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Nature's role in national security

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Abstract

The ability of a nation to protect its citizens, institutions, and interests from domestic and foreign threats is one of the foundational responsibilities of any government. However, the ability of sovereign nations to ensure national security for their citizens and institutions has been increasingly challenged by various forms of anthropogenic global change. While the link between climate change and national security has already received considerable attention, biological changes in nature that generate ecological disruptions and increase national security risks have been comparatively overlooked. This is unfortunate given that ecological disruptions like habitat loss and degradation, biodiversity loss, invasive species, pest and disease outbreaks, overharvesting, and others can contribute to food and water scarcity, energy shortages, economic crises, disease outbreaks, property destruction on scales comparable to climate change. Here we draw explicit links between biological forms of global change that generate ecological disruptions and security risk. We focus on five key aspects of national security: *food security*, *water scarcity*, *health security*, *protection from natural disasters*, and *environmental crime*. For each aspect, we discuss how ecological disruptions impact social and political stress and use case studies to illustrate how such disruptions impact national security. Collectively, the suite of examples suggests that ecosystems and biological communities that underlie human well-being form a natural infrastructure that helps ensure national security. This natural infrastructure operates much like a nation's physical infrastructure (e.g., communication networks, electrical grids, and transportation networks) to buffer against the worst impacts of natural resource shortages, energy shortages, economic crises, and public health emergencies. Given this, we suggest the role of nature and its natural infrastructure warrants greater attention in security planning.

Keywords: National security, ecosystem services, environmental change

Introduction

National security – the ability of a nation to protect its citizens, institutions, and interests from domestic and foreign threats -- is one of the foundational responsibilities of any government. National security includes not only protection from foreign military aggression, but also domestic stability and non-military protection from terrorism, organized crime, cyberattacks, economic pressures, and social unrest (Romm 1993). The concept of national security has also been extended in the past few decades to include critical dimensions of human safety and well-being, such as the protection from poverty, hunger, disease, natural disasters, and political violence (Bajpai 2003; UNDP 1994).

The ability of sovereign nations to ensure security for their citizens and institutions has been increasingly challenged by various forms of global change caused by human activities. For example, it is well-known that anthropogenic climate change exacerbates natural disasters, increases the frequency and magnitude of food, water and energy shortages, creates public health emergencies, and generates economic crises that lead to loss of property and livelihoods (Jones & Sullivan 2020; Vogler 2023). In turn, climate change can generate or worsen social and political instabilities that leads to domestic and international conflict (Hendrix et al. 2023). Therefore, many nations now explicitly account for the impacts of climate change in their national intelligence and security plans (NIC 2021a).

While the link between climate change and national security has received considerable attention, the effects of other forms of anthropogenic change – namely biological changes to nature that generate ecological disruptions -- have received much less attention (Schoonover et al. 2021). Ecological disruptions like habitat loss and degradation, biodiversity loss, invasive species, pest and disease outbreaks, overharvesting, and others can contribute to food and water scarcity, energy shortages, economic crises, disease outbreaks, property destruction and more (**Figure 1**). In some instances, these biological forms of global change interact with abiotic disruptions like climate change to exacerbate threats to national security. But many times, the biological changes themselves can directly impact ecosystems on scales that are at least comparable to those of climate change (Duffy et al. 2017; Jackson et al. 2016; O'Neill et al. 2018; Rockstrom et al. 2009; Smith et al. 2015). When ecological disruptions occur, the resulting social and political stress can put national security at risk by promoting mass migrations, border breaches, violence and crime, or even warfare (Schoonover et al. 2021).

While it has long been known that ecological disruptions impact the safety and well-being of individuals and communities, their consequences for the stability of, and interactions among, sovereign nations have rarely been considered. Indeed, the ecological foundations of national security have not been widely appreciated, in part, because ecological disruptions are "actorless threats" (those lacking a clear proximate actor) that have been left out of 20th century doctrines on what constitutes national security. However, there is growing evidence that ecological disruptions can influence national security when governments, their citizens, and institutions fail to protect natural resources that are required to meet basic human needs. An increasing number of governmental agencies have become concerned about the ecological underpinnings of national security (NIC 2021b), and the topic has begun to receive more attention in federal policies and international initiatives [e.g., the United Nation's COP 15 & 16 Kunming-Montreal Biodiversity Framework (Hughes & Grumbine 2023), and the World Economic Forum (WEF 2020b)].

