Why Are Some Countries More Resilient Than Others During Acts of God?

Why are Some Countries More Resilient Than Others During Acts of God?

Adam Delaney Nowell

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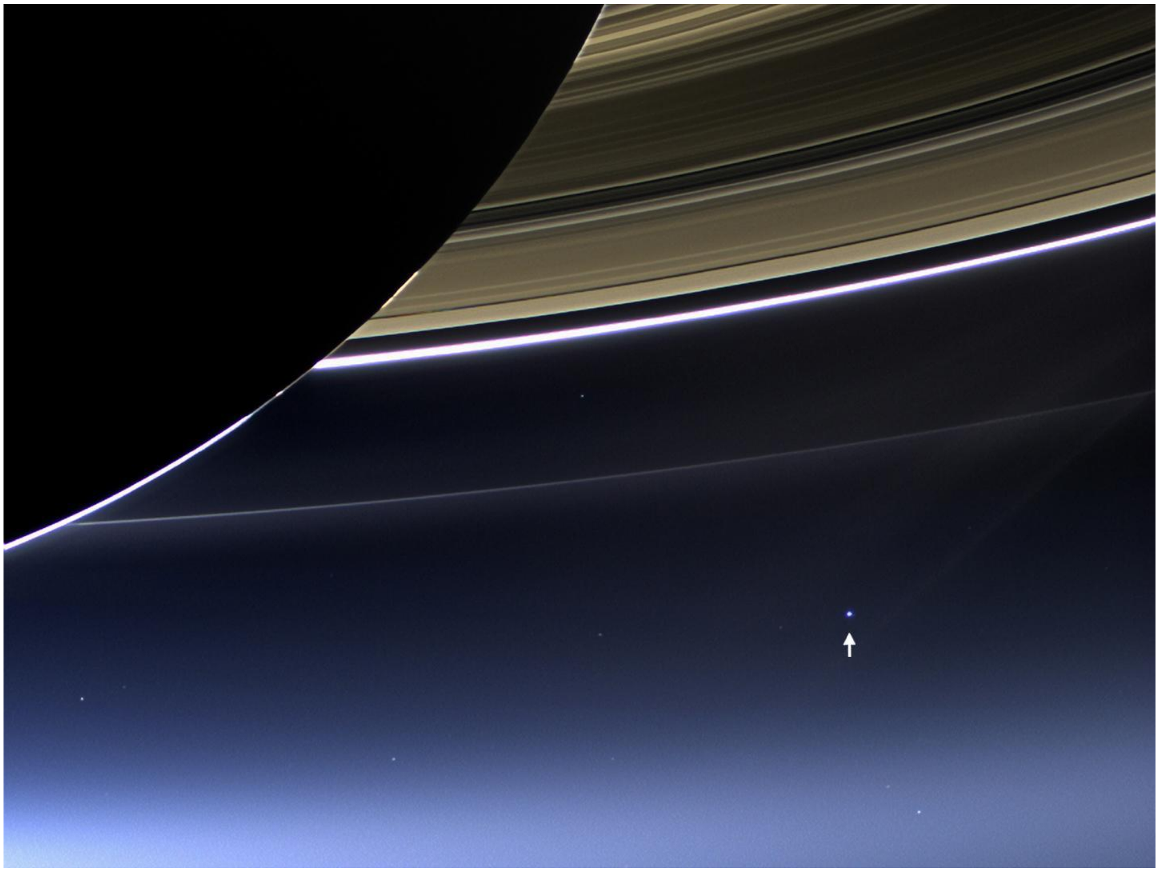
Abstract

International human rights laws protect us from natural disasters, but how human rights violations cause or perpetuate natural disasters is unclear. Earthquakes can be devastating and are believed to be independent of climate change. Wildfires are believed to be at least partially influenced by climate change, and their unpredictability often leads to unexpected increases in mortality and morbidity. A panacea for increased natural disaster resiliency exists for all types of natural disasters through an increase in each country's World Happiness Report Score (WHRS). This score not only considers human rights violations, but a multitude of factors: GDP per capita, social support, health life expectancy, freedom to make life choices, generosity, trust, and perceptions of corruption. The goal of this research was to examine if these indirect drivers of ecosystem change do explain the differences in countries' natural disaster resiliencies, which I define as the reduction in human suffering when a disaster occurs. My specific hypothesis was that a country's human rights violations score is negatively correlated with natural disaster resiliency. Using multivariate analysis to control for other factors also correlated with natural disaster resiliency, especially the magnitude of the disaster, this research indicates that an increase in human well-being and poverty reduction alone may reduce impacts of climate change. Evidence in support of this hypothesis was provided in the sets of data I examined.

I created two data sets, one for earthquakes and one for wildfires by merging information from the EM-DAT database, the Significant Earthquake Database, World Happiness Reports 2012-2017, the CIA World Factbook, and Human Rights Watch

Reports 1990-2016. These data were used to explore my hypothesis by creating MLR models to examine how the total deaths that result from a discreet natural disaster was influenced by natural disaster resiliency, equal to magnitude of a natural disaster and the WHRS. Other physical and social predictor variables were also explored, such as the duration of a natural disaster and the percentage of atheists that reside in a country. Slight variations of resiliency, such as the percentage of population killed by a discreet natural disaster, the total amount of people injured, and the total damage in US dollars were used to create alternative MLR models. By looking at two cases studies of data that were highly influential for all MLR models (the 2010 Haiti earthquake and the 2013 Yarnell wildfire), I conclude that most of the deaths from catastrophic natural disasters are humanitarian failures. I discuss the possibility that true natural disasters (ones free from anthropogenic origins) are inherently destructive, but not necessarily deadly.

Frontispiece



Author's Biographical Sketch

Adam Delaney Nowell, ALM is the sole founder of R3AD, a green consulting firm. With a specialization in Sustainability from Harvard University and a passion for divinity cultivated during his early childhood, he is a lifetime student of universality.

Basketball and videogames have always been his favorite hobbies, but those hobbies have extended way beyond recreational benefits. Statistical analysis has changed the way he enjoys basketball, and augmented reality has turned videogames into simulations of real world events.

His future plans include growing R3AD into a global entity and possibly pursuing a DPhil in Theology and Religion at Oxford University.

Dedication

I dedicate this work to Sandra Nowell, my Mom. Without her, I wouldn't be here.

Acknowledgments

Thank you, Mark Leighton, for helping me immensely. Through your guidance, kindness, and patience, I now know how to create a methodology that makes sense.

Thank you, Ramon Sanchez, for always being available and having a positive attitude towards helping me develop my initial thesis proposal. Your methodology of RPN inspired me.

Finally, I want to thank Tom Gloria. Every time I came into 51 Brattle, you greeted me with a warm smile and made me feel at home. If it weren't for you, I probably would not have homed in on wildfires.

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Definition of Terms

Acts of God: a legal term for events outside of human control, whereby no one can be held accountable or responsible for their occurrence, severity, and detection; traditionally natural disasters are Acts of God.

Augmented Reality: a technology that superimposes a computer-generated image on a user's view of the real world, thus providing a composite view.

EM-DAT Database: the International Disaster Database for the Centre for Research on the Epidemiology of Disasters (CRED); this is the database where all the natural disaster magnitude and death data will be obtained.

FEMA: Federal Emergency Management Agency.

HRW: Human Rights Watch, Non-governmental organization, founded in 1978, that conducts research and advocacy on human rights.

Hypocenter: The earthquake rupture origin point below the surface of the Earth; the epicenter is the point directly above the hypocenter, measured at the surface of the Earth.

IPCC: Intergovernmental Panel on Climate Change; formed in 1988 and set up by the United Nations to provide an objective view on climate change and its political and economic impacts.

MEA: The Millennium Ecosystem Assessment; this is a framework that links ecosystem change to human wellbeing. This framework provides the indirect drivers of ecosystem change for this research and allows me to hypothesize some statistical significant social variables associated with variations in natural disaster resiliency amongst different countries.

Natural Disaster: a non-anthropogenic event such as a flood, earthquake, or hurricane that causes great damage, increased morbidity, and/or loss of life.

NEIC: National Earthquake Information Center, part of the United States Geological Survey Government Agency.

NOAA: the United States (U.S.) National Oceanic and Atmospheric Administration; a government agency founded in 1970.

Resilience: The reduction in the number of deaths when accounting for the magnitude of the disaster. For example, a 7.0 earthquake with a death rate of 50 people indicates greater societal resiliency than one with 500 deaths.

SREX: Special Report on Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation.

R Studio: Open source and enterprise-ready professional software for R.

TIROS-1: Television Infrared Observation Satellite; NASA's first experimental step to prove that satellites could be useful at studying the earth.

UNISDR: United Nations International Strategy for Disaster Risk Reduction.

USGS: The United States Geological Survey government agency.

Chapter I

Introduction

Legally, Acts of God (Natural Disasters) are events beyond human control; no one can be held responsible for their occurrence. In 2012, the African Union enforced the world's first binding regional instrument on internal displacement. This agreement requires nations to prevent displacement of people due to natural disasters, and support solutions to displacement from natural disasters (Bookmiller, Ferris, Gerrard, & Nifosi-Sutton, 2014). There has been a global concerted effort to utilize international law to save people from natural disasters, by linking them to human rights violations (Bookmiller et al., 2014). However, on a national level, governments continue to wash their hands of natural disaster culpability. Historically, governments and various brain trusts have been concerned more about mitigating damage from natural disasters, as it is largely believed to be impossible to predict and prevent natural disasters from occurring in the first place. Recently a transition has taken place, with the United Nations International Strategy for Disaster Risk Reduction (UNISDR) leading the way.

The UNISDR reported that half of the world's inhabitants (expected by 2025 to increase to two-thirds), the majority of property, and the majority of wealth are concentrated in urban areas that are already prone to natural disasters (Ayyub, 2014). Established in the early 2000s, UNISDR has advocated natural disaster risk reduction through various global initiatives, mostly through infrastructure improvements, better governance, understanding climate change as a predictor variable for future natural disaster occurrences, and improving early warning systems associated with natural disaster detection (Ayyub, 2014). The U.S. based federal agency FEMA (Federal Emergency Management Agency, established in 1979) predates UNISDR, but FEMA spends most of their efforts on post disaster recovery (Olshansky, 1999). Prior to 1970, both NOAA and the modern-day internet had not been created yet. This severely hampered past researchers' ability to track the movement and magnitude of natural disasters, as well as communicate information regarding natural disasters, in a timely manner. In 1960, TIROS-1 (Television Infrared Observational Satellite) proved that a meteorological satellite could be flown to provide cloud-cover information, describing the location of weather systems and infers atmospheric motions (Vaughan & Johnson, 1994). Doppler radar, in theory had been around since 1842, but it was not until 1953, that Donald Staggs became the first person to record radar observations of a tornadic thunderstorm (Nixon et al., 2009). Before 1950, all measurements and predictions largely relied on direct human observations. Around the early 1900s, sailors and airplane pilots could radio back information regarding an actual natural disaster they were experiencing in real time, coordinating with manned U.S. Weather Bureau weather stations in the West Indies, Cuba and Mexico (Coleman et al., 2011). Going back further marks the transition between the role of religious institutions in explaining natural disaster phenomena by supernatural means and the birth of organizations dedicated to explaining natural disasters by scientific means.

One of these scientific organizations, the Intergovernmental Panel on Climate Change (IPCC), was founded in 1988. In 2012, the IPCC produced their findings in a report entitled *Special Report on Managing the Risks of Extreme Events and Disaster to Advance Climate Change Adaptation (SREX).* In this report, the IPCC classifies natural disasters as biological (epidemic), geophysical (volcano), hydrological (flood), meteorological (storm), and climatological (heat wave) (Sauerborn & Ebi, 2012). The sub types in parenthesis are listed in the actual report, but are not the only kinds of biological, geophysical, hydrological, meteorological, and climatological disasters known to man.

Much of the mysticism associated with natural disasters has been eliminated, but a small amount remains. Historic data is unreliable, the role of climate change in natural disaster perpetuation is unclear, and we lack a single model that predicts natural disaster future events. Traditional cultural, spiritual, and religious beliefs shape how we view new scientific information, and it has been difficult to reconcile the remaining natural disaster mysticism with our developing scientific theories. Differences in natural disaster resiliency provides information regarding the harmonization between science and mysticism.

Resilience is defined as the persistence of a system's performance, with an uncertainty factor associated with disturbances and discrete states (Ayyub, 2014). There are many definitions of resilience, but the definitions amenable to developing consistent resiliency metrics have components of: (1) system performance defined in terms of requirements or objectives, and examined in the form of output, throughput, structural integrity, lifecycle cost, etc., (2) uncertainty relating to events such as storms, disturbance, conditions, and system states, and (3) persistence examined in terms of enduring the events, recovery, continuance, and/or resumption of performance (Ayyub, 2014).

Resiliency to natural disasters would be indicated by relatively less damage or fewer human deaths or injuries for a given magnitude of a disaster, such as an earthquake or wildfire. A country's social institutions and attitudes towards human suffering, that might be negatively associated with its human rights violation score, for instance, might contribute to this resilience.

Research Significance and Objectives

This research examines if policies that eliminate human rights violations decrease the chances or intensity of natural disasters. If a country's human rights violation score is negatively correlated with natural disaster resiliency (using multivariate analysis to control for other factors), then changes made at the individual level could result in increased resiliency to all types of natural disasters.

The IPCC classification of natural disasters and various input from environment science academe bolsters the logic behind investigating geophysical disasters and climatological disasters separately, and then identifying overlapping predictor variables. The remaining types of natural disasters were omitted to create a binary analysis between largely non climate change related disasters (geophysical/earthquakes) and moderately climate change related disasters (climatological/heatwaves).

My research objectives were to:

- Create four multilinear regression models to approximate the definition of resiliency. The four response variables of the models are total deaths, total injuries, total damage, and percentage killed from either earthquakes or wildfires for two data sets. The predictor variables used are both physical in nature, such as the magnitude and duration of a natural disaster and social in nature, such as the WHRS and percentage of atheist in a country.

- Invalidate the notion that natural disasters are solely Acts of God, where national governments cannot assign responsibility to individuals, and instead demonstrate these to be partially anthropogenic. Mitigating these anthropogenic causes would therefore increase natural disaster resiliency.

Background

It is difficult to demarcate different types of natural disasters based on how much climate change induces natural disaster occurrence. In response to that, this background section reviews research regarding the MEA framework and how it can be modified to show that ecosystem indirect drivers of change, as well as climate change, penetrates all demarcation systems. Looking at the magnitude and resilience of a natural disaster, at the country level, offers explanatory power regarding the individual's impact on creating or mitigating that natural disaster.

