion included abrasions/contusions, lacerations/penetrating trauma, traumatic brain injuries/concussions, hearing problems, eye injuries, inhalation injuries, sprains/strains, fractures/dislocations, pneumothorax, blast lung/abdomen, and burns (WMCPHD & TXDSHS, 2014). Of those injured, approximately 55% reported being inside a structure at the time of explosion, while 13% were outside and 8% were inside a vehicle (WMCPHD & TXDSHS, 2014).

Additionally, “[t]he explosion caused extensive damage to the homes, businesses, and schools near the plant” and left a crater at the site of the explosion measuring 10 feet deep by 90 feet in width (WMCPHD & TXDSHS, 2014, p. 4). The explosion’s strength was measured as 2.1 on the Richter magnitude scale (WMCPHD & TXDSHS, 2014). Of those surveyed, 71 people reported that they have moved since the date of the explosion. Due to the extent of the explosion on a rural community, it is crucial to examine both the physical and psychological outcomes of the community to understand if the community’s needs were left unmet. Additionally, knowledge of how mental health outcomes as time elapses from a disaster will allow for more appropriate long-term interventions to improve overall mental health conditions.

Purpose

The purpose of this study is to examine the relationship between the geospatial distance between the site of the West, TX fertilizer plant explosion and the participant’s residence at the time of the explosion and mental health outcomes.

Research Question

This study aims to answer and provide insight into two questions:

1. Is the distance between the place of residence and explosion site associated with adverse mental health outcomes at a large scale in the rural town of West, TX?
2. When a disaster impacts a large portion of a rural town, are adverse mental health outcomes still prevalent years after the event?

Hypotheses

We hypothesize that as the Euclidean distance measured between the participant's place of residence and the explosion site increases, the prevalence of potential PTSD will decrease. Additionally, we hypothesize that adverse mental health outcomes will still be present and at elevated numbers six years post-disaster.

Significance of the Study

While much research has been conducted evaluating the impact of disasters on the general health of populations, few have evaluated the mental health of rural communities post-disaster. This study will contribute to the growing body of literature surrounding the effects of disasters by providing valuable insights into how mental health is impacted in a rural community.

CHAPTER II

LITERATURE REVIEW

Disasters

While the definition of disasters often varies throughout the literature, it usually consists of several key characteristics, including a threat of harm or death to a large population, a disruption of day-to-day services, and often have consequences that occur after the disaster has concluded (Goldmann & Galea, 2014). Although previous literature has often held different definitions of what constitutes a disaster, recent works in the field attempt to provide a clear definition. In 1976, an argument was made that “[w]ithout people there is no disaster” and that disasters were the interface of extreme physical phenomena on a vulnerable population (O’Keefe et al., p. 566). They argued that the use of “natural” when referring to disasters took the blame off those in charge of taking appropriate precautionary planning necessary to build a community resilient to extreme phenomenon (O’Keefe et al., 1976).

In recent years, many disaster research organizations have begun to adopt the philosophy that there are no natural disasters, only natural hazards (*About Our Campaign*, 2022; Wisner & Fordham). These hazards will only become disasters when they begin to impact a society or community that is vulnerable to the hazard, which can stem from socioeconomic factors and decisions (*About Our Campaign*, 2022; Wisner & Fordham). Researchers tend to agree that the term “natural disaster” often allows government relief agencies and politicians to emphasize the term natural as a means to shift responsibility away from the root cause of the disaster (Olson, 2018). Recognizing that disasters stem

from human vulnerability to a hazard allows for researchers, public health officials, and governments to focus on why some people are more vulnerable to a hazard than other groups (von Meding & Chmutina, 2020).

When disasters occur, they often can result in prolonged exposures to hazardous situations. Hazardous situations can vary depending on the type of natural hazard that occurred. Hazards left in the wake of earthquakes, landslides, and hurricanes can include damage to infrastructure, shelter and the inability to access safe drinking water. These prolonged exposures often result in the community impacted being forced to adjust (Smith et al., 2006). The inability to adjust or cope with the ongoing hazards can result in the population's quality of life and overall health to deteriorate. While research has clearly shown that disasters have an immediate and prolonged impact on the health of a community, the extent to which geospatial locations in relationship to a disaster in rural communities impacts mental health has often been overlooked.