Here we draw more explicit links between biological forms of global change that generate ecological disruptions and highlight several case studies of how such disruptions increase national security risk. We focus on five key aspects of national security: *food security*, *water scarcity*, *health security*, *protection from natural disasters*, and *environmental crime*. For each, we discuss why it is important for national security, how ecological disruptions influence security risk, and provide examples to demonstrate the links. Throughout the paper, we avoid repeating the known and important effects of climate change on national security as these are already well-established. We do, however, occasionally point out examples where ecological disruptions interact with climate change to magnify security risks. Our hope is to draw greater attention to the role that biological changes in nature play in mediating national security risks.

Food security

Food security is central to national security because hunger can be a powerful driver of political instability and civil strife. Food shortages can undermine confidence in a government's ability to ensure its citizens' basic needs are met and, when this happens, governments struggle to maintain legitimacy and stability (ICRC 2022). In addition, high food prices that occur during periods of low food supply can act as a catalyst for violent protest and armed conflict (NIC 2015). For example, protests driven by high food prices were partly responsible for toppled governments in Madagascar in 2007-08 (Berazneva & Lee 2013). Extreme food price volatility similarly contributed to insecurity in the Middle East and North Africa where five years of food related riots were a major contributor to mass uprisings of the Arab Spring (Hendrix 2016). These mass uprisings in turn led to toppled regimes, civil wars and insurgencies, and social and political unrest that played a key role in recruiting young rebel soldiers to the Islamic State in Syria with the promise of food (Katsos 2017a).

Threats to food security are projected to increase over the next several decades in many parts of the world as human population growth outpaces advances in food production (Mbow et al. 2019) or where transportation chains are inadequate to overcome food shortages (Hendrix 2016; NIC 2015). Although food insecurity is caused by a complex set of socioeconomic and political factors, ecological disruptions can play a key role. For agricultural systems that rely on crops and livestock, ecological disruptions often result from ecosystem mismanagement like soil degradation and deforestation. More than a third of the world's soil, which produces 95% of the world's terrestrial food supply, is currently degraded, and that fraction is projected to increase as the global population grows (NIC 2017). Soil degradation contributes to desertification, which threatens food supplies of more than a billion people worldwide (Geist 2017). Deforestation compounds soil degradation by promoting erosion and reducing soil fertility. For example, after high demand for fuel wood decreased Haiti's forest cover from >60% in the 1920's to less than 1% today, deforestation and steep topography precipitated widespread erosion and soil nutrient loss that left soils unstable and infertile, lacking the organic matter to meet plant nutrient demands (Bargout & Raizada 2013; Hedges et al. 2018; Paskett & Philoctete 1990). Reduced crop yields forced Haiti to rely on imports for more than 50% of all food and 80% of its main staple, rice (Bargout & Raizada 2013; Kennedy et al. 2016). When the price of imported beans and rice rose by 50% during the 2007-08 global food crisis, starvation led to widespread violent protests and civil unrest that toppled the Haitian government (**Figure 2, Electronic Supplemental Material - ESM no. 1**). Fleeing refugees strained national security elsewhere, such as in the United States where a decades-long deterrence strategy involving the U.S. Coast Guard, Department of Justice, and National Security Council focused on intercepting Haitian boats outside US waters and returning refugees to Haiti (Hendrix 2016). Other countries have similarly experienced food shortages driven by deforestation and poor land management (**Figure 2 and ESM no. 2**).

Food security in agricultural systems can also be jeopardized by outbreaks of pests and disease. Crop pests and pathogens reduce global yields of wheat (-21.5%), rice (-30.0%), maize (-22.5%), potato (-17.2%) and soybean (-21.4%) with the greatest losses occurring in food-deficient regions that experience re-emerging pests and diseases (Savary et al. 2019). The 2019-21 transcontinental outbreak of desert locust (*Schistocerca gregaria*) is an illuminating example (**Figure 2 and ESM no. 3**). The outbreak began in the Horn of Africa and spread north to Iran, Pakistan, and India and south to East Africa (FAO 2023). Desert locusts rank among the world's most destructive migratory pest with swarms that encompass 80 million individuals, travel up to 90 miles a day, and consume the same amount of food per day as 35,000 people (Babar 2023). By the end of 2019, locust swarms had destroyed crops, trees, pastureland, and threatened food security in Ethiopia, Eritrea, Somalia, Kenya, Saudi Arabia, Yemen, Egypt, Oman, Iran, India, and Pakistan (Peng et al. 2020). In 2020, Pakistan and Somalia declared national emergencies in response to locust outbreaks that were jeopardizing the food and economic security of their nations (**Figure 3A**).