The Role of Climate Change in Geophysical Disasters

In 2006, Robert A. Stallings, from the University of Southern California's Department of Sociology, conducted a literature review on "Causality and Natural Disasters"; he accomplished this by comparing five books with different etiologies and causal models of various disasters (Stallings, 2006). Stallings opens his literature review with two statements from Russell Dynes: (1) the 1755 Lisbon Earthquake is the world's first modern earthquake, and (2) the government replaced the role of the Church, regarding natural disaster recovery and response activities (Stallings, 2006). Also at this time, some Portuguese changed their belief that the Lisbon Earthquake was an act of God via divine retribution for their sins (Stallings, 2006). Earthquakes are geophysical natural disasters, whereby a sudden and violent shaking of the ground sometimes leads to great destruction via the movements within earth's crust or volcanic action. The United States Geological Survey (USGS) states that it is unlikely that we will ever be able to predict earthquakes, and it is unclear whether there is a climatological factor associated with earthquake generation, as well as whether animals can detect earthquakes (Wald, 2016). The USGS recognizes "The Ring of Fire", also called the Circum-Pacific belt, as a zone where 90% of the world's earthquakes occur. The next most seismic region (5-6% of earthquakes) is the Alpide belt (extending from the Mediterranean region, eastward through Turkey, Iran, and northern India). Plate tectonics is believed to be behind "The Ring of Fire", but while some believe it is a theory based on unproven assumptions, others would call the science behind plate tectonics as factual and well-established theory (Euster, 2015).

While geophysical disasters (earthquakes, volcanoes, and mass movement), are believed not to be significantly influenced by human interactions with nature, hydrological (floods), meteorological (storms such as cyclones and thunderstorms), and climatological (extreme temperature, droughts, and drought-induced wildfires) disasters contribute greatly to changes in human health and well-being. From 1996-2005, ~ 90% of natural disasters (meteorological and climatological) were weather related and lead to many deaths in low-income countries (Sauerborn & Ebi, 2012).

However, new research indicated that climate change may indirectly play a role in geophysical disasters. Climate change is a change in global or regional environmental conditions, ultimately caused by increased levels of carbon dioxide and other greenhouse gas emissions via a greater consumption of oil and natural gas resources. Wei Gan and Cliff Frohlich (2013), provided significant evidence regarding how climate change plays a role in geophysical disasters. They evaluated the injection and extraction of oil, water, and gas in the Cogdell field (Gan & Frohlich, 2013). Prior to 2006, the Cogdell field experienced a 24-year period of no earthquakes; however, beginning with an increased injection of gas circa 2006, 18 earthquakes have been reported by the National Earthquake Information Center (NEIC) (Gan & Frohlich, 2013). Many of the epicenters of these earthquakes were found within 2 kilometers of actively injecting wells, and there were no significant changes in rates of water injection from 1990 to 2006 (Gan & Frohlich, 2013). So, while carbon dioxide above the ground may not affect geophysical disasters, it is plausible that directly injecting it into the earth, may induce earthquakes and by inference, volcanoes. Experts feel that it is relatively safe to store carbon dioxide underground, if we monitor the effects of different amounts of carbon dioxide at different depths.

A Quick Look at the Shaanxi and 2010 Haiti Earthquakes

Although the Lisbon earthquake might have been the first modern natural disaster, it was by no means the deadliest. On February 2, 1556 the 8.25 magnitude Shaanxi earthquake fell just short of claiming one million lives, the deadliest earthquake in human history. The complex tectonic architecture of East Asia lends itself to geophysical disasters, via collisions of the Indian and Eurasian plates to the southwest and the subduction of the Philippine Sea and the pacific plates to the east (Lei et al., 2013). Most of the people at the time lived in yaodongs (house caves), and it is easy to understand why houses carved out of hillsides are more susceptible to damage via earthquakes. By comparison, the Lisbon earthquake was equal in magnitude to the Shaanxi earthquake, but claimed as little as 10,000 lives. In 200 year's time, changes in resiliency led to a death toll reduction by 100-fold, in earthquake events with the same magnitude.

The 2010 earthquake of Haiti was the last major disaster that resulted in the magnitude of hundreds of thousands of deaths. The death toll of Hurricane Katrina, and all ensuing disasters after the 2004 Indian Ocean's earthquake and tsunami, is on the order of hundreds to low thousands of deaths. The high death toll in Haiti (more than twice as lethal than any other 7.0 magnitude earthquake) has been linked to poor construction of buildings (Bilham, 2010). It's strange that an earthquake in 2010 could result in just as many deaths as one in 1755 (Lisbon), even when adjusting for the population increase. Although Haiti is disease ridden and impoverished, with half its population living on a less than a dollar per day, it is unclear whether poverty is a leading indicator of natural disaster resilience. One aspect glossed over concerning Haiti, is that 98% of Haitian forests are felled and burned for firewood (Miller, 2010).

What is the relationship between different kinds of natural disasters, and are there common initial conditions between the various disasters that guarantee the disasters future occurrences? India, Bangladesh, and China are global outliers when it comes to population susceptible to river floods. Looking at deforestation and flood occurrence in these countries and comparing it to the earthquake in Haiti, may shed some light on natural disaster causality.

Deforestation as an Amplifier of Flood Risk and Severity in the Developing World

Via data collected from 1990 to 2000 from 56 developing countries, linear and mixed-effects models showed a negative correlation of flood frequency and the amount of remaining natural forest; likewise, the models confirmed the positive correlation between flood frequency and natural forest area loss (after controlling for rainfall, slope and degraded landscape area) (Bradshaw et al., 2007). The best models accounted for 65% variation in flood frequency, with ~ 14% being due to forest cover variables (Bradshaw et al., 2007). Severe earthquakes can be triggered by dewatering and flooding of mines, as these activities induce changes in the loading of the Earth's crust and tectonic stresses in its interior. This is backed up by 200 studies where human-induced stresses may have reactivated preexisting faults, triggering earthquakes with seismic moment magnitudes of up to M = 7 on the Richter scale (Klose, 2007).

It seems plausible that tree felling has a threshold value associated with the initial conditions required to cause an earthquake. This is indirect as tree felling could cause erosion, which would then loosen faults. Moreover, there are many threshold natural disaster variables associated with ecological change, all of them capable of inducing significant natural disasters. Most threshold variables fall under the category of indirect drivers of ecosystem change, according to the MEA framework and are discussed in greater detail in the methods section.

The Birth of Four Models: How we View Natural Disasters Today

2006's Hurricane Katrina marked the expansion of our culture to accept four ideal models for explaining natural disasters: (1) as acts of God, (2) as acts of nature, (3) as products of human agency, and (4) as purely chance or coincidence. The next four sections are Stallings' interpretations of various authors' causality arguments, whether they use multiple models to explain causality, and the models' harmonious existence (Stallings, 2006).

The Sociology of Natural Disasters

Zebrowski and Craig (1998) hypothesized that our natural human nature to cluster provides "Mother Nature" more opportunities to wreak havoc; furthermore, they explore the butterfly effect to justify science's inability to explain, predict, control, and reproduce the initial conditions associated with natural disasters (Stallings, 2006). Zebrowski and Craig summarizes how unplanned population growth can deplete natural life support systems and also mentions resiliency from a material science perspective. Houses that are made from wood can withstand greater tensile forces than stone buildings, but when engineered like Roman arches, stone buildings can be equally as good, if not better than wooden houses at withstanding natural disasters like earthquakes (Zebrowski & Craig, 1998). Likewise dams with their horizontal load bearings and bridges with their vertical load bearings play a huge role in resilience against natural disasters. This sentiment is echoed by Pelling as mentioned in Stallings (2006). Pelling focuses on the poor, powerless, and marginalized people living in urban areas in the developing world; he states that natural disasters are a product of human agency and largely stem from poor housing conditions that affect the air quality and subsequently the environmental-triggers associated with natural disasters. Every other author explored by Stallings (2006) also directly mentions poor housing as a leading indicator of low resilience to natural disasters. This is a well-known issue, debated for years.

Stallings (2006) didn't touch on the resiliency transformation prior to modern day natural disasters, but his literature review did provide clarity regarding our current resiliency transformation. Just like in Zebrowski and Craig (1998), housing is listed as a main variable explaining discrepancies in the resiliency of natural disasters, as well as the human element. In Pelling's case (as summarized by Stallings 2006), it is humanity's inability to solve air quality issues and provide adequate housing for all. Poverty is mentioned and power too; the latter is usually synonymous with land ownership and the former antonymous with land ownership. Klinenberg (as reviewed by Stallings, 2006), blames human agency for exacerbating the deprivation and suffering associated with the heat wave that plagued Chicago in 1995. He also mentions the media's ability to sway the public perception of methods linked to a disaster. This is the exact point made also by Zebrowski and Pelling in Stallings (2006), but it is applied to a heat wave in Chicago; moreover, Klinenberg noted the media's power to filter information prior to delivering it to the public. Only those who have access to a wealth of resources can adequately fact check causality relationships. Steinberg (as cited in Stallings, 2006), investigated parties responsible for natural disaster response and recovery, as opposed to what was the causality behind it. As he explored through four cases, the government made it harder for people to receive post disaster aid (Acts of God are not the responsibility of the Government or anyone) and the government borrowed from everyday social benefit programs to set aside relief for future disasters. Steinberg uncovered a potential financial partnership between the government and the media to protect each other. The media would filter causality information that would cost the government too much money to fix. In return, the government would leak stories to cooperative media outlets. The "borrowing" of funds allocated for future natural disaster recovery became justified, due to our inability to predict or reduce natural disaster occurrences by a significant amount. Finally, Clarke (in Stallings, 2006), introduces the thought experiment of nature at its worst and human agency at its least; what results is a gap between risk perception and risk reality.

Resource Depletion and its Role in Natural Disaster Causality

Resource depletion also changes natural disaster resiliency. Zebrowski and Craig (1998), cite the example of Easter Island, where a lush subtropical paradise in the 15th century quickly turned into a death trap. The Polynesian people built 200 gigantic statues around the island. The natural resources were abundant initially, but within 200 years, the forest ecosystem services ceased to exist. With no trees to harvest and the animal stock depleted, the Polynesian people were driven to cannibalism and very close to extinction. Survivability from human attacks generally takes precedence over resiliency of natural disasters; it's a good thing that all the volcanoes on the island are extinct.

We don't know the exact initial conditions of natural disasters, nor do we know all causality variables of natural disasters, but we still can identify more variables and make chaos theory less chaotic. So, while ecosystem change does not directly cause natural disasters, it can serve as a proxy for climate change, and it does induce resiliency changes, under certain initial conditions. Although Zebrowski and Craig (1998) were the only ones out of the five references to attack resource depletion in depth, I believe they present a case for why we need the Millennium Ecosystem Assessment framework to make sense out of natural disaster causality.

Anthropogenic Factors Modify Natural Disasters

There is no such thing as a purely natural disaster; a social component exists in all "natural" disasters (Sauerborn & Ebi, 2012). Secondly, even what we call natural disasters are always modified, to some degree, by anthropogenic activities relating to the burning of fossil fuels and deforestation; these activities influence the frequency, intensity, duration, and spatial extent of extreme weather and climate events (Sauerborn & Ebi, 2012). The traditional framework used by Sauerborn and Ebi looks at health risks from disasters as a function of the hazard (flooding, heat wave, etc.), the exposure (for example, the time a human is exposed to a heat wave without air conditioning), and vulnerability (distance of subject to "ground zero"/point of origin of disaster). Since 1950, statistical detection of changes in frequency, intensity, spatial extent, and duration of "rare" events such as heat waves, extreme high coastal waters (both increased) and "very cool" nights (decreased) might be straightforward, but climate causality modeling is not.

Millennium Ecosystem Assessment Links Ecosystem Change to Human Well-Being

The Millennium Ecosystem Assessment (MEA, 2005) was carried out between 2001 and 2005 to assess the consequences of ecosystem change for human well-being and to establish the scientific basis for actions needed to enhance the conservation and sustainable use of ecosystems and their contributions to human well-being. The MEA responded to government requests for information received through four international conventions—the Convention on Biological Diversity, the United Nations Convention to Combat Desertification, the Ramsar Convention on Wetlands, and the Convention on Migratory Species—and is designed to also meet needs of other stakeholders, including the business community, the health sector, nongovernmental organizations, and indigenous peoples. The sub-global assessments also aimed to meet the needs of users in the regions where they were undertaken.

The assessment focused on the linkages between ecosystems and human well-being and on "ecosystem services." An ecosystem is a dynamic complex of plant, animal, and microorganism communities and the nonliving environment interacting as a functional unit. The MEA deals with the full range of ecosystems—from those relatively undisturbed, such as natural forests, to landscapes with mixed patterns of human use, to ecosystems intensively managed and modified by humans, such as agricultural land and urban areas. Ecosystem services are the benefits people obtain from ecosystems. These include provisioning services such as food, water, timber, and fiber; regulating services that affect climate, floods, disease, wastes, and water quality; cultural services that provide recreational, aesthetic, and spiritual benefits; and supporting services such as soil formation, photosynthesis, and nutrient cycling (Figure 1). The human species, while buffered against environmental changes by culture and technology, is fundamentally dependent on the flow of ecosystem services.

The MEA examines how changes in ecosystem services influence human well-being. Human well-being is assumed to have multiple constituents, including the basic material for a good life, such as secure and adequate livelihoods, enough food at all times, shelter, clothing, and access to goods; health, including feeling well and having a healthy physical environment, such as clean air and access to clean water; good social relations, including social cohesion, mutual respect, and the ability to help others and provide for children; security, including secure access to natural and other resources, personal safety, and security from natural and human-made disasters; and freedom of choice and action, including the opportunity to achieve what an individual wants to do and be. Freedom of choice and action is influenced by other constituents of well-being (as well as by other factors, notably education) and is also a precondition for achieving other components of well-being, particularly with respect to equity and fairness.