Much of the current literature often focuses on urbanized communities despite rural communities often being especially vulnerable to adverse impacts of a disaster (Chan et al., 2019; Kapucu & Rivera, 2020). Although focus is often on urban centers, research conducted in rural communities frequently highlights the need to increase focus on these vulnerable communities. Unfortunately, rural communities frequently are composed of households with higher poverty rates and have fewer resources available to the community in the event of a disaster (Horney et al., 2017). Studies of rural communities have often found that rural communities' disaster mitigation plans focus more on response instead of mitigation and prevention (Berke et al., 2013; Horney et al.,

2017). Evidence of poor mitigation planning was still evident at the conclusion of the 2020 hurricane season as “as least hundreds, if not thousands, of people still needed help in preparing for winter storms” (Maldonado & Peterson, 2021). Additionally, those who lost their homes due to storms were without shelter because the emergency shelters closed at the end of the hurricane season (Maldonado & Peterson, 2021).

Injuries and illnesses associated with disasters will vary depending on the type of hazard that resulted in the disaster. Populations impacted by a disaster can suffer from respiratory illnesses due to overcrowded emergency shelters or pollutants in the air caused by the event (Giorgadze et al., 2011). Inability to access safe, clean drinking water can result in gastrointestinal illnesses or disease (Giorgadze et al., 2011). Additionally, flesh wounds, fractures, and sprains are all possible depending on the type of hazard impacting the community (Bartholdson & Von Schreeb, 2018; Giorgadze et al., 2011).

Mental Health

Before considering what mental health is, we first must understand what health constitutes. The World Health Organization (WHO) has defined health as “a state of complete physical, mental, and social well-being and not merely the absence of disease or infirmity” (2018). As such, mental health is considered “a state of well-being in which an individual realizes his or her own abilities, can cope with the normal stresses of life, can work productively and is able to make a contribution to his or her community” (WHO, 2018). Because mental health is a state of well-being, it is something that can change over time and can be influenced by both external and internal factors (Centers for Disease Control and Prevention [CDC], 2021).

A person's mental health can be impacted by several factors, including social, psychological, and biological, which can ultimately result in the development of a mental illness (CDC, 2021; WHO, 2018). Mental illness can impact anyone and is more common than most people think. In fact, it is estimated that in the United States, one in every five Americans will experience mental illness in any given year and that more than 50% will be diagnosed with some form of mental illness during their lifetime (CDC, 2021).

Although many Americans will experience mental illness at some point in their life, few will admit that they are diagnosed with one, and fewer will seek help for their condition. Unfortunately, despite the fact that many Americans will eventually be impacted by mental illness or degraded mental health, people choose not to discuss or seek help due to their perceptions and attitudes about mental illness and how others might view them (Kobau et al., 2012). This stigma towards mental health results in people having negative attitudes towards others and can result in people who are open about their struggles with mental illness to be discriminated against (Kobau et al., 2012).

As the occurrence of disasters increases, the number of communities at risk for mental health disturbances also increases (Gruebner et al., 2017). Mental health disturbances resulting from disasters most frequently result in diagnoses of post-traumatic stress disorder, depression, generalized anxiety disorder, panic disorder, agoraphobia, and substance use dependence (Fergusson et al., 2014; Gruebner et al., 2017). Few studies to date have evaluated when mental health disturbances occur over time; however, one study found that the prevalence of potential PTSD six months after the terrorist attack at the World Trade Center was approximately 8.6% which later increased to 11.1% three

years after the attack (Berninger et al., 2010). Changes between the DSM-IV and DSM-V specify that PTSD is considered delayed onset if the symptoms occur at least 6 months after the stressor; however, the DSM-V clarifies that “the onset and expression of some symptoms may be immediate” (Substance Abuse and Mental Health Services Administration, 2016).