Invasive or introduced species can have either positive or negative impacts on food security depending on the context. One example serves to illustrate both points. Cassava (*Manihot esculenta*) was introduced to Africa from South America about 300 years ago, and by the middle of the twentieth century it had become a staple food for more than 200 million people in sub-Saharan Africa (**Figure 2 and ESM no. 4**). In the 1970s, the cassava mealybug (*Phenacoccus manihoti*) was accidentally introduced as an alien invasive species from South America. In the absence of natural enemies, it spread rapidly. By the 1980s, the cassava mealybug had become a major pest causing up to 50% crop loss of cassava and threatening to cause widespread economic losses and starvation (Norgaard 1988). Biologists then discovered a small parasitic wasp (*Epidinocarsis lopezi*) that was a biological control agent of the mealybug in its home range of South America. The parasitic wasp was intentionally introduced as a biological control agent and, by 1987, the wasp had established in 90% of the cassava-growing regions of Africa (Norgaard 1988). Losses caused by mealybug were almost immediately brought under control, and the project soon after earned the World Food Prize for saving millions of lives and billions of dollars across the African continent (Leybold-Johnson 2011). Other examples similarly illustrate how invasive or introduced species can jeopardize food security (**Figure 2 and ESM no. 5-6**).

Natural predators, parasites, and pathogens often control pests of agricultural crops, and extirpation (i.e., local extinction) as well as population declines of these animals provide another example of ecological disruptions that affect food security. The pest control services of predatory bugs alone is worth an estimated $50-196 billion per year globally (Costanza et al. 2014), surpassing the gross domestic product of entire countries like Tunisia, Paraguay, or Bahrain. But many of the insects that provide pest control services are in global decline, with some countries reporting >80% population decay over the past few decades (Hallmann et al. 2017; Wagner et al. 2021). Pollination is another key service in agriculture and much recent attention has focused on how this service is jeopardized by the worldwide decline in insect pollinators. Wild and domesticated pollinators are essential to global food security because the fruit, vegetable, and seed production of the 87 leading food crops that collectively represent 35% of the total global food production are partially or wholly dependent upon animal pollination (Klein et al. 2007). Pollinators are responsible for up to 40 percent of the world’s supply of nutrients (Eilers et al. 2011), especially in children where 69% or more of vitamin A in diets comes from fruits and vegetables that depend on pollinators (Eilers et al. 2011). Yet, colony collapse disorder has eliminated 30% or more of colonies of domesticated honeybees (*Apis mellifera*) in many parts of the world (Evans & Chen 2021). Wild insect pollinators like native bees, butterflies, and moths are experiencing large population declines as well (IPBES 2019), with one recent study suggesting 20% of butterfly species have gone extinct and surviving species have experienced a 50% population decline, on average, throughout Europe (Warren et al. 2021). Although the decline of pollinators has yet to be directly linked to famine or starvation, recent studies suggest that even a 3% to 5% declines in fruit, vegetable, and nut production caused by inadequate pollination could lead to 427,000 deaths annually due to diseases associated with nutrient deficiencies (Smith et al. 2022). As a result, several national intelligence bodies have begun to consider how pollinator declines might imapct local fruit and vegetable supplies, leading to malnutrition, starvation, and social unrest (Chaplin-Kramer et al. 2014; Schoonover 2022).

In contrast to agriculture, overexploitation is a common pathway of ecological disruption in food systems based on wild capture fisheries or bushmeat for protein. More than 3 billion people rely on wild capture fisheries for 20% or more of their daily intake of animal protein (FAO 2022, 2024). Global demand for fish has led to an estimated one-third of all ocean fisheries being overexploited, where capture exceeds the potential for regeneration (Ritchie & Roser 2024). Fisheries overexploitation has jeopardized food supplies historically, leading to several domestic and international disputes that nearly or actually erupted into armed conflict. For example, in the 1970s an international conflict broke out between British and Icelandic fishermen over the Icelandic cod fisheries, which had been depleted by overfishing (**Figure 2 and ESM no. 7**) (Steinsson 2016). When British trawlers continued to fish for cod even after a ban was put into place by the Icelandic government, confrontations led to the British Royal Navy being dispatched to protect British trawlers that were being threatened by Icelandic gunboats. The resulting “Cod War” broke diplomatic relations between Iceland and the United Kingdom and led to threats by Iceland to close a U.S. military base and withdraw from the North Atlantic Treaty Organization, NATO (Steinsson 2017). A similar dispute over exploited fisheries led to conflict between Canada and Spain in the Northwest Atlantic Ocean in the 1990s (**Figure 2 and ESM no. 8**).