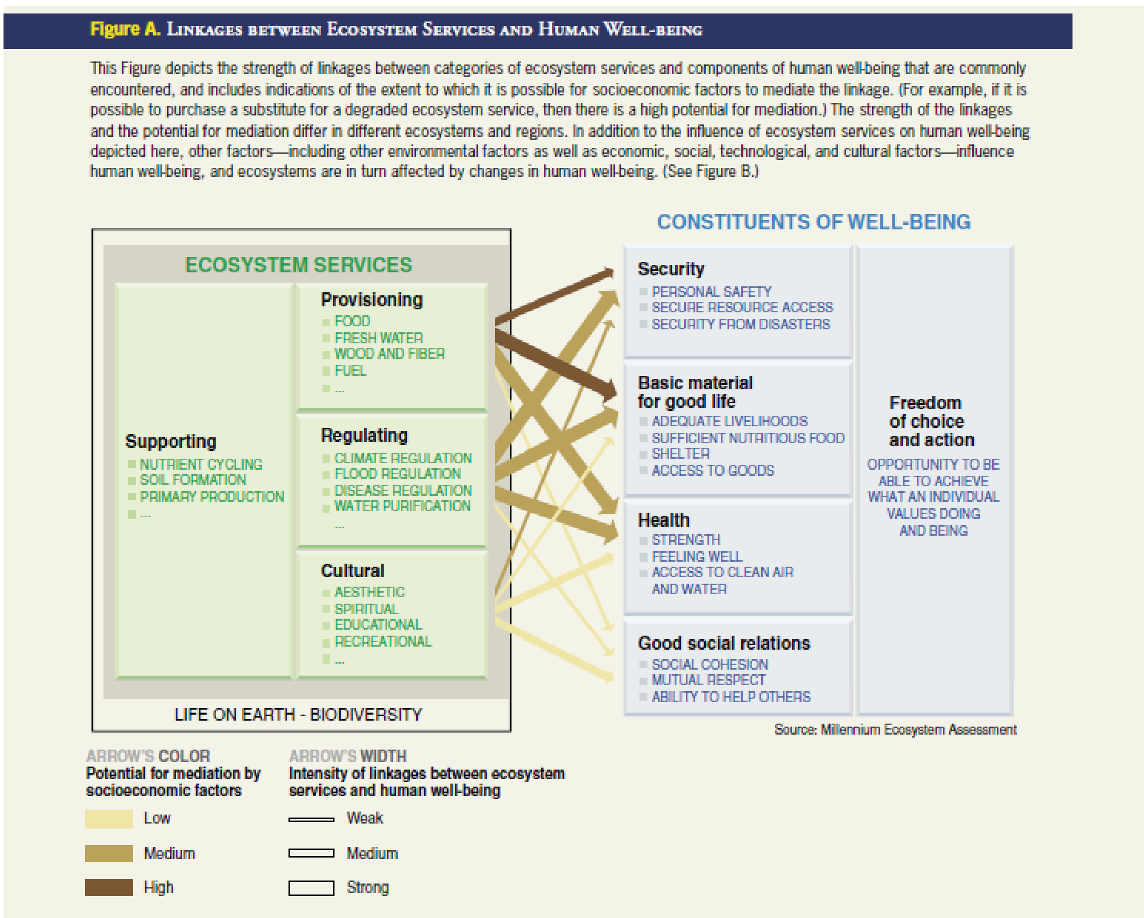

Figure 1. Linkages (ecosystem services and human well-being) (MEA, 2005).

The conceptual framework for the MEA posits that people are integral parts of ecosystems and that a dynamic interaction exists between them and other parts of ecosystems, with the changing human condition driving, both directly and indirectly, changes in ecosystems and thereby causing changes in human well-being (Figure 2). At the same time, social, economic, and cultural factors unrelated to ecosystems alter the human condition, and many natural forces influence ecosystems. Although the MEA emphasizes the linkages between ecosystems and human well-being, it recognizes that the actions people take that influence ecosystems result not just from concern about human well-being but also from considerations of the intrinsic value of species and ecosystems. Intrinsic value is the value of something in and for itself, irrespective of its utility for someone else. The MEA synthesizes information from the scientific literature and relevant peer reviewed datasets and models. It incorporates knowledge held by the private sector, practitioners, local communities, and indigenous peoples. The MEA did not aim to generate new primary knowledge, but instead sought to add value to existing information by collating, evaluating, summarizing, interpreting, and communicating it in a useful form. Assessments like this one apply the judgment of experts to existing knowledge to provide scientifically credible answers to policy-relevant questions. The focus on policy-relevant questions and the explicit use of expert judgment distinguish this type of assessment from a scientific review (Millennium Ecosystem Assessment [MEA], 2005).

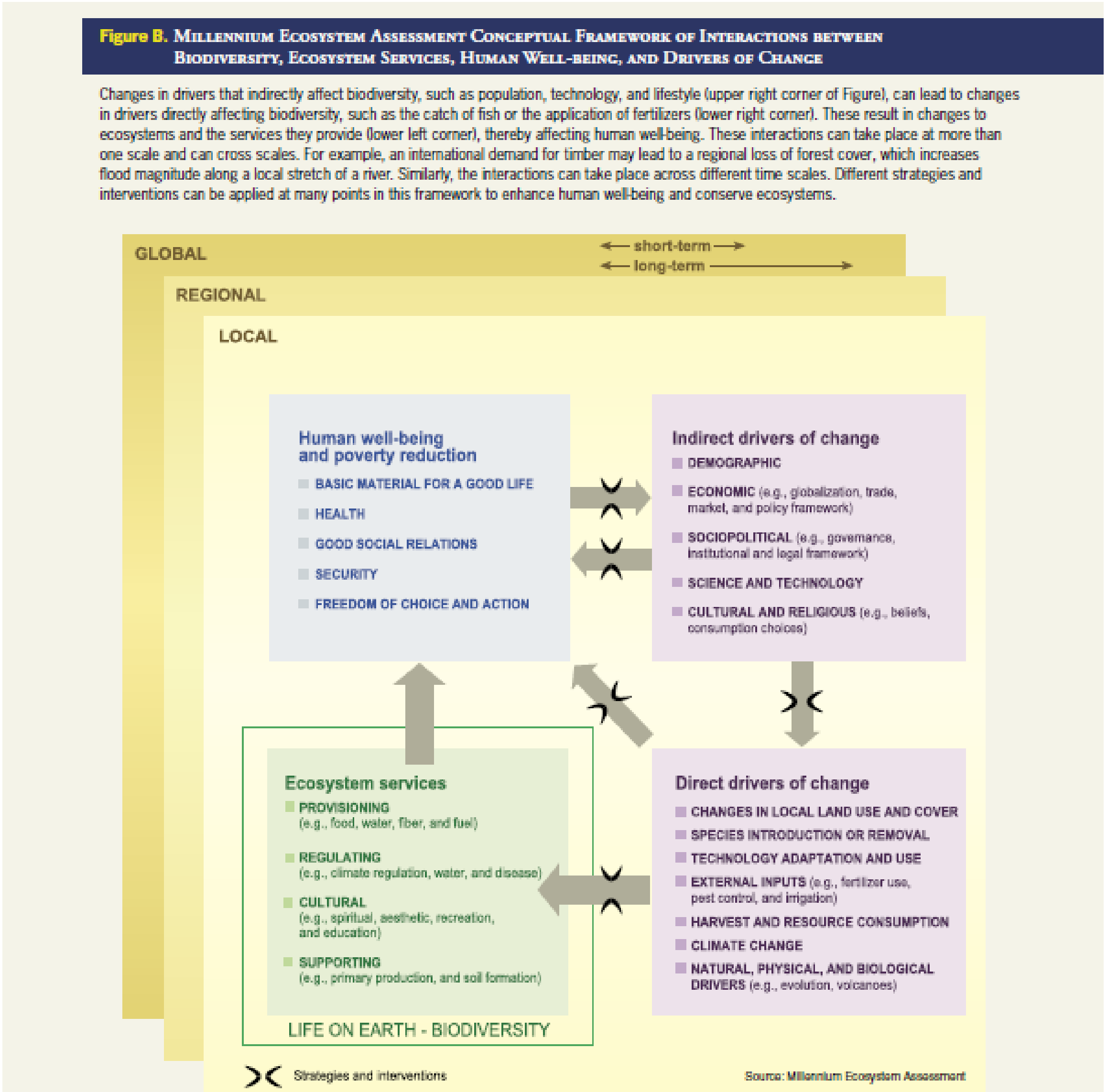

Figure 2. MEA conceptual framework of interactions between biodiversity, ecosystem services, human well-being, and drivers of change (MEA, 2005).

It is easy to scoff at the idea that human rights violations could somehow be correlated with natural disaster resiliency, but the Millennium Ecosystem Assessment (MEA, 2005) provides a framework for this link.

Human Rights Violations

The NGO Human Rights Watch (HRW) conducted a report on the events of 2014, regarding 90 plus countries with human rights issues. This report is limited by a countries' willingness to allow HRW to physically investigate human rights issues, evaluating the total number of people affected, severity of abuse, access to country and information about it, the susceptibility of abusive forces to influence, and country specific local rights organizations' goals to guide their investigations (Human Rights Watch, 2015). Their report is divided into two sections; the first section is in essay form, regarding global human rights violations without clear demarcation of geo-spatial origin, and the second section pertains to country-specific violations (Human Rights Watch, 2015). For instance:

- China remains an authoritarian state and systematically curbs fundamental rights (freedom of expression, association, assembly, and religion); it has a higher population density and a smaller ecological footprint lower than the USA, but with more perceived human rights violations.
- Qatar's most recent negative claim to fame involves their successful bid of hosting the 2022 FIFA World Cup and their subsequent use of low-paid migrant work to improve the country's ability to support the event; their population density and ecological footprint are higher than the USA.
- In the areas of criminal justice, immigration, and national security, US laws and practices routinely violate rights. Often those least able to defend their rights in court or through the political process include: racial and ethnic minorities,

immigrants, children, the poor, and prisoners; US population density and human rights violations are lower than Qatar's and China's.

Human Rights Violations as a Leading Indicator of Ecosystem Change

Indirect drivers of change can come from a change in demographics, economics, sociopolitical systems, science and technology, and culture and religious beliefs (MEA, 2005). Furthermore, these changes are linked to direct drivers of ecosystem change and are manifested via: changes in local land use and cover, species introduction or removal, technology adaptation and use, external inputs (e.g. fertilizer use, pest control, and irrigation), harvest and resource consumption, climate change, and natural, physical, and biological drivers (e.g. evolution, volcanoes) (MEA, 2005). The direct drivers are linked to ecosystem services: provisioning (e.g. food, water, fiber, and fuel), regulating (e.g. climate regulation, water, and disease), cultural (e.g. spiritual, aesthetic, recreation, and education), and supporting (e.g. primary production and soil formation) (MEA, 2005). The ecosystem services directly control human well-being and poverty reduction through the form of basic material for a good life, health, good social relations, security, and freedom of choice and action (MEA, 2005). Figure 2 provides a visual explanation of these relationships.

In order to quantify and best capture all of the indirect drivers of ecosystem into a single number, I chose to track the human rights deaths a country experienced in a given year versus the deaths a country experienced by natural disasters in that same year. The HRW reports are more qualitative in nature, and it is very difficult to confirm when deaths are a result of human rights violations. I used the WHRS as a proxy for human rights violations. The WHRS is a single number for each country and although it does capture human rights violations, it does not decouple that information from GDP per capita, social support, health life expectancy, freedom to make life choices, generosity, trust, and perceptions of corruption.

Research Question, Hypothesis, and Specific Aims

This research is centered on answering this question: Can indirect drivers of ecosystem change explain differences in countries' natural disaster resiliencies? According to the MEA framework, indirect drivers of ecosystem change (demographics, economic, social political, science and technology, and cultural and religious) are link to direct drivers of ecosystem change (changes in local land use and cover, species introduction or removal, technology adaptation and use, external inputs like fertilizer use and pest control, harvest and resource consumption, climate change, and natural/physical/biological drivers like evolution and volcanoes).

My main hypothesis is that natural disaster resiliency will correlate negatively with country's human rights violations record for the year of disaster occurrence. Specifically, I examined this relationship for two natural disasters, earthquakes and wildfires. I defined natural disaster resiliency as four related but separated response variables: total deaths, total injuries, total damage, and percentage of population killed, with all of the measurements taken at the time of a discreet natural disaster event. I used multivariate analysis to control for other factors also correlated with natural disaster resiliency.

Specific Aims

To conduct this research, I:

1. Compiled data sets of earthquake and wildfire measurements and merged data from Guha-Sapir (2017), The Significant Earthquake Database (NOAA, 2017), SDSN (2012), Central Intelligence Agency [CIA] (2017), HRW (2015), National Interagency Fire Center [NIFC] (2017), and List of wildfires (Wikipedia, 2018).
2. Organized the independent disaster events into two spreadsheets (earthquakes and wildfires), associated with a set of both response and predictor variables. This was done to analyze and explore the data of earthquakes and wildfires separately from each other.
3. Loaded the data into R Studio to identify multicollinearity amongst the variables. A correlation matrix was created for all variables, eliminating some that did not have independent predictive power.
4. Selected the best response and predictor variables for both earthquakes and wildfires.
5. Created a baseline MLR model for both earthquakes and wildfires, along with three slight variations of MLR models by changing the response variables from total deaths to total injuries, total damage, and percentage of population killed. Eight MLR models were created, four MLR models for earthquakes and four MLR models for wildfires.

Chapter II

Methods

My research methodology was designed to eliminate the dichotomy between natural disasters traditionally thought to be exacerbated by climate change and ones in which climate change plays little to no role in their occurrence, severity, and detectability. Traditionally, earthquakes and volcanoes are believed to not be affected by climate change. My goal was to find a set of variables that allows us to predict and minimize the total number of deaths from all future natural disasters, while still impacting climate change in a positive indirect way.

To accomplish this, I created multiple regression models of indirect drivers of eco system change, which is related to human-wellbeing and poverty reduction (MEA, 2005). I created four multiple regression models in R Studio, corresponding to four separate independent or response variables, numbers 1-4 below. The indirect drivers of ecosystem change variables (dependent/predictor) are numbers 5-11 below.

Independent (Response) and Dependent (Predictor) Variables

1. Total deaths: Human death toll associated with each discreet natural disaster event, via the NOAA Significant Earthquake Database Search (NSEDS).
2. Injuries: Total amount of people who experience decreased vitality, immediately after a discreet natural disaster, via NSEDS.
3. Total damage: Sum of damage to property, crops, and livestock. The value of the damage is given in US dollars. For each disaster, the registered figure

corresponds to the damage value at the moment of the event; i.e., the figures correspond to the year of the event (from EM-DAT database for climatological data and NSEDS for earthquakes).

4. Percentage Killed: This is calculated as 'total deaths' divided by the total population who experienced the discreet natural disaster (population data were sourced from the UN data). Each singular measurement for percentage killed, corresponds to the worst natural disaster a country experienced that year, measured by highest death toll from a singular event.
5. Magnitude: A number that describes the relative size of a natural disaster. Basic reproduction rate (R0) for epidemics, Richter scale for geophysical (volcano) and Volcanic Explosivity Index (VEI) for volcanoes; hydrological magnitude is measured by discharge (how much water is flowing past a certain point in a given period of time), meteorological magnitude is measured by wind speed, and climatological magnitude is measured in temperature relative to the average historic temperature experienced in a specified time period. Earthquake data was sourced from NSEDS. For the wildfire/climatological data, magnitude is measured in millions of acres burned, with data sourced from the National Interagency Fire Center.
6. Location: Latitude and longitude of affected area used to describe the physical location of a natural disaster on the earth's surface. This helps determine geospatial patterns and the independent variable of percentage of population killed from a natural disaster event. However, longitude was dropped as a dependent variable when constructing the four multiple regression models, due to

its arbitrary nature (latitude corresponds to distance from equator and is not considered arbitrary). For the regression models I used the absolute value of latitude and log transformed the data.