Accessing mental health services in rural communities can be a significant challenge for residents and obstacles to access to appropriate care can be further exacerbated by being more remote (Roberts et al., 1999). These challenges are caused by a several factors including geographic isolation, stigma towards mental health, and limited access to resources necessary to cope with stressors (Letvak, 2002). Due to the remote nature of some rural communities, it has been argued that work needs to be done to improve access to psychiatric services in these communities (Roberts et al., 1999).

It is vital to consider mental health when preparing and responding to disasters due to the underlying stigma that persists worldwide regarding mental illnesses. Additionally, knowing what factors protect or influence mental illness is important to consider when preparing communities for the potential of a disaster. Items that can contribute to an increased vulnerability for adverse mental health are things such as being from a low socioeconomic background and being exposed to disaster-related stressors for prolonged periods of time (Gruebner et al., 2015). Protective factors for mental health include building resilient communities and interventions that help people manage stressful situations (Mental Health First Aid USA, 2022).

Posttraumatic stress disorder (PTSD)

The Mayo Clinic describes PTSD as a “mental health condition that’s triggered by a terrifying event – either experience it or witnessing it” (Mayo Clinic Staff, 2018). Symptoms of PTSD may include having flashbacks of the traumatic event, nightmares, severe anxiety, and intrusive thoughts of the event (Mayo Clinic Staff, 2018). To be diagnosed with PTSD one must meet the criteria that have been established in the *Diagnostic and Statistical Manual of Mental Disorders (DSM)* since the third edition of the book (Friedman, 2019). As PTSD impacts a person’s mental health, it additionally can cause harm to their physical well-being by influencing the choices they make and can reduce overall productivity (*What is Mental Health?*, 2020).

As previously highlighted, PTSD is a mental health condition that may develop in persons who are impacted by traumatic events. Therefore, understanding how PTSD influences overall health after a disaster will allow local communities, governmental agencies, and public health officials to better intervene after the occurrence of a disaster. Prior works have examined the impacts of the terrorist attacks that occurred in the Boston metropolitan area on April 15, 2013, just days before the explosion at the West, TX fertilizer plant (Jose, 2018). Interestingly, this study described that the majority of participants did not seem to be at risk for PTSD, and the only cluster of potential PTSD was immediately surrounding the attack site (Jose, 2018). However, it is important to mention that despite these findings, the area of study was a large metropolitan population and can be suggestive of having greater access to resources needed to cope with a traumatic event.

Additional studies have found clusters of negative emotions by analyzing spatial data collected from data collected from Twitter users after Superstorm Sandy in New York City (Garske et al., 2021). While their study looked at positive and negative emotion, it provides evidence that supports the possibility that mental health outcomes can vary based on sociodemographic and socioeconomic factors (Garske et al., 2021). Altogether, this indicates that research must be focused on examining the spatial relationships between mental illnesses such as PTSD and the community factors associated with protective and inhibitory factors to maintain positive mental health.

Resilience

In disaster epidemiology, resilience can often be considered as the collective resilience of the community. As such, Community Health Resilience (CHR) is defined as “the ability of a community to use its assets to strengthen public health and healthcare systems and to improve the community’s physical, behavioral, and social health to withstand, adapt to, and recover from adversity” (*Community Resilience*, 2015). Communities vary greatly in terms of population size, socioeconomic status, and distribution of resources. These differences result in a similarly wide variety of community impacts when disaster strikes.

Thus, it can be argued that building a community that is resilient can help buffer adverse outcomes associated with a disaster occurrence. Some strategies that have been offered to build resilient communities include: strengthening/promoting access to public health, healthcare, and social services; promoting health alongside disaster preparedness; expanding communications and collaboration within a community; engaging those at-risk

individuals and connecting them to programs that serve them; and building social connections within the communities (*Community Resilience*, 2015). Enhancing community resilience occurs when communities focus on empowering people to use the resources available to help cope when disasters occur (Kwon & Ryu, 2020). Interestingly, it is suggested that networking survivors of prior disasters with members currently experiencing disasters can foster resilience throughout the course of the event (Kwon & Ryu, 2020).