More recently, China’s rampant overfishing of its own coastal waters has contributed to expanded fishing operations in the South China Sea where it has used fishing fleets to assert new territorial claims (**Figure 2 and ESM no. 9**) (Zhang 2024). Indonesia has responded by blowing up more than 40 Chinese vessels accused of fishing illegally in its exclusive economic zone and stealing more than $4 billion per year in Indonesian profits (Tennesen 2018). The United States, Australia, New Zealand and Britain have stepped up naval patrols for illegal fishing among Pacific Island nations, leading to conflicts with Chinese Coast Guard vessels that routinely escort fleets illegally entering other countries' exclusive economic zones (Needham & Craymer 2024). Additionally, China's distant-water fishing fleets have increased their presence along the coasts of Africa (Paleczny et al. 2015) and South America (Montecalvo et al. 2023), depleting fish stocks and fueling political instability.

Wild animals, including insects, amphibians, reptiles, birds, fish, crustaceans, molluscs, rodents, and larger mammals, are the primary source of protein for people living in some countries. For example, hunting and collecting wild animals for meat makes up about 40% of the protein consumption in Botswana and about 80% in the Democratic Republic of Congo. Throughout the world, 130 million tons of fish, crustaceans, and molluscs, mainly wild species, are harvested each year, with 100 million tons constituting marine catch and 30 million tons constituting freshwater catch (Chivian & Bernstein 2008). Overexploitation of wild sources of protein not only contributes to food insecurity in several parts of the world (Cawthorn & Hoffman 2015; Fa et al. 2003), but also serves as a primary route for zoonotic diseases that are responsible for global pandemics (Jones et al. 2008) —another form of ecological disruption we discuss further in the section on Public Health.

Water scarcity

Like food security, water security is a basic need for sustaining human life and is thus inextricably tied to social and political stability. Approximately 3.5 million people die each year due to inadequate water supply, sanitation, and hygiene. As such, conflict over water resources has been a persistent problem in various forms for thousands of years (Gleick 1993; Gleick 2019). But the number of water-related conflicts has increased exponentially throughout much of the 21st century (**Figure 4**). In 2023, 347 water-related conflict events were recorded, representing a 50% increase over 2022. Water conflicts are expected to grow even further in the coming decades as more than half of the world's population is likely to face water shortages by 2032 (Vass 2002). North Africa, the Middle East, Central Asia, and South Asia all face a combination of circumstances that create serious concerns for water-related national security risks (NIC 2012). In these regions, the scarcity of water has routinely escalated into violence, humanitarian crises, and mass migrations that all have potential to impact national security (Busby 2017; Gleick 1993).

Most experts recognize that water shortages can be a problem for national security, and that these shortages often arise from water diversions (e.g., dams, irrigation, or water infrastructure projects). In fact, water diversions are often used as a weapon during conflict, such as when participants damage or assume control over water infrastructure to manipulate flows, contaminate or poison supplies (Gleick 2017; NIC 2012; von Lossow 2016). A central strategy of the Islamic State (ISIS) has been to gain control over large dams on the Tigris and Euphrates Rivers and use them to create water shortages, generate floods, and threaten hydropower supplies (von Lossow 2016). The potential dire consequences of ISIS control of Iraq's largest dam (Mosul, 2014) and Syria's largest dam (Tabqa, 2017) prompted the U.S. military to intervene to prevent mass devastation (O'Connor ; von Hein 2016; von Lossow 2016).

While the influence of physical water diversions on conflict dynamics is well understood, the effects of biological changes on hydrologic regimes have received far less attention. Changes to vegetation, biodiversity, or ecosystem functioning can significantly affect freshwater availability and distribution, intensifying water scarcity for both agriculture and human consumption. One key mechanism through which biology shapes hydrology is plant transpiration -- the movement of water from the soil water table, through a plant, with subsequent loss of water vapor from stomata in the leaves. Global water budgets show that roughly 40% of the precipitation that falls on Earth's terrestrial surface each year is due to plant transpiration (Schlesinger & Jasechko 2014). This proportion is even higher in densely vegetated regions; in tropical rainforests, for example, up to 70% of atmospheric moisture and subsequent rainfall can be traced to plant transpiration (Schlesinger & Jasechko 2014).