7. World Happiness Report Score: a measure of happiness published by the United Nations Sustainable Development Solutions Network. This score is calculated by collecting data from countries. Each variable is a populated-weighted average score 0-10, in comparison to other countries, and is tracked over time. These variables include GDP per capita, social support, health life expectancy, freedom to make life choices, generosity, trust, and perceptions of corruption. Each country is compared against a hypothetical nation called Dystopia, which represents the lowest national average for each key variable and is, along with residual error, used as a regression benchmark. This score is an attempt to capture a multitude of demographic information and normalize it into one aggregate score. I used the log transformed score for the multiple regression models.
8. Atheism: Atheism the belief that there are no deities of any kind, the data are from the CIA World Fact Book, and report the percentage of population that is atheistic. This was chosen to determine the role culture and religion plays in natural disaster resiliency; more specifically, to identify beliefs and consumption choices that will lead to a measurable increase in natural disaster resiliency (decrease in deaths from natural disasters). The CIA World Fact Book reports the percentage of population that is atheistic, so I used the arcsine transformation of this variable for the regression analysis.

9. Natural: distinguishes if a wildfire was started by a human. A score of 1 indicates the fire is arson, 5 indicates it is started by humans but without malicious intent (smoke signals, controlled burn, etc.), and a 10 indicates the fire is of natural causes (lightning strike).
10. HRDC: Human Rights Deaths Confirmed, from the 1990-2016 Human Rights Watch Reports. HRDC is the number of people who died via human rights violations in a single year for a stated country. These deaths have been reported from government or "official" sources. This was tracked to determine if a decrease in human rights violations lead to an increase in natural disaster resiliency across all types of natural disasters. These data were also log transformed during regression analysis.
11. Focal Depth (for earthquakes) or Duration (for wildfires): The depth of an earthquake hypocenter. Duration refers to the number of days a wildfire is active, used only in the climatological/wildfire regression analysis. Focal Depth is sourced from NSEDS and Duration from searching the Historically Significant Wildland Fires via Google.

Earthquake Data Set

The earthquake data set is comprised of 23 categories and involved merging data from Guha-Sapir (2017), The Significant Earthquake Database (NOAA, 2017), SDSN (2012), CIA (2017), and the 1990-2016 HRW reports. The data set contains 50 points that met the requirements of having reliable information in all 23 categories. From Guha-Sapir (2017) and via the advanced search option on the EM-DAT international disasters database, I used the time period qualifier of 1990-2015 and looked at

"Group/Subgroup/Type/Subtype" of "Natural/Geophysical/Earthquake". No subtype was selected. The location qualifier was set to "Country" and I looked at every single country. Please note that the HRW reports only cover roughly one hundred countries and around fifty for the earliest reports. Grouping the results by year, country name, and disaster subtype, I searched the database and saved the table produced from the EM-DAT website as a CSV file. From this particular source I only used the data on "Year", "ISO", "Country name", and "Total deaths". This source contains data on deaths, injuries, and damages used to match up the earthquake events with events listed in the Significant Earthquake Database (NOAA, 2017). This served as a master Excel template for entering and merging data from the other sources.

The Significant Earthquake Database (NOAA, 2017) contains data on destructive earthquakes from 2150 B.C. to the present that meets at least one of the following qualifiers: Moderate damage (~ one million dollars or more), ten or more deaths, Magnitude of 7.5 or greater, Modified Mercalli Intensity X or greater, or the earthquake generated a tsunami. I used the same time period qualifiers from above (1990-2015) and selected only countries covered in the 1990-2016 HRW reports. This database contains information on dates, locations, deaths, injuries, and damages for earthquakes, just like the EM-DAT database. I carefully matched up the points and entered the new data for magnitude, latitude, and focal depth into the master Excel template with the original EM-DAT data. I gave priority to the numbers listed in this database over the EM-DAT database for deaths, injuries, and damages. The percentage killed was calculated from taking the deaths listed in the Significant Earthquake Database (NOAA, 2017) and dividing it by the population living in the earthquake location at that time. The

"Earthquake Location" field in this database aided in locating population data for the year the disaster occurred. Most population data are from the UN data website, and the original source can usually be traced by to government census data. If I could not find the population for the exact area and year in question, I multiplied the population data by a modifier ratio of (country population in year of the natural disaster/country population in year I found). The entire population of every country has been tracked for years, but exact cities, states and more specific locations have not.

All World Happiness Report Scores are from SDSN (2012). The scores have only been tracked since 2012, so I used the scores from the year closest to when the earthquake occurred. The percentage of atheist in each country was found in the CIA World Fact Book (CIA, 2017). "Unaffiliated" and "None" are not the same as "Atheism" according to CIA, 2017, so I entered "0", when no value for Atheism was present. Finally, the HRDC data was found in the 1990-2016 HRW reports. I read through the reports and added up all of the deaths mention in the reports. I always used the most conservative definitions for ambiguous words. For example if the report said "thousands" of people died, I used 1001. If it said "several", which is defined as more than two but not many, I used "3". Several thousand deaths would be 2001. Several deaths would be 3 deaths. If the report said 5000 people died from 1985-1990 (5 year span), I took the average (1000 people). Except for the 1990 report, when I looked at an earthquake in a particular year (i.e. 1995), I used the Human Rights Watch Report of the following year (i.e. 1996). The 1996 Human Rights Watch Report covers the information on human rights developments in 1995. To analyze all of this data once it was entered into a single spreadsheet, I used R Studio. The "dplyr" and "rafalib" libraries were needed to perform regression analysis on the data, and I loaded the data with the "Import Dataset" function in R Studio. The Wildfire Data Set Methodology is very similar and thus abbreviated.

Wildfire Data Set

The wildfire data set is comprised of 20 categories and involved merging data from the Guha-Sapir (2017); List of wildfires (Wikipedia, 2018), sources checked and compared with NIFC (2017); and SDSN (2012). The data set contains 17 points that met the requirements of having reliable information in all 20 categories. From Guha-Sapir (2017) and via the advanced search option on the EM-DAT international disasters database, I used the time period qualifier of 1990-2015 and looked at "Group/Subgroup/Type/Subtype" of "Natural/Climatological/Wildfire", with no subtype selected. I created a second Excel template from the categories "Year", "ISO", "Country name", "Total deaths", "Injured", and "Total damage".

The magnitude, duration, and natural data came from NIFC (2017) and Wikipedia (2018). I checked the total deaths values from EM-DAT database with these sources. Sometimes they differed slightly. I used the values that were already there and if a value was missing, I used the NIFC website value first and then Wikipedia if it was missing from the NIFC website also. Percentage killed and WHRS were obtained the same way as in the Earthquake Data Set methodology. The data were analyzed in R Studio.

Chapter III

Results

The response variables for modeling natural disasters (earthquakes and wildfires) were Total Deaths (TD), Injuries (Inj.), Damages in US Millions (D(US$)), and Percentage of Population Killed (%K) (Table 1). Magnitude (Mag), Latitude (Lat), World Happiness Report Score (WHRS), Percentage of the Population who are Atheist (Ath.), Human Rights Deaths (HRD), and Focal Depth (FD) are measurements that can be made before a natural disaster occurs or at the onset on a natural disaster and were chosen as the predictor variables.

Transforming Variables through Use of Diagnostic Plots

Prior to log transforming the earthquake variables, the regression analysis yielded no statistically significant predictor variables. However, diagnostic plots of residuals versus predicted values checked the assumption of linearity and homoscedasticity, and indicated that variables should be transformed to fit assumptions required for linear regression (Figure 3-7, Table 2).

For linearity the residuals should not be too far away from 0. In this case, which is a standardized normal distribution with mean 0 and standard deviation 1, values less than -2 or greater than 2 are worth investigating. For homoscedasticity, there should be no pattern in the residuals, denoted by the equal spread of residuals around the y= 0 line. The test for independence cannot be tested via diagnostic plots and was revealed by investigating the study design (Boston University School of Public Health [BU], 2016).

The second plot (Normal Q-Q) verifies the normality assumption when the observations lie closely along the 45-degree line. The third plot (scale-location) also checks for homoscedasticity. If there is no pattern in the residuals, the variability of the response variable is equal across the range of values of the predictor variables that predict it, otherwise known as homoscedasticity. If there is a clear pattern, it suggests heteroscedasticity. The fourth and final plot (Cook's distance) measures the influence of each observation on the regression coefficients. Statistically, Cook's distance takes each observation and checks the extent of change in model estimates when a particular observation is excluded; any observation where Cook's distance is ~1+ or is noticeably higher than other Cook's distances (highly influential data points) is worth investigating. Outliers are sometimes influential points, but not always. Influential outliers are a priority and should never be ignored. Sometimes data entry is the cause, but not always. I did not exclude them from my final fitted model, but if I did, I then investigated them on an individual case basis. Based on repeating these diagnostic tests for each variable, the original variables were log transformed to correct for non-normality, right-skewness, and/or heteroscedasticity.

Earthquake Disasters

To identify multicollinearity in the multiple regression analyses, I created a correlation matrix for the earthquake log transformed variables (Table 1). Given the weak correlations between the predictor variables, I concluded that multicollinearity was not a problem. Among the response variables, there are strong correlations between total deaths from earthquakes and injuries from earthquakes, as well as between injuries and damages in US dollars (Table 1). A moderate correlation exists between total deaths and damage in US dollars. Finally, there is a negative near-moderate correlation between total deaths and the World Happiness Report Score. (In Table 1, magenta corresponds to weak correlation, cyan to moderate, and yellow to strong).

Table 1. Correlation matrix for log-transformed variables, earthquake dataset.

	TD	%K	Inj.	D(US$)	Mag.	WHRS	Ath.	HRD	Lat.	FD
Total Deaths	1.00	0.44	0.76	0.52	0.31***	-0.48**	-0.09	0.29	0.06	-0.14
% Killed W		1.00	0.19	0.18	0.20	-0.08	0.06	0.30*	0.34*	-0.17
Injuries			1.00	0.75	0.15	-0.30*	-0.18	0.19	0.21	-0.08
DamageUS$				1.00	0.12	0.04	-0.11	0.01	0.42**	-0.08
Magnitude					1.00	0.13	0.26	-0.09	0.02	0.24
WHRS						1.00	0.09	-0.35	0.17	0.24
Atheism							1.00	0.01	-0.09	0.04
HRD								1.00	-0.03	-0.01
Latitude									1.00	-0.27
Focal Depth										1.00
KEY	*:p<.05	**:p<.01	***:p<.001	>=wc	>=mc	>=sc				

Diagnostic Plots for Earthquake Variables

An example of the use of diagnostic plots is provided by the Total Deaths (TD) data. The assumptions of linearity and homoscedasticity were false (Figure 3), but the assumptions of linearity and homoscedasticity were verified after log transformation of TD (Figure 4). However, points 28 (1999 Colombia Earthquake) and 41 (2008 China Earthquake) warrant investigation. The case was similar for normality with 28 and 41 still standing out but also 12 (1994 Japan). All three points of 12, 28, and 41 showed up again in the Scale-Location plot that checks for homoscedasticity. Finally, the points of 28 (1999 Colombia Earthquake), 44 (2010 Haiti Earthquake), and 45 (2010 Mexico

Earthquake) appeared on the Cook's distance plot and justified further investigation. Generally, when Cook's distance > k/n, where k is equal to the number of predictors and n is the sample size (6/50 = 0.12), a point should be investigated.

All untransformed MLR models violated linearity and homoscedasticity so the figures and tables for the remaining untransformed data are not presented. The remaining diagnostic plots analysis (Figures 5-7) are summarized in Table 2. Exclusive to Figure 7, all three assumptions appeared to be true, but homoscedasticity was questionable, as opposed to probable. This was more than likely due to the inconsistent nature of measuring exactly what area an earthquake impacted. There was not equal spread in the variation of the residuals. Please note that the 2010 Haiti Earthquake is the only event that is highly influential to all four MLR models and is the featured earthquake case in the Discussion section.

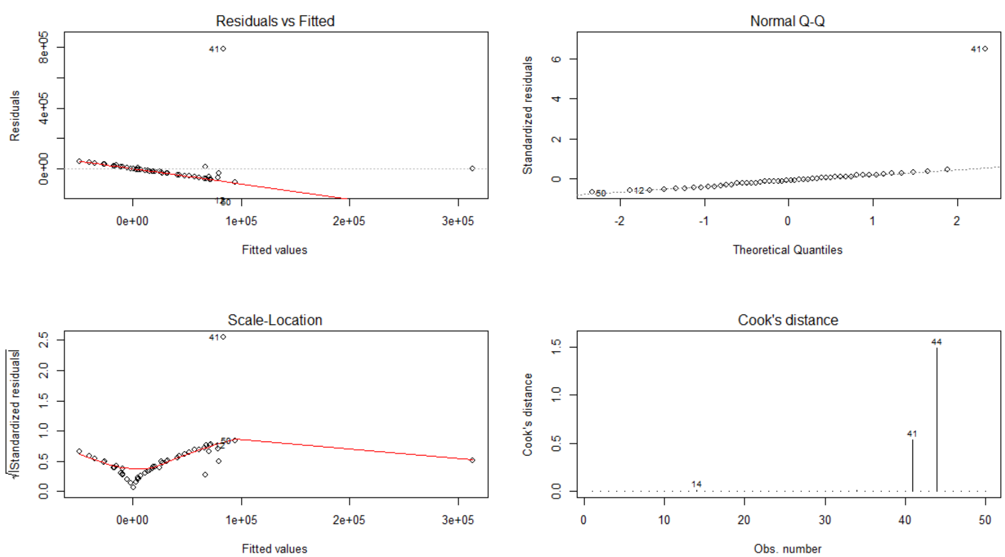

Figure 3. Diagnostic plots for Total Deaths, earthquake MLR model.