CHAPTER III

METHODOLOGY

The purpose of this study is to evaluate the role, if any exists, that geospatial distance from the site of the explosion to the participant's home address has on potential PTSD symptoms. Additionally, we aim to assess if the prevalence of potential PTSD symptoms has reduced to what the expected average in the general population six years after the disaster occurred. This study was approved by Middle Tennessee State Universities Institutional Review Board (19-1257).

Participants

Participant recruitment and data collection occurred from April 1, 2019 to May 31, 2019. Initial attempts to recruit participants were conducted by mail distribution to all households in the City of West (N = 1066) requesting recipients to participate in an online questionnaire. After two weeks, contact was attempted to be made on all households (N = 915) that did not initially respond to the mailed invitation. The survey team left door-hangers at households that no contact was made (N = 218) that provided additional contact information and a link to complete the questionnaire. At the conclusion of the data collection period, the survey team collected 373 completed questionnaires, of which 224 were completed online and 149 in-person. After data cleaning, a total of 273 questionnaires were included in this study for analysis.

Materials and Procedure

To assess potential adverse mental health outcomes the use of two different short surveys was included built-in to the main questionnaire. The surveys used to collect information pertaining to potential PTSD were: the *Kessler-6 short scale of psychological distress* and the *Posttraumatic Stress Disorder- 8 a short PTSD inventory*.

Posttraumatic Stress Disorder-8 a short PTSD inventory

The *Posttraumatic Stress Disorder-8 (PTSD- 8) inventory* was developed using questions from the first 16 items of the Harvard Trauma Questionnaire (HTQ) Part IV (Hansen et al., 2010). These items were selected as they represented the basis for meeting the diagnostic criteria for PTSD in the DSM-IV (Hansen et al., 2010). Analyses were conducted comparing the PTSD- 8 to the HTQ and found that the eight questions were highly correlated (adjusted $R^2 = 0.80-0.87$) across the scales (Hansen et al., 2010). A recent analysis has further validated the PTSD- 8 in patients undergoing chronic pain rehabilitation (Andersen et al., 2018). However, this study also found that the optimal cutoff score was slightly higher than the 18 points previously established by Hansen (Andersen et al., 2018; Hansen et al., 2010).

Kessler-6 short scale of psychological distress

The *Kessler-6 (K-6) short scale of psychological distress* is “a six-question short-form scale” that is used to measure the severity of psychological distress in respondents (Kessler et al., 2002). The K-6 scores range between zero and 24 with higher scores indicating a greater likelihood of mental illness (Prochaska et al., 2012). The scores are

based on individual ratings for each of the six questions. The K-6 has previously been validated and shown to have consistent psychometric properties across sociodemographics groups (Kessler et al., 2002). Additionally, the scale has been shown to be able to discriminate between cases and non-cases of disorders in the DSM-IV (Kessler et al., 2002; Prochaska et al., 2012). See Table 2 in the appendix for the phrasing of each question and how the questions are scored.

Analysis Plan

Data Preparation

The data collected were made available in the form of a Microsoft Excel spreadsheet. Functions built into Microsoft Excel will be utilized to recode variables to numerical values that can be used to measure levels of psychological distress using standardized scores that have been previously validated for the K-6 and PTSD-8 instruments. This data will be saved as a comma-separated values (CSV) file and will be imported into GIS software.

GIS Tools and Preparation

To begin the process of geospatial analysis, data files from the US Census Bureau will be downloaded and stored locally which will include: 2013 tigerline shapefiles and tables for area landmarks, places, point landmarks, tabulation (census) blocks, census tracts, McLennan County address range relationships, features, roads, and the 2013 US county shapefiles. The data will be imported into a file geodatabase using ArcCatalog (Redlands, CA, Version 10.8.2). ArcGIS Pro (Redlands, CA, Version 2.9) will be utilized

to map geospatial relationships between Euclidean distance and potential PTSD symptoms. Clustering will be analyzed using the Spatial Autocorrelation tool included in ArcGIS Pro that provides an estimation of the Global Moran's Index.