Because plant transpiration can control regional climate and precipitation (Wright et al. 2017) as well as the recharge of groundwater and surface aquifers (Huntington 2006), land-use practices that destroy vegetation (e.g., deforestation) can have dramatic impacts on water available to people for drinking and irrigation (Brown et al. 2005). For example, from 2014 to 2017, a prolonged lack of rain triggered a severe drought across southeastern Brazil, impacting major metropolitan areas —including São Paulo, home to more than 20 million people (Millington 2018). While the water crisis in São Paulo was connected to an El Niño–Southern Oscillation (ENSO) event in the Pacific Ocean, conditions were intensified by rampant deforestation throughout the Amazon Basin that reduced plant transpiration, leading to significant reductions in local precipitation (Bagley et al. 2014; Marengo & Espinoza 2016; Nazareno & Laurance 2015). Millions of São Paulo residents were subjected to water rationing and daily water shutoffs during the drought, leading to potable water shortfalls that most affected people in poorer districts who lacked the resources to buy bottled water or water storage tanks (**Figure 2 and ESM no. 10**). Water shortages led to social unrest and protests against the government that sometimes turned violent (**Figure 3B**). Similar water-related protests linked to deforestation have taken place in Venezuela, Colombia, and Peru (PI 2024).

In addition to influencing water quantity, ecological disruptions can degrade water quality, rendering it unsuitable for drinking, irrigation, and aquaculture. One of the most widespread causes of degraded water quality worldwide is nutrient overloading, particularly from nitrogen and phosphorus compounds. Overloading typically results from poorly managed agricultural systems, where excessive fertilizer runoff enters freshwater and coastal ecosystems, fuelling harmful algal blooms (HABs). These blooms deplete oxygen levels and can trigger large-scale die-offs of aquatic life. Globally, HABS have led to an estimated 245,000 km^2 of anoxic "dead zones" in 400+ coastal habitats around the world (Diaz & Rosenberg 2008). Dead zones often drive failures of commercial and recreational fisheries and closures of aquaculture farms (Brown et al. 2020; Lenzen et al. 2021; Mardones et al. 2020). For example, in 2016 an exceptionally large bloom of dinoflagellates (a "red tide") hit the coast of Chile, causing massive deaths of fishes and mollusks and destroying 100,000 MT of Chile's salmon production representing ca. 12% of Chile's annual production (**Figure 2 and ESM no. 11**) (Díaz et al. 2019). Fishermen staged protests and established roadblocks demanding government assistance. Industry sources estimated losses of US$9 million/day in sales due to the roadblocks. The drop in production increased the average price for Chilean salmon in the United States by 54% going from $3.5 USD/lb. in January MY2016 to $4.97 USD/lb. in June MY2016 (Arriagada 2019). Other examples illustrate how ecological disruptions degrade water quality, leading to water scarcity, economic hardships, and civil unrest (**Figure 2 and ESM no. 12-14**).

Public health

A healthy population is essential to the functioning, safety, and security of any nation (Katsos 2017b). Protecting public health not only saves lives, it also sustains public trust in government institutions (Katsos 2017b). Public health emergencies can rapidly escalate into national security threats by endangering citizens, undermining military readiness, and exacerbating social fragmentation, economic decline, and political instability (NIE 2000).

Infectious disease outbreaks, such as pandemics, are among the most common and destabilizing sources of public health emergencies, with far-reaching consequences for national and global security. Worldwide, infectious diseases are the leading cause of death and, in the last 25 years, at least twenty known diseases have reemerged or spread (e.g., tuberculosis, malaria, Ebola) and at least thirty previously unrecognized diseases have emerged for which no cures are available (e.g., HIV/AIDS, hepatitis C, Nipah virus). Zoonotic diseases, which account for more than 60% of the 1,415 pathogens known to infect humans, are caused by viruses, fungi, and parasites that spill over from animals to humans. These diseases have driven some of the most devastating pandemics in history (e.g., bubonic plague, HIV) and continue to fuel the rise of Emerging Infectious Diseases (EIDs) such as Zika (Uganda), Ebola (West Africa), SARS (China), Avian influenza (China), Brucellosis (Malta), and West Nile virus (Uganda). Globalization has substantially accelerated the spread of EIDs, enabling them to reach larger populations at faster rates, increasing the risk of global pandemics (Jones et al. 2008).