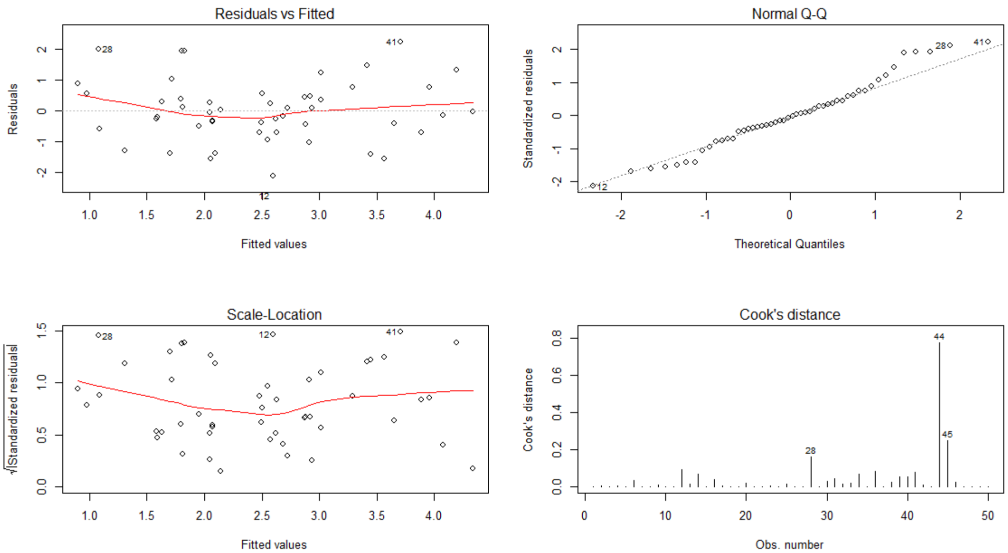

Figure 4. Diagnostic plots for log transformed TD, earthquake MLR model.

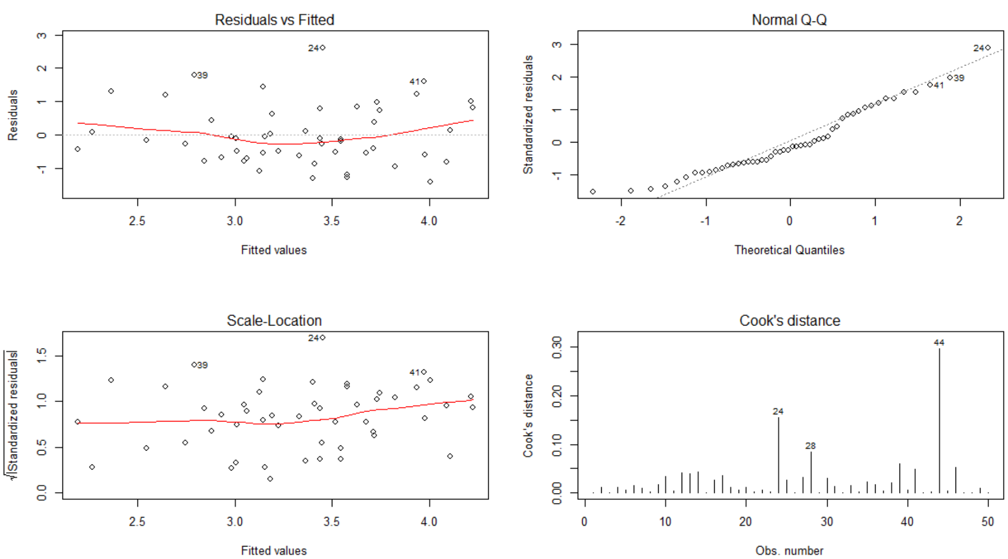

Figure 5. Diagnostic plots for log transformed Injuries, earthquake MLR model.

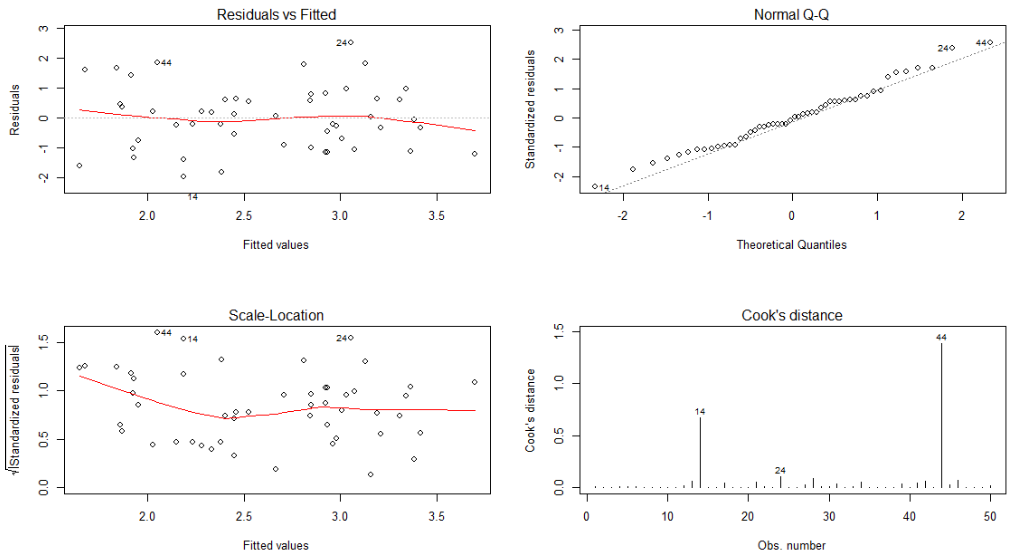

Figure 6. Diagnostic plots for log transformed Damages, earthquake MLR model.

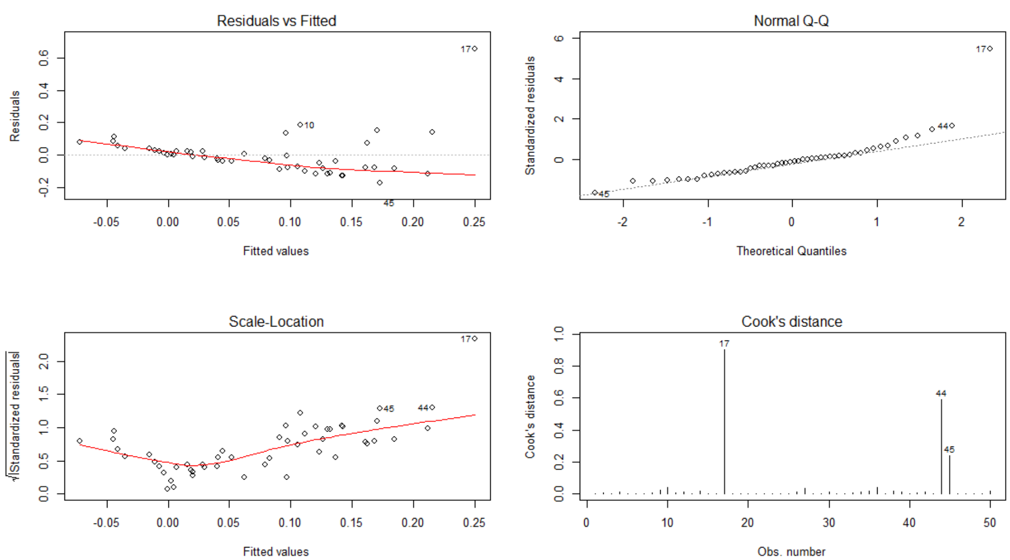

Figure 7. Diagnostic plots for log transformed % Killed, earthquake MLR model.

Table 2. Summary table of diagnostic plots for earthquakes.

Fig. Summary Table	Fig. 4 Total Deaths	Fig. 5 Injuries	Fig. 6 Damages $	Fig. 7 % Killed
10 (1993 Russia)				X
12 (1994 Japan)	X			
14 (1995 Chile)			XX	
17 (1995 Russia)				XX
24 (1998 China)		XX	XX	
28 (1999 Colombia)	XX	XX		
39 (2006 Indonesia)		X		
41 (2008 China)	X	X		
44 (2010 Haiti)	XX	XX	XX	XX
45 (2010 Mexico)	XX			XX
KEY:	**X:Outlier**	**XX:Highly Influential**		

Multiple Linear Regressions for Earthquakes

The log total deaths resulting from an earthquake was significantly predicted by the magnitude of the earthquake, and the World Happiness Report Score (whrs), but inversely related to whrs, as indicated by the negative sign for the model parameter estimate associated with this variable (Table 3). The amount of injuries that result from an earthquake was similarly negatively related to whrs (Table 4). The absolute value of latitude (absla) was statistically significant in the model used to predict the total damage in US dollars of an earthquake (Table 5), indicating countries located nearer the equator suffered more damage. The deaths from human rights violations (hc) and the latitude of a country were statistically significant in predicting the percentage of country's population that dies from an earthquake (Table 6).

Table 3. MLR 1 Model summary statistics (log Total Deaths).

Residuals:	Min	1Q	Median	3Q	Max
	-2.117	-0.582	-0.050	0.525	2.239
Coefficients:	Estimate	Std. Error	t value	Pr(>|t|)	
(Intercept)	4.298	2.581	1.666	0.103	
geodata$magnitude	0.859	0.235	3.652	0.001	***
geodata$log10whrs	-10.527	3.055	-3.446	0.001	**
geodata$arcsina	-2.514	2.048	-1.227	0.226	
geodata$log10hc	0.170	0.119	1.420	0.163	
geodata$absla	0.010	0.012	0.787	0.436	
geodata$log10fd	-0.468	0.608	-0.769	0.446	
Signif. codes:	0 ‘***’	0.001 ‘**’	0.01 ‘*’	0.05 ‘.’	0.1 ‘ ’

Residual standard error: 1.06, df = 43
Multiple R-squared = 0.44, Adjusted R-squared = 0.36
F-statistic: 5.62; df = 6, 43; p-value = 0.00022

Table 4. MLR 2: Model summary statistics (log Injuries).

Residuals:	Min	1Q	Median	3Q	Max
	-1.408	-0.627	-0.1545	0.7052	2.6201
Coefficients:	Estimate	Std. Error	t value	Pr(>|t|)	
(Intercept)	4.39533	2.34366	1.875	0.0675	.
geodata$magnitude	0.35627	0.21365	1.668	0.1027	
geodata$log10whrs	-5.7138	2.7742	-2.06	0.0455	*
geodata$arcsina	-2.4638	1.86035	-1.324	0.1924	
geodata$log10hc	0.0838	0.10851	0.772	0.4442	
geodata$absla	0.04063	0.55241	0.074	0.9417	
geodata$log10fd	0.01869	0.01108	1.686	0.099	.
Signif. codes:	0 ‘***’	0.001 ‘**’	0.01 ‘*’	0.05 ‘.’	0.1 ‘ ’

Residual standard error: 0.96, df = 43
Multiple R-squared = 0.23, Adjusted R-squared = 0.13
F-statistic: 2.18; df = 6, 43; p-value: 0.064

Table 5. MLR 3: Model summary statistics (log Damages).

Residuals:	Min	1Q	Median	3Q	Max
	-1.96628	-0.88575	-0.03108	0.61608	2.52523
Coefficients:	Estimate	Std. Error	t value	Pr(>|t|)	
(Intercept)	0.39031	2.73641	0.143	0.8872	
geodata$magnitude	0.24346	0.24945	0.976	0.3345	
geodata$log10whrs	-0.62793	3.2391	-0.194	0.8472	
geodata$arcsina	-1.66065	2.1721	-0.765	0.4487	
geodata$log10hc	0.02147	0.1267	0.169	0.8662	
geodata$absla	0.03672	0.01294	2.838	0.0069	**
geodata$log10fd	0.04963	0.64498	0.077	0.939	
Signif. codes:	0 ‘***’	0.001 ‘**’	0.01 ‘*’	0.05 ‘.’	0.1 ‘ ’

Residual standard error: 1.13, df = 43
Multiple R-squared = 0.20, Adjusted R-squared = 0.09
F-statistic: 1.85; df = 6, 43; p-value: 0.11

Table 6. MLR 4: Model summary statistics (log Percentage Killed).

Residuals:	Min	1Q	Median	3Q	Max
	-0.17199	-0.07751	-0.01157	0.02784	0.65917
Coefficients:	Estimate	Std. Error	t value	Pr(>|t|)	
(Intercept)	-0.318472	0.322662	-0.987	0.3292	
geodata$magnitude	0.053557	0.029414	1.821	0.0756	.
geodata$log10whrs	-0.05813	0.381937	-0.152	0.8797	
geodata$arcsina	0.061952	0.256122	0.242	0.81	
geodata$log10hc	0.035149	0.01494	2.353	0.0233	*
geodata$absla	0.003436	0.001526	2.252	0.0295	*
geodata$log10fd	-0.071916	0.076052	-0.946	0.3496	
Signif. codes:	0 ‘***’	0.001 ‘**’	0.01 ‘*’	0.05 ‘.’	0.1 ‘ ’

Residual standard error: 0.13, df = 43
Multiple R-squared = 0.28, Adjusted R-squared = 0.18
F-statistic: 2.85; df = 6, 43; p-value: 0.020

Wildfire Disasters

The response variables for modeling wildfires were Total Deaths, Injuries, Damages in US Millions, and Percentage of Population Killed, the same as for the earthquake models. Because I could only find 17 data points, I simplified my MLR models into two categories: a test that measures physical criteria (P) of a wildfire and a test that measures social criteria (S) of a wildfire. The first test uses the physical predictor variables of Magnitude and Duration and the second test uses the social predictor variables of WHRS and Natural. Note that all these variables were log-transformed, and correlation and regression results reported here are after transformation.

To identify multicollinearity in the multiple regression analyses, I created a correlation matrix (Table 7) for the wildfire log transformed variables, preceding the wildfire regression diagnostic plots. There were weak correlations between Total Deaths and Percentage Killed, and WHRS and Natural, and between Percentage Killed and Injuries, Total Deaths and WHRS, Injuries and WHRS, Damage and WHRS, and Magnitude and WHRS (Table 7). Total Deaths and Damages were moderately correlated, as well as Magnitude and Duration. Finally, there was a moderate negative correlation between percentage killed and magnitude.