CHAPTER IV

RESULTS

On April 17, 2013, the rural town of West, TX, experienced a disaster that directly injured 252 citizens and fatally wounded an additional 15 people. Thus, this study explored the relationship between adverse mental health outcomes and the distance between a person's place of residence and the site of the disaster.

Measures of Potential PTSD

Prevalence

The prevalence of potential PTSD was evaluated using the PTSD-8 cut point of 18 that was established by Hansen and colleagues. Of those included in the study, 127 met the criteria for Potential PTSD and the prevalence for this population was approximately 46.5%.

Spatial Density of Potential PTSD

The spatial density of potential PTSD was measured using ArcGIS Pro's kernel density tool. In Figure 1, the highest density of potential PTSD was immediately surrounding the West Fertilizer Company, where the explosion occurred. As distance increased from the explosion site, densities of potential PTSD can be seen decreasing. Global Moran's I was calculated utilizing ArcGIS Pro's Spatial Autocorrelation tool with $I = 0.38, p < 0.01$, indicating spatial clustering of potential PTSD.

Measures of any Potential Mental Illness

Prevalence

The prevalence of any potential mental illness was evaluated using the previously validated K-6 cut point of five (Prochaska et al., 2012). Of those included in this study, 128 met the criteria for any potential mental illness, and the prevalence for this population was approximately 47.2%.

Spatial Density of any Potential Mental Illness

Spatial density for any potential mental illness was completed in a similar to that of the potential PTSD measure, except it utilized scores from the K-6 survey. In Figure 2, the density of any potential mental illness was located closest to the site of the explosion. Similar to Figure 1, the potential for any mental illness decreased as distance from the site of explosion increased. Moran's I statistic was also calculated using ArcGIS Pro's Spatial Autocorrelation tool with $I = 0.40$, $p < 0.01$, indicating spatial clustering of people potentially suffering from any form of mental illness.

Relative Risk

The K6 survey questions were completed by all participants regardless of their place of residence at the time of the explosion. Therefore, we calculated the relative risk for any potential mental illness among survey respondents. Given the survey responses, those living in West, TX, at the time of the explosion were 1.67 times more likely to meet the criteria for any form of potential mental illness.