Table 7. Correlation matrix for log-transformed variables of the wildfire dataset

	TD	%K	Inj.	D(US$)	Mag.	Dur.	WHRS	Nat.
Total Deaths	1.00	0.34	0.22	0.56	-0.09	0.05	-0.39*	0.29*
% Killed W		1.00	-0.34	-0.23	-0.56	-0.08	0.29	0.28
Injuries			1.00	0.24	0.27	-0.07	-0.33	0.21
DamageUS$				1.00	-0.09	-0.18	-0.42	0.07
Magnitude					1.00	0.65	-0.31	-0.30
Duration						1.00	0.09	0.14
WHRS							1.00	0.44
Natural								1.00
KEY	*:p<.05	**:p<.01	***:p<.001	>=wc	>=mc	>=sc		

Diagnostic Plots for Wildfire Variables

The % Killed data were linear, but homoscedasticity was violated (Figure 8). The remaining untransformed diagnostic plots similarly indicated violation of the rules required for regression analysis and are omitted. In the log transformed % Killed physical diagnostic plots (Figure 9), the assumption of linearity appeared to be true, but homoscedasticity was false, with points 9 (2006 Cabazon, CA), 14 (2012 Colorado Springs, CO), and 16 (2013 Yarnell & Peeples Valley AZ) standing out. The data was fairly normal with points 1 (1991 Oakland, CA), 14 (2012 Colorado Springs, CO), and 16 (2013 Yarnell & Peeples Valley AZ) as outliers. This was likely due to the inconsistent nature of measuring exactly what area a wildfire impacted. There was not equal spread in the variation of the residuals: points 1 (1991 Oakland, CA), 13 (2011 Bastrop County, TX), and 16 (2013 Yarnell & Peeples Valley AZ) were highly influential. Statistical analysis was impractical and the multiple regression model was omitted. For the log transformed % Killed social diagnostic plots (Figure 10), the data was somewhat linear, but violated homoscedasticity. Further analysis of untransformed variables was not warranted, and multiple regression modeling was not performed.

The log transformed Total Deaths physical diagnostic plots (Figure 11) showed the data was fairly linear and did not violate homoscedasticity. The data was also normal with points 1 (1991 Oakland, CA), 11 (2008 California), and 15 (2013 Black Forest & Colorado Springs, CO) as outliers. Points 1 (1991 Oakland, CA) and 11 (2008 California) were also highly influential, as well as point 16 (2013 Yarnell & Peeples Valley AZ). After log transformation, the Total Deaths social diagnostic plots (Figure 12), indicated the data were linear and met the assumption of homoscedasticity, with points 2 (1993 Laguna Beach, CA), 4 (1998 Florida), and 16 (2013 Yarnell & Peeples Valley AZ) as outliers. Points 4 (1998 Florida), 15 (2013 Black Forest & Colorado Springs, CO) and 16 (2013 Yarnell & Peeples Valley AZ) were highly influential. Further analysis was warranted. These are summarized in Table 8.

The log transformed Total Death physical MLR model (Figure 11) and the log transformed Total Death social MLR model (Figure 12) were the only models eligible for MLR. Other variables violated the requirements for MLR even after they were log transformed (Figures 13-16). The 2013 Yarnell & Peeples Valley, AZ wildfire was the only event that was highly influential to both MLR models (Transformed Total Death Physical and Transformed Total Death Social) and is featured in the Discussion section.

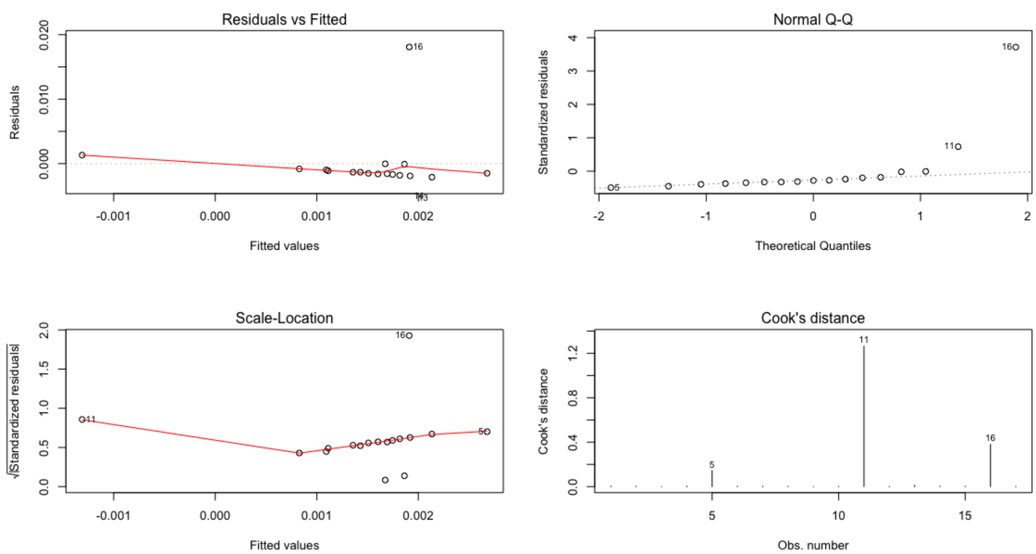

Figure 8. Diagnostic plots for untransformed % Killed, wildfire P MLR model.

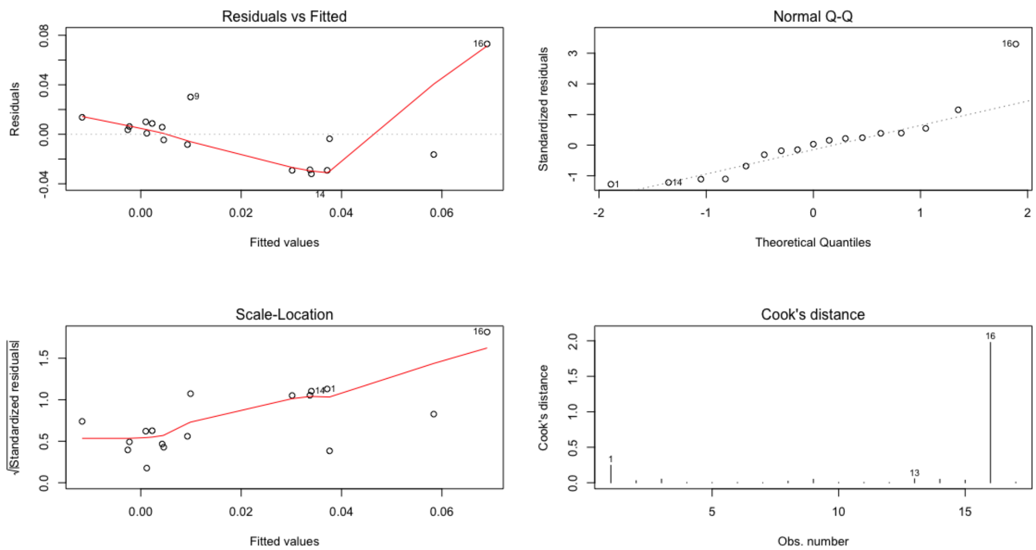

Figure 9. Diagnostic plots for log transformed % Killed, wildfire P MLR model.

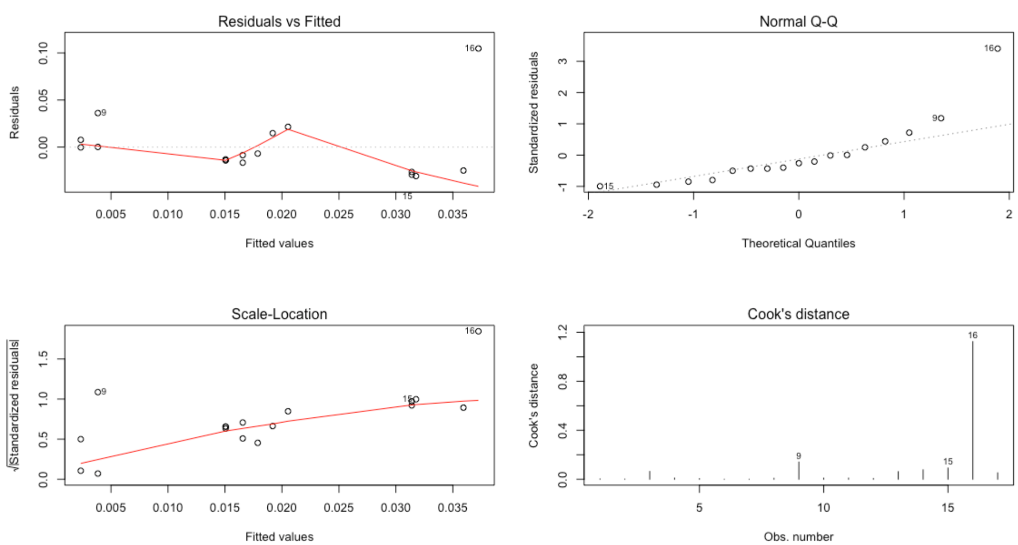

Figure 10. Diagnostic plots for log transformed % Killed, wildfire S MLR model.

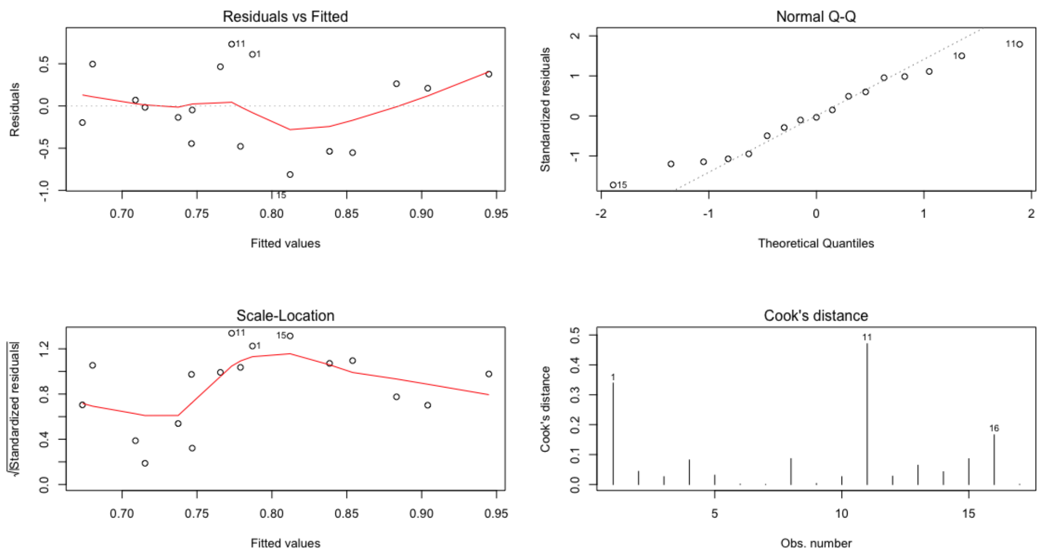

Figure 11. Diagnostic plots for log transformed TD, wildfire P MLR model.

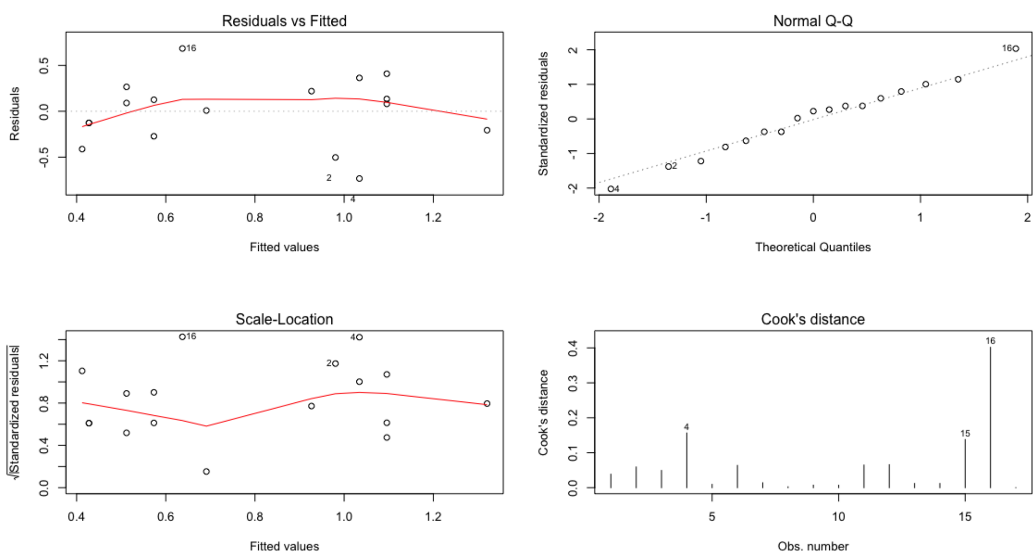

Figure 12. Diagnostic plots for log transformed TD, wildfire S MLR model.

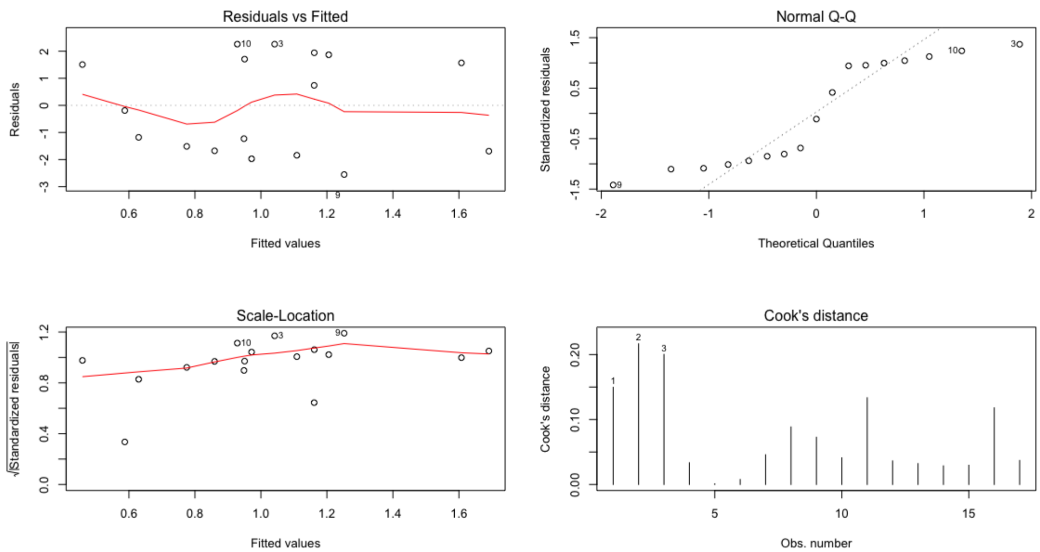

Figure 13. Diagnostic plots for log transformed D(US$), wildfire P MLR model.