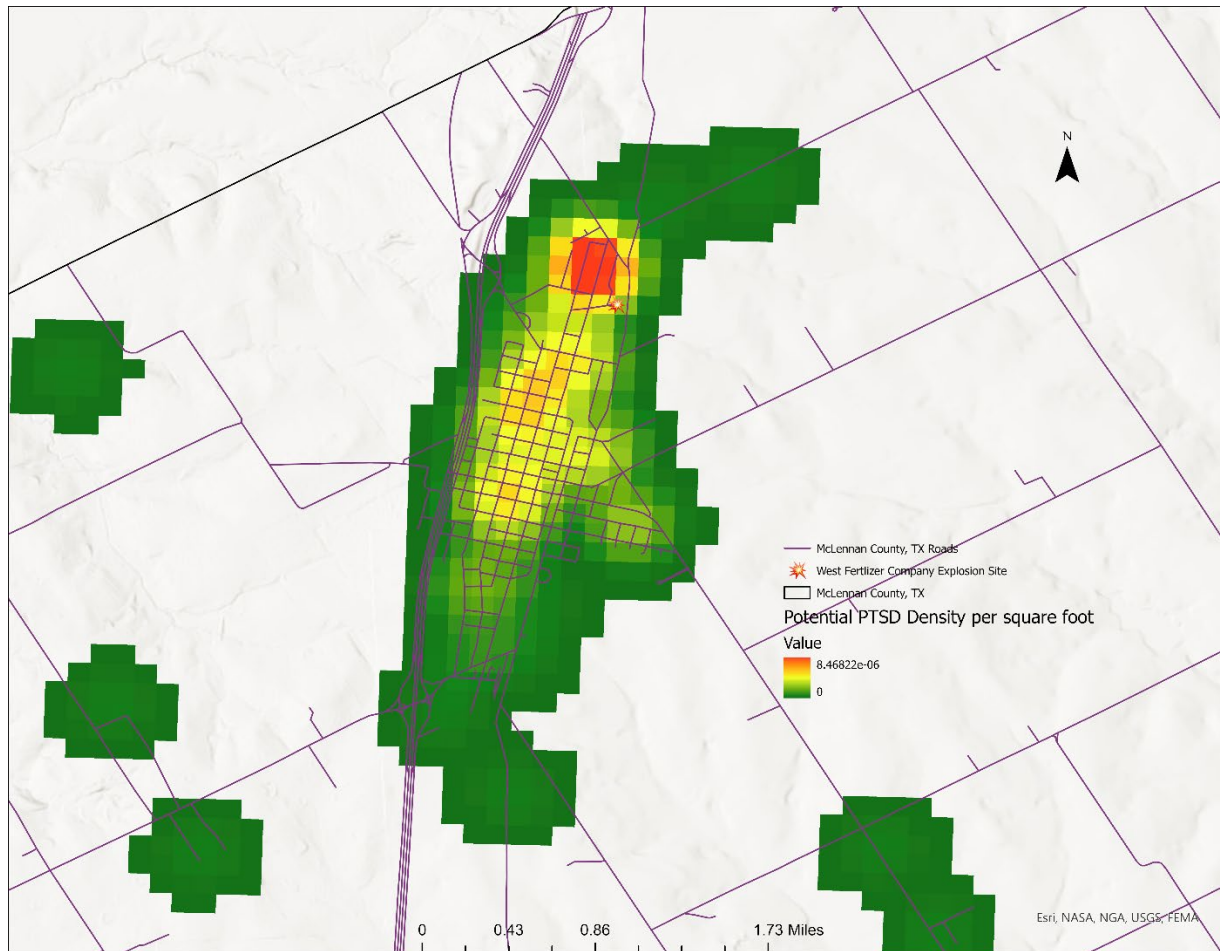


Figure 1: Density of Potential PTSD

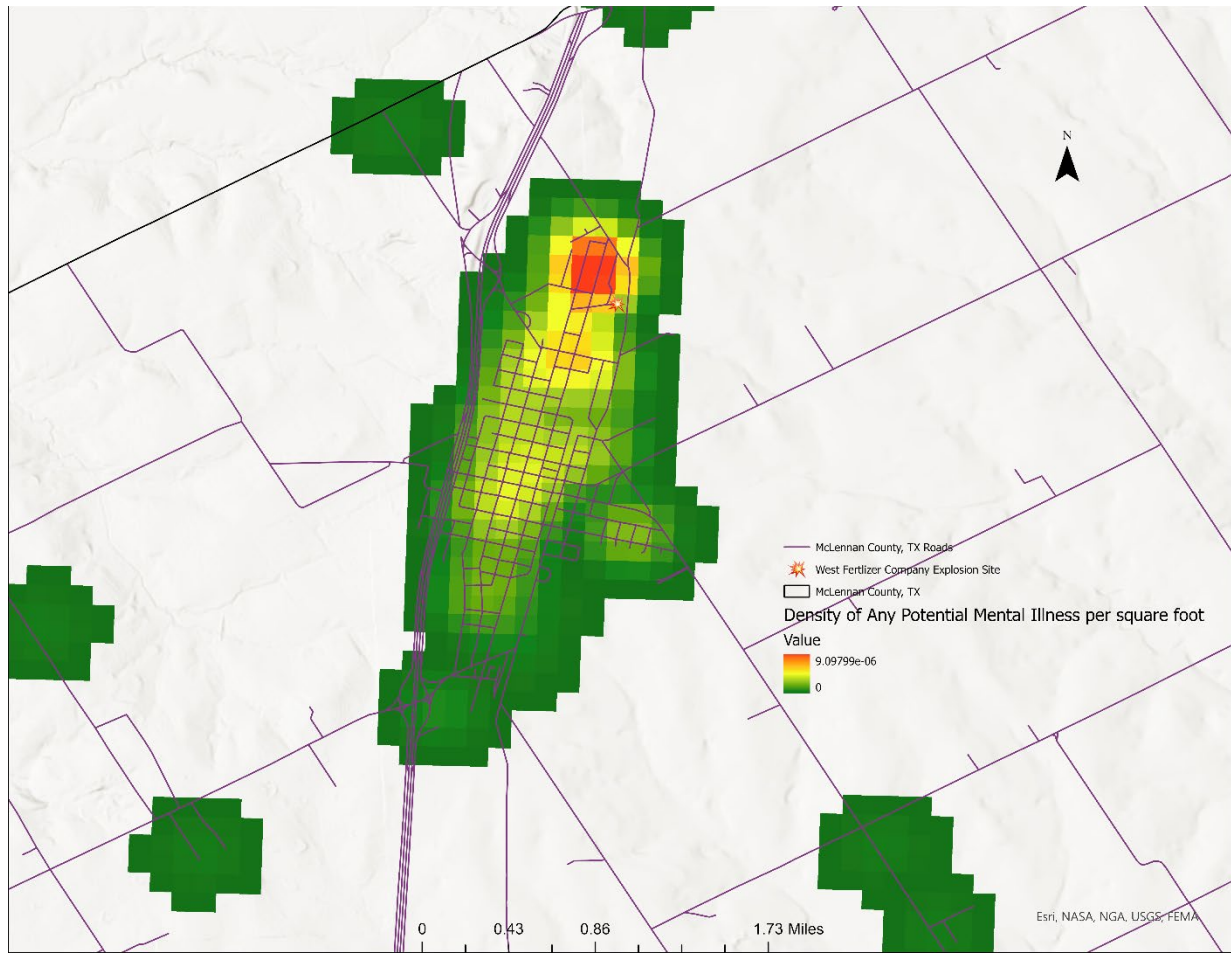


Figure 2: Density of Any Potential Mental Illness

CHAPTER V

DISCUSSION

Natural hazards will continue to interact with communities, some of which will result in disasters for the communities impacted by the hazard. As a society, we must learn to no longer downplay disasters as an outcome that we cannot prevent. While we will not be able to stop natural phenomena, we are able to make a difference in mitigating and responding to disasters before they impact communities. As research often focuses on disaster outcomes and mitigation in urban communities, this research set out to explore the outcomes of a rural community largely impacted by an explosion at the West Fertilizer Company that occurred on April 17, 2013.

Findings from this study provide a unique perspective of a rural community impacted by a devastating explosion. Spatial analysis revealed similar results to other studies investigating mental health outcomes post-disaster in that clustering of potential mental illness was greatest the closer a person was to the exposure (Gruebner et al., 2018; Gruebner et al., 2015; Gruebner et al., 2017; Neria et al., 2008). Our first hypothesis suggested that as distance increased from the explosion site, the prevalence of PTSD would decrease. Our results from this study support this hypothesis and can be seen in Figures 1 and 2, which demonstrates the highest density of potential PTSD was closest to the site of the explosion, and as distance increased, the relative density of PTSD decreased.

The second hypothesis of this study sought to answer whether the prevalence of PTSD was still present in the community six years post-disaster. We can answer this question by comparing the prevalence of PTSD or any potential mental illness to other studies investigating mental health outcomes in relation to disasters. The prevalence of PTSD post-disaster is most commonly cited as being 30-40% among victims and that general populations generally are between 5-10% (Goldmann & Galea, 2014; Küçüköğlü et al., 2015; Neria et al., 2008; Seyedin et al., 2017). Our findings support the claims that those impacted by a disaster experience an increased risk for PTSD or any mental illness, with the prevalence being 46.5% and 47.2%, respectively.