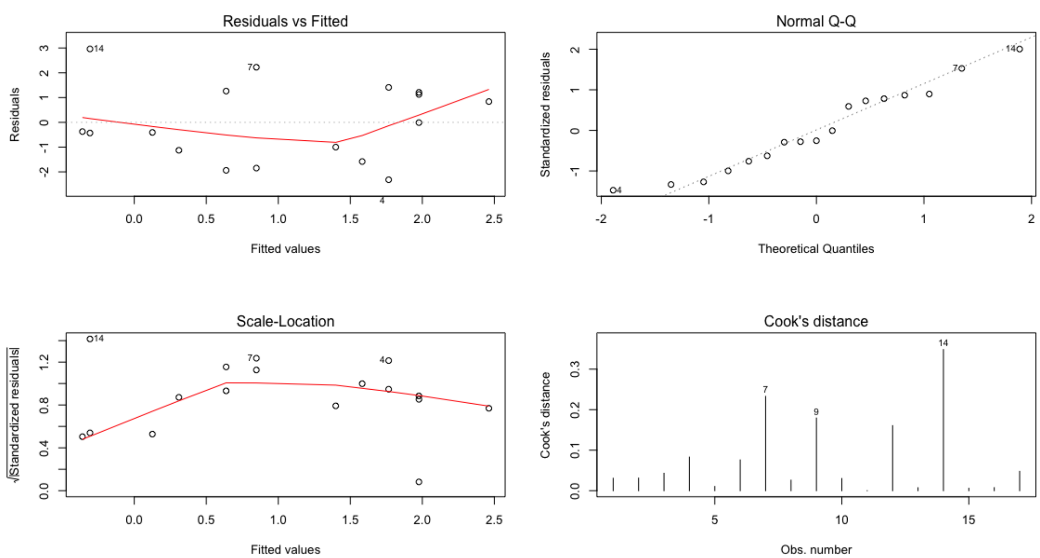

Figure 14. Diagnostic plots for log transformed D(US$), wildfire S MLR model.

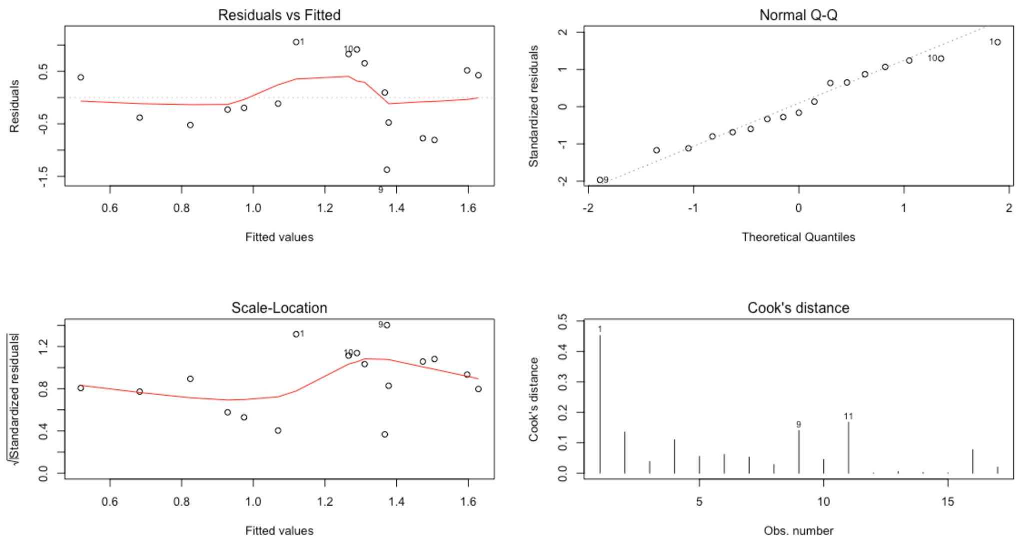

Figure 15. Diagnostic plots for log transformed Injuries, wildfire P MLR model.

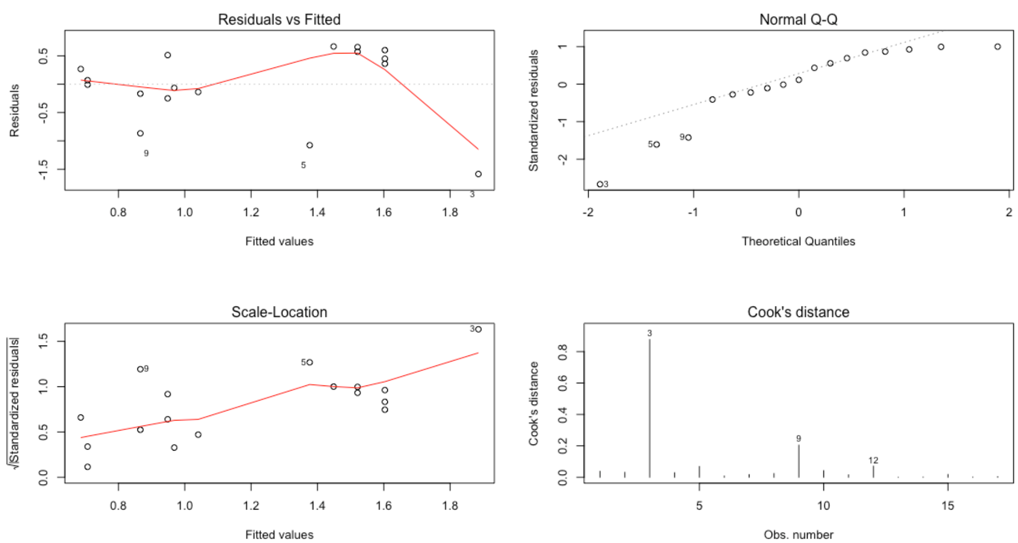

Figure 16. Diagnostic plots for log transformed Injuries, wildfire S MLR model.

Table 8. Summary table of diagnostic plots for Total Deaths from wildfires.

Fig. Summary Table 2	Fig. 11 Total Deaths Physical	Fig. 12 Total Deaths Social
1 (1991 Oakland, CA)	XX	
2 (1993 Laguna Beach, CA)		X
4 (1998 Florida)		XX
11 (2008 California)	XX	
15 (2013 Black Forest & Colorado Springs, CO)	X	XX
16 (2013 Yarnell & Peeples Valley AZ)	XX	XX
KEY:	**X:Outlier**	**XX:Highly Influential**

Multiple Linear Regressions for Wildfires

MLR was not conducted using Injured, Damages in US $, or Percentage Killed as response variables both because assumptions for regression remained unmet after transforming variables, and insufficient data points for the number of predictor variables. Only models for Total Deaths were examined. Neither Magnitude nor Duration were statistically significant as physical criteria (P) (Table 9). However, Natural and World Happiness Report Score were significant among social criteria (S) (Table 10).

Table 9. MLR 1: Model summary statistics (log Total Deaths physical).

Residuals:	Min	1Q	Median	3Q	Max
	-0.81215	-0.44532	-0.01629	0.37712	0.73186
Coefficients:	Estimate	Std. Error	t value	*Pr(>|t|)*	
(Intercept)	0.474	0.5151	0.92	0.373	
cldata2$log10m	-0.1111	0.1812	-0.613	0.55	
cldata2$log10duration	0.1393	0.2648	0.526	0.607	
Signif. codes:	*0 '***'*	*0.001 '**'*	*0.01 '*'*	*0.05 '.'*	*0.1 ' '*

Residual standard error: 0.49, df = 14
Multiple R-squared = 0.028 Adjusted R-squared = -0.11
F-statistic: 0.20; df = 2, 14; p-value: 0.82

Table 10. MLR 2: Model summary statistics (log Total Deaths social)

Residuals:	Min	1Q	Median	3Q	Max
	-0.73322	-0.20654	0.08036	0.21925	0.68471
Coefficients:	Estimate	Std. Error	t value	*Pr(>|t|)*	
(Intercept)	6.4309	2.1181	3.036	0.00889	**
cldata2$log10n	0.7472	0.2999	2.492	0.02588	*
cldata2$log10whrs	-7.6769	2.7601	-2.781	0.01471	*
Signif. codes:	*0 '***'*	*0.001 '**'*	*0.01 '*'*	*0.05 '.'*	*0.1 ' '*

Residual standard error: 0.38, df = 14
Multiple R-squared = 0.41, Adjusted R-squared = 0.33
F-statistic: 4.87; df = 2, 14; p-value: 0.025

Chapter IV

Discussion

Results from multiple regression analysis indicate that indirect drivers of ecosystem change can explain differences in countries' natural disaster resiliencies. Recall that indirect drivers of change can come from a change in demographics, economics, sociopolitical systems, science and technology, and culture and religious beliefs (MEA, 2005). These drivers are captured by the World Happiness Report Score (WHRS). The WHRS attempts to evaluate rights in general through surveys and questionnaires. This includes democratic rights, human rights, children's rights, civil rights and social rights. The WHRS does not explicitly track human rights violations, more than likely because they are difficult to quantitatively track.

My main hypothesis, that each country's human rights violations aggregated yearly is negatively correlated with natural disaster resiliency, was supported when using the WHRS as a proxy for human rights violations for both earthquakes (Tables 3 & 4) and wildfire disasters (Table 10). When I attempted to decouple this information, by using only confirmed human rights deaths found in the annual Human Rights Watch reports as a proxy for human rights violations, no effect was found on the number of deaths from a discrete natural disaster event. However, the hypothesis was confirmed by weighting the total number of deaths from an earthquake by the total number of people affected by that natural disaster, calculating percentage killed (Table 6).

Earthquake Total Death Model Interpretation

Not surprisingly, results demonstrated that the magnitude of an earthquake is a significant predictor of total deaths, but that deaths are reduced in relation to a country's WHRS. The variables of atheism, human rights deaths, latitude, and focal depth were statistically insignificant in predicting total deaths from an earthquake. The relationship between the magnitude of the earthquake and the total deaths that result from the earthquake was significant at the $p = <0.001$ level and accounts for ~10% of the variation associated with total deaths from an earthquake. The WHRS is significant at the $p = <0.05$ level and accounts for ~25% of the variation in total deaths during an earthquake. Even though the magnitude is significant at a smaller p value level than WHRS, it accounts for less variation. My model does not adjust for tsunamis that occur because of an earthquake, and a more in depth analysis of the relationship between earthquakes and tsunamis needs to be explored. The WHRS covers such a wide variety of variables that multicollinearity is bound to exist between some of the variables, so these cannot be teased apart from this analysis.

Other Earthquake Response Variables

WHRS was statistically significant in predicting the injuries that result from an earthquake, and this negative relationship is consistent the main hypothesis that a country's human rights violation score is inversely related to its WHRS. WHRS is significant at the $p = <0.05$ level and accounts for ~10% of the variation in injuries during an earthquake. Injuries are strongly correlated with total deaths (r ~. 8), but WHRS does explain as much variance in injuries as it does in total deaths. One possible explanation is that injuries are more difficult to accurately estimate than mortalities.

A country's latitude was significant in predicting earthquake damage (US$) at the p = <0.05 level and accounts for ~16% of the variation in damage. I used the absolute value of latitude, so the farther away from the equator, the greater the damage. The exact relationship between latitude and prosperity/development is unclear and needs further investigation.

Latitude and human rights deaths were significantly related to the percentage of the affected population killed from an earthquake. In keeping with the other models, no support was found for the hypotheses that magnitude, atheism, WHRS, and focal depth were statistically significant in predicting the percentage killed from an earthquake. Latitude and human rights deaths are significant at the p = <0.05 level, with latitude accounting for ~10% of the variation associated with percentage killed and human rights deaths accounting for another ~10%. Prosperity/development and human rights deaths are probably linked. Moreover, the results are consistent with covering up human rights deaths under the guise that they were natural disaster related.

Why were Focal Depth and Atheism Statistically Insignificant?

From Table 1, there is virtually no correlation between focal depth and damage, but this can be explained because the real predictor variable that influences damage is magnitude. However, if an earthquake has a shallow focal depth, then the seismic waves have less distance to travel before they exert a force on objects above ground. So, the destructive force is governed by the magnitude of the earthquake measured at the epicenter and not the focus (at its focal depth).

Atheism appeared to have weak negative correlation and was statistically significant in one of the MLR models until I introduced the 2010 Haiti earthquake data point into the analysis. Note that only this data point was an outlier, and highly influential in all MLR models. Below is a brief analysis of the event.

2010 Haiti Brief Case Study

The 2004 Indian Ocean earthquake and tsunami may have been twice as deadly as the 2010 Haiti earthquake, but the tsunami that resulted from the 2004 Indian Ocean earthquake is believed to be the worst tsunami in history, as measured by death toll. I could not include a data point for the 2004 Indian Ocean natural disaster event, because it did not have reliable data for deaths, injuries, damage, and percentage of population affected. Anywhere from ~100,000 to 316,000 casualties resulted from the Haiti earthquake. This higher figure was used in my data analysis and comes from the em-dat database, with its original source being the Haitian government. This higher figure would make the 2010 Haiti earthquake the deadliest earthquake since the 1556 Shaanxi earthquake and the deadliest natural disaster since the 1931 China floods. The higher reported death toll of 316,000 is greater than the 2004 Indian Ocean earthquake and tsunami calamity. Even using the lower estimate of ~100,000 deaths, it is still the worst earthquake in this data set by deaths. The second deadliest earthquake is the 2008 China/Sichuan earthquake with a death toll of 87,564.

The second thing that stands out about Haiti is the unusually small number of reported injuries from the earthquake, 30,000. Generally, there are more injuries than deaths during an earthquake. At the very least, they are on the same order of magnitude. The 1995 Neftegorsk/Russian earthquake (data point 17) had 1989 deaths to 750 people injured and displayed the same death injury disparity. It was reported by the New York Times that the Russian earthquake hit an island during a time when most people would be sleeping. Thirteen five-story houses, made of prefabricated blocks, collapsed on about 3000 people during this earthquake (The New York Times, 1995). Hundreds were reportedly saved, so it is possible that most people killed in the 1995 Russian earthquake were sleeping in the 13 five-story houses. This would explain the anomaly of such a high percentage (~62% of the population) being killed for the total area that was affected, and I think the 2010 Haiti case is similar.

Over 12% of the population of Port-au-Prince (Haiti's capital) was killed during the earthquake. The 2010 Haiti earthquake epicenter was about 16 miles west of the capital, with a magnitude of 7.0. Cite Soleil is a shantytown within Port-au-Prince with half the houses made from cement with a metal roof and the other half made completely out of scavenged material (Environmental Health Project [EHP] & GreenCOM, 1997). Furthermore, an estimated 65+ % of the houses did not have access to a latrine (EHP & GreenCOM, 1997). After a reported 150,000 had died from the earthquake, food aid on a significant scale arrived in Cite Soleil nearly two weeks after the earthquake began on January 12, 2010, 21:53 UTC (Euronews, 2010). Finally, the reported damage from this earthquake was equal to 8 billion USD compared to the 1994 United States/Northridge earthquake (data point 13) that had a reported damage figure over 5 times the 2010 Haiti earthquake, but resulted in 60 deaths compared to 316,000 deaths from the Haiti earthquake. Damage only refers to the USD amount lost from destruction of property, crops, and livestock. Loss of life, injuries, wages, and a multitude of things are not captured in traditional accounting.

Wildfire Total Death Model Interpretation

Results indicate that both the magnitude of a wildfire (measured in millions of acres burned) and the duration (measured in days the wildfire is active) were not statistically significant in predicting the total deaths that occur from a wildfire (Table 9). The population density of the area affected by the wildfire is vastly more important than the total acres burned from a wildfire. The distance from the origin of the fire to the nearest densely populated area, in combination with the time it takes for the fire to reach that populated area, is more important than the duration of the fire itself.

Wildfire Total Death Model Interpretation (Social)

Results indicate that the origin of the wildfire (if it occurred naturally) and the World Happiness Report Score were both statistically significant ($p = <0.05$) in predicting the total deaths that result from a wildfire. The WHRS comprises many different variables and accounted for 15% of the variation. Natural, just like atheism in the earthquake case, attempts to capture the inherent purpose of a natural disaster, if it has one. Fires that start naturally are innately different than fires with anthropogenic origins.

2013 Yarnell Hill Wildfire Brief Case Study

On June 28th 23:36 UTC lightning struck 3.5 miles west of Yarnell, Arizona creating a wildfire that burned approximately 8,400 acres of land (National Wildfire Coordinating Group, 2013). By July 10 the wildfire was 100% contained, but not before claiming 19 Granite Mountain Hotshots (elite firemen) and injuring 8 people, making it the greatest loss of firefighters in the United States since the September 11, 2001 attacks. Two particularly interesting things occurred in the wildfire's aftermath. First, FEMA ruled that the fire did not qualify for disaster aid to homeowners because most of the homeowners had insurance; this was later appealed but ultimately the Obama Administration rejected Arizona's appeal for federal assistance in response to the Yarnell Hill fire (ADI News Services, 2013). For those who qualified, the Small Business Administration (SBA) said it would offer low-interest disaster loans up to $200,000 to repair the damaged or replace the destroyed personal property; this amount was limited to $40,000 for people outside Yavapai, Arizona and the neighboring counties (ADI News Services, 2013). The second rather interesting event occurred on December 4, 2013 when the Industrial Commission of Arizona, by unanimous vote, levied a $559,000 fine on the Arizona Forestry Division for prioritizing protecting land assets over firefighter safety (Johnson, 2013). Almost all the money went directly to the families of the fallen firefighters (Johnson, 2013). The total damage in US dollars reported for this event was $523,400, probably in relation to the fine levied.

Conclusions

Each country's human rights violations aggregated yearly is negatively correlated with natural disaster resiliency when using the World Happiness Report Score (WHRS) as a proxy for human rights violations. This held true for both earthquakes (non-climate related disasters traditionally) and wildfires (climate related disasters traditionally). However, the WHRS not only considers human rights violations, but a multitude of factors: GDP per capita, social support, health life expectancy, freedom to make life choices, generosity, trust, and perceptions of corruption. True natural disasters, such as the Haiti earthquake (anthropogenic causal factors unclear or largely believed to be irrelevant), and the Yarnell Wildfire (absent of arson and/or malicious intent) seem to be destructive by nature but not as deadly as the results would indicate. The majority of deaths and injuries come from prioritizing damage mitigation. The cost of damage mitigation is the total market value of damage to property, crops, and livestock true to the year of the disaster, but the cost of increased morbidity and mortality is $0 by traditional accounting. The immediate aftermath of a natural disaster turns into a humanitarian disaster when we deny people aid that is required for basic survival or we sacrifice the basic human rights of a few to benefit others. Increasing a country's WHRS, also increases its resiliency against both climate and non-climate related disasters.

Research Limitations and Caveats

Meteorological, biological, and hydrological natural disasters were omitted from analysis. Instead I concentrated on the link between Geophysical disasters (traditionally occurs independently from climate change) and Climatological disasters (traditionally caused by long-lived, meso- to macro-scale atmospheric processes ranging from intra-seasonal to multi-decadal climate variability) (Guha-Sapir, 2017). This binary analysis between largely non climate change related disasters (geophysical/earthquakes) and moderately climate change related disasters (climatological/heatwaves) created a scope of research that was manageable but contained the following flaws:

- Generally, you need 10 data points per predictor variable to avoid overfitting, otherwise known as the one in then rule. For the earthquake dataset this was not a serious issue. For the wildfire dataset I could only find 17 data points and therefore simplified the MLR models into two categories: a test that measures physical criteria of a wildfire and a test that measures social criteria of a wildfire. The first test therefore only used the physical predictor variables of magnitude and duration and the second test was restricted to the social predictor variables of WHRS and natural.

- Ideally, I desired similar models for both earthquakes and wildfires. At the very least, all of the models should have had similar predictor variables and the same amount of predictor variables in order to show that a generalized resiliency model for all natural disasters could be created. Both earthquakes and wildfires were linked by WHRS, but I was unable to include the predictor variables of atheism, human rights deaths, elevation (focal depth for earthquakes), and latitude in the wildfire MLR model.
- All of the percentage killed measurements had an extra element of random error due to how we define the physical boundaries of where a natural disaster occurred. Developing nations had a tendency to report natural disasters as affecting their entire country. Developed countries might specify a single city or town as being affected. It was always unclear whether the deaths reports were a direct or indirect result of a natural disaster.
- Regarding the predictor variables, reporting of human rights violations is still largely a qualitative process. It is very difficult to verify quantitative data regarding human rights violations and deaths. The percentages for atheists in a country are subjective because we do not clearly differentiate people who are theistic and consider themselves irreligious from those who consider themselves atheistic.

Questions for Further Research

An explicit inference from this research is that by increasing our WHRS we are increasing our resiliency against both climate and non-climate related disasters. This needs to be thoroughly tested, expanding the scope of research to include meteorological, biological, and hydrological natural disasters. A more reproducible and systematic methodology needs to be created to model all natural disasters. To apply this research, we have to identify the best ways of increasing the WHRS for all countries. Wearable augmented reality (AR) devices will provide us real time data to monitor small changes in the environment. This technology should aid in tracking and measuring the impact of an increasing WHRS on climate change and natural disaster resiliency.

Implicitly, I believe this research justifies the testing of an expanded hypothesis: all true natural disasters (natural disasters that are largely free from anthropogenic origins) have a statistically significantly different death toll than natural disasters that have large anthropogenic origins. The significance of this new research would be to determine whether true natural disasters are completely fatalistic and less deadly than anthropogenic disasters.

Building on this research and through literature review, I would hope to identify natural disasters as truly natural on a 1-10 scale (1 defined as completely anthropogenic in origin and 10 as completely free of anthropogenic origin). To quantify fate and its relationship with different types of belief systems, I posit a simple survey that identifies a person's religious affiliation and their views on fatalism (1-10 scale), as it pertains to calamities. Via the scientific method and multivariate analysis to control for other factors, I define Resiliency: Total Deaths = (How anthropogenic in origin a disaster is?) +

(How fatalistic a natural disaster is perceived to be?). The categorical religious affiliation data should be utilized, via Analysis of Variance (ANOVA), to determine if there is a statistical difference in the means of perceived fatalism among different religions.

Additionally, I hope to identify differences in religions that explain differences in natural disaster resiliency. I desire to eliminate all research limitations and quantify beliefs that are statistically proven to increase resilience to all types of natural disasters. More specifically, I desire to quantify the absence of theistic beliefs (atheism) and compare fatalism across all religious doctrines, with respect to resiliency during acts of God. This research should provide us with a blueprint to eliminate deadly beliefs rooted in traditionalism and emphasizes positive resiliency similarities among all philosophies that increase the wellbeing of all individuals.

References

ADI NEWS SERVICES. (2013, September 14). Obama administration denies yarnell fire victims assistance. Retrieved December 30, 2017, from https://arizonadailyindependent.com/2013/09/14/obama-administration-denies-yarnell-fire-victims-assistance/

Ayyub, B. (2014). Systems resilience for multihazard environments: definition, metrics, and valuation for decision making. *Risk Analysis*, *34*, 340-355.

Bilham, Roger. (2010). Lessons from the Haiti earthquake: Roger Bilham, one of the first seismologists to visit Haiti after last month's earthquake, calls for UN enforcement of resistant construction in cities with a history of violent tremors. (Viewpoint essay). *Nature*, *463*, 878.

Bookmiller, K., Ferris, E., Gerrard, M., & Nifosi-Sutton, I. (2014). Can international norms protect us from natural disasters? *Proceedings of the Annual Meeting (American Society of International Law)*, *108,* 173-186.

Boston University School of Public Health. (2016, January 6). Regression Diagnostics. Retrieved December 30, 2017, from http://sphweb.bumc.bu.edu/otlt/MPH-Modules/BS/R/R5_Correlation-Regression/R5_Correlation-Regression7.html

Bradshaw, Corey J.A., Sodhi, Navjot S., Peh, Kelvin S.-H., & Brook, Barry W. (2007). Global evidence that deforestation amplifies flood risk and severity in the developing world.(Author abstract)(Report). *Global Change Biology*, *13*, 2379.

Central Intelligence Agency (CIA). (2017). The World Fact Book. Retrieved March 7, 2018, from https://www.cia.gov/library/publications/the-world-factbook/

Coleman, Timothy A., Knupp, Kevin R., Spann, James, Elliot, J.B., & Peters, Brian E. (2011). The history (and future) of tornado warning dissemination in the United States.(ESSAY)(Author abstract)(Report). *Bulletin of the American Meteorological Society*, *92*, 548.

EHP & GreenCOM. (1997). A Plan for CDS to Establish a Water and Sanitation District In Cité Soleil, Haiti and Monitoring Visit Report(Rep. No. 21). Retrieved December 30, 2017, from USAID website: http://pdf.usaid.gov/pdf_docs/PNABY701.pdf

Euronews. (2010, January 25). Quake aid finally reaches Haiti's Cite Soleil slum. Retrieved December 30, 2017, from http://www.euronews.com/2010/01/25/quake-aid-finally-reaches-haitis-cite-soleil-slum

Euster, L. (2015). Ring of Fire: An Encyclopedia of the Pacific Rim's Earthquakes, Tsunamis, and Volcanoes. Reference & User Services *Quarterly*, *55*, 77-78.

Gan, W., & Frohlich, C. (2013). Gas injection may have triggered earthquakes in the Cogdell oil field, Texas. *Proceedings of the National Academy of Sciences of the United States of America*, *110*, 18786-91.

Guha-Sapir, D. (2017). EM-DAT | The international disasters database. Retrieved December 30, 2017, from http://www.emdat.be/

Human Rights Watch. (2015). Human Rights Watch World Report 2015: Events of 2014. Retrieved May 21, 2016, from https://www.hrw.org/sites/default/files/world_report_download/wr2015_web.pdf

Johnson, M. A. (2013, December 05). Yarnell Hill fire: Arizona agency didn't prioritize Hotshots' safety, officials say. Retrieved December 30, 2017, from https://www.nbcnews.com/news/other/yarnell-hill-fire-arizona-agency-didnt-prioritize-hotshots-safety-officials-f2D11698307

Klose, C. (2007). Mine Water Discharge and Flooding: A Cause of Severe Earthquakes. *Mine Water and the Environment*, *26*, 172-180.

Lei, Xie, Fan, & Santosh. (2013). Seismic imaging of the deep structure under the Chinese volcanoes: An overview. *Physics of the Earth and Planetary Interiors*, *224*, 104-123.

Millennium Ecosystem Assessment, 2005. Ecosystems and Human Well-being: Synthesis. Island Press, Washington, DC.

Miller, L. (2010, Jan 25). Why god hates haiti. Newsweek, 155 Retrieved from http://search.proquest.com.ezp-prod1.hul.harvard.edu/docview/214247239?accountid=11311

National Interagency Fire Center. (2017). Historically Significant Wildland Fires. Retrieved December 30, 2017, from https://www.nifc.gov/fireInfo/fireInfo_stats_histSigFires.html

National Wildfire Coordinating Group. (2013, July 10). Yarnell Hill Fire. Retrieved December 30, 2017, from https://inciweb.nwcg.gov/incident/3461/

The Significant Earthquake Database. (2017). Retrieved December 30, 2017, from https://www.ngdc.noaa.gov/nndc/struts/form?t=101650&s=1&d=1. doi:10.7289/V5TD9V7K

Nixon, E., Holland-Crimmin, S., Lupotsky, B., Chan, J., Curtis, J., Dobbs, K., & Blaxill, Z. (2009). Applications of Adaptive Focused Acoustics to Compound Management. *Journal of Biomolecular Screening*, *14*, 460-467.

Olshansky, R. (1999). Natural hazard mitigation: Recasting disaster policy and planning. *American Planning Association.Journal of the American Planning Association*, *65*, 453. Retrieved from http://search.proquest.com.ezp-prod1.hul.harvard.edu/docview/229611199?accountid=11311

Sauerborn, R., & Ebi, K. (2012). Climate change and natural disasters: Integrating science and practice to protect health. *Global Health Action*, *5*, 1-7.

Slettebak, R., & De Soysa, I. (2010, June 21). High Temps, High Tempers? WeatherRelated Natural Disasters & Civil Conflict. Retrieved June 7, 2016, from http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.629.7203&rep=rep1&type=pdf

Stallings, R. (2006). Causality and "Natural" Disasters (Book Review). *Contemporary Sociology*, *35*, 223-227.

Sustainable Development Solutions Network (SDSN) (2012). World Happiness Report (2012-2017). Retrieved March 07, 2018, from http://worldhappiness.report/

The New York Times. (1995, May 29). Quake on Russian Island in Pacific Kills at Least 300. World. Retrieved December 30, 2017, from www.nytimes.com/1995/05/29/world/quake-on-russian-island-in-pacific-kills-at-least-300.html

The universal declaration of human rights. (2012). Forced Migration Review, , 6-7. Retrieved from http://search.proquest.com.ezp-prod1.hul.harvard.edu/docview/1033046612?accountid=11311

Vaughan, William W., & Johnson, Dale L. (1994). Meteorological satellites - the very early years, prior to launch of (TIROS-1). (Television and Infrared Observing Satellite). *Bulletin of the American Meteorological Society*, *75*, 2295.

Wald, L. (2016, April 7). The Science of Earthquakes. Retrieved July 15, 2016, from http://earthquake.usgs.gov/learn/kids/eqscience.php

Wikipedia. (2018, February 15). List of wildfires. Retrieved March 7, 2018, from https://en.wikipedia.org/wiki/List_of_wildfires

Zebrowski, E., & Craig. (1998). Perils of a restless planet: Scientific perspectives on natural disasters. *Physics Today*, *51*, 83-84.