Rural communities have routinely been identified as an especially vulnerable group and are often at a greater disadvantage regarding mental health (Letvak, 2002; Roberts et al., 1999). Despite six years passing between the evening of the disaster and data collection, the community in West, TX, is still plagued by a significant burden of adverse mental health conditions. Thus, it is imperative to consider ways to reduce the burden on rural communities. Stigma and limited resources often prevent residents of rural communities from receiving the care they desperately need (Letvak, 2002; Mental Health First Aid USA, 2021). A relatively inexpensive way for communities to foster a resilient community is to build the foundation for social support and social connectedness (Letvak, 2002; Mental Health First Aid USA, 2022). Training provided by Mental Health First Aid “can help you dismantle the stigma that keeps people from speaking up and getting help,” which could help curtail adverse mental health outcomes post-disaster (Mental Health First Aid USA, 2021). Additionally, providing rural communities with equitable access to mental health services could foster better mental health outcomes.

This study presents a unique insight into the potential differences between rural and urban communities with respect to mental health outcomes. After the Boston Marathon Bombing, a study investigating spatial relationships to mental health outcomes found that “the vast majority of people did not appear at risk for PTSD or report high levels of acute stress or fears and worries in the aftermath of the bombings” (Jose, 2018, p. 484). In this study, nearly half of the survey participants met previously validated criteria to be considered as potentially being impacted by a mental illness. However, in comparison to the Boston bombing both studies found clustering near the explosion site. The results raise an important question of whether the cause of Boston respondents not being impacted by PTSD were related to access to more resources or some other confounding variable not measured in this study. The discrepancies can most likely be attributed to the difference between communities and unequal access to mental health services associated with rural communities (Roberts et al., 1999).

Limitations and Future Directions

Although this study found spatial relationships between mental health disturbances and distance from the disaster site, there are some limitations. The first limitation was the study design not including a question soliciting the age or gender of the survey participants. Unfortunately, the initial survey design only sought to determine if participants were 18 or older to determine the respondent’s eligibility. Prior research on mental health outcomes has shown that PTSD as a result of a disaster is associated with age and gender (Adams & Boscarino, 2006). Future researchers should include survey

questions that ask participants for their age and gender so that these variables can be controlled for in data analyses.

Another limitation of this study is related to a relatively small sample size when compared to total households in West, TX, at the time of the explosion. Out of the 373 completed questionnaires, only 273 could be retained for analysis due to incomplete surveys or no address data being provided. Despite this limitation, other studies conducting similar research only had a slightly higher sample size despite being in an urban population (Jose, 2018). Future researchers will need to identify methods that can be utilized to foster increased survey response.

Additionally, future researchers should attempt to identify the resources that communities can readily access. As previously mentioned, access to community resources during times of disaster can help mediate adverse mental health outcomes. A thorough analysis of the community's hazard mitigation plans can shed light on what the community can readily access to help reduce adverse outcomes.

Despite the limitations, this study provides a solid framework for the basis of future studies investigating adverse mental health outcomes in rural communities. This study demonstrated an elevated prevalence of potential PTSD and mental health outcomes six years after a disaster. Future studies can conduct longitudinal research investigating the prevalence of PTSD as a function of time. Longitudinal studies would be able to demonstrate how PTSD manifests itself in a community and would shed light on the course of PTSD post-disaster.

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Appendix

Table 1: PTSD- 8 Questionnaire

The following are symptoms that people sometimes have after experiencing, witnessing or being confronted with a traumatic event. Since the explosion, how much have the following symptoms bothered you?

Item #	Item
1	Recurrent thoughts or memories of the event.
2	Feelings as though the event is happening again.
3	Recurrent nightmares about the event.
4	Sudden emotional or physical reactions when reminded of the event.
5	Avoiding activities that remind you of the event.
6	Avoiding thoughts or feelings associated with the event.
7	Feeling jumpy/easily startled.
8	Feeling on guard.

Scoring: 1- Not at all, 2- Rarely, 3- Sometimes, 4- Most of the time

Table 2: K- 6 Questionnaire

During the past 30 days, about how often did you feel...

Item #	Item
1	...nervous?
2	...hopeless?
3	...restless or fidgety?
4	...so depressed that nothing could cheer you up?
5	...that everything was an effort?
6	...worthless?

Scoring: 0- None of the time, 1- A little of the time, 2- Some of the time, 3- Most of the time, 4- All of the time.