Ecological disruptions influence zoonotic disease in many ways, including via increased human-wildlife contact, wildlife trade and consumption, disruption of host and vector ecology (e.g. via loss of predators), agricultural intensification that crowds livestock hosts together, and by interfering with the dilution effect by which alternate hosts tend to reduce pathogen and parasite transmission in diverse natural ecosystems. Human-wildlife conflict, particularly through consumption of wild animals as bushmeat, facilitates transfer of zoonoses that have direct transmission from animals to humans. A recent example is the SARS-CoV-2 coronavirus responsible for the 2019 COVID-19 global pandemic (**Figure 2 and ESM no. 15**). Epidemiological and genetic studies strongly suggest that SARS-CoV-2 first spilled over to humans from wild animals sold in the Huanan live animal market in Wuhan, China (Hao et al. 2022; Holmes et al. 2021). Although the specific animal that served as the original host is still under investigation, virologists point to bats and other mammals as likely natural reservoirs of SARS-CoV-2, given that they harbor other coronaviruses with closely related genomes (Singh & Yi 2021). Following the zoonotic spillover event, the pathogen spread rapidly across the globe, killing more than 7 million people and causing acute disruptions not only to global markets and supply chains but also to social cohesion and political stability (Verma & Prakash 2020). Countries with high COVID-19 mortality rates had elevated levels of civil disorder and fatalities caused by political violence as citizens lost trust in the ability of governments to protect them (Bloem & Salemi 2021; Farzanegan & Gholipour 2023). Many other zoonotic diseases caused by human-wildlife contact (e.g., Zika, Ebola, SARS, and West Nile) have similarly generated international crises (**Figure 2 and ESM no. 16**) (**Figure 3C**) (Everard et al. 2020).

Ecological disruptions can also increase the abundance of disease vectors. Roughly 17% of zoonotic diseases are transmitted to humans via an intermediate ‘vector’ (e.g., ticks, fleas, or mosquitoes) that carries the disease. Vector-borne diseases cause >1 million deaths annually. Malaria, once thought to be under control and even eradicated in some places, reemerged over the past 50 years as one of the world’s deadliest infectious diseases. The World Health Organization estimated that in 2015, 212 million people contracted malaria, and half a million died; of those who died, 70% were under 5 years old (WHO 2016). A complex set of factors has contributed to the reemergence and spread of malaria, including deforestation, human migration, poorly designed irrigation and water storage systems, inadequate housing, poor sanitation, and drug and insecticide resistance (Martens & Hall 2000; NIE

2000; Sachs & Malaney 2002). Some of the strongest cases relating the prevalence of malaria to ecological disruption come from the Amazon region of South America. In the northern Amazon region of Peru (**Figure 2 and ESM no. 17**), strong population growth in the late 20th century prompted rural expansion into previously unsettled land. Subsistence agriculture and road development drove deforestation, which peaked from 1983-1995. At the same time, the area experienced a dramatic rise in malaria, which had previously been low following eradication efforts in the 1960s. Studies have shown that ecological alterations from progressive deforestation promoted the presence and increased the biting rate of South America's most significant malaria vector, *Anopheles darlingi*. Changes in shade cover, vegetation, and hydrology resulting from deforestation and road construction, combined with the creation of artificial water bodies such as wells and fish farms, created ideal habitat conditions for the disease vector to thrive (Vittor et al. 2006; Vittor et al. 2009). In the Brazilian Amazon, a similar increase in malaria and reappearance of *A. darlingi* was attributed to urban encroachment on surrounding forest lands (Póvoa et al. 2003).

Disaster mitigation

Natural disasters pose a significant threat to national security (NIC 2016). Their impacts often lead to cascading social, economic, and political consequences, as humanitarian crises emerge from disruptions in food production and availability, widespread power outages, contaminated or reduced water supplies, disease outbreaks, property destruction, and loss of life. The most vulnerable areas are often the most densely populated, increasing likelihood of major societal disruptions from natural disasters (NIC 2016). Disasters can spur migrations, both within and between nationas, that strain relations and overwhelm the host country's infrastructure and resources. In areas with existing risk factors for unrest, natural disasters can heighten social and political tensions and contribute to large-scale instability, as well as the need for foreign aid, disaster relief, or military action (Busby 2007; NIC 2016).

Natural disasters are expected to increase in the coming century as climate change raises the frequency and severity of droughts, floods, fires, heat waves, and intense tropical storms (IPCC 2007). Ecological disruptions can amplify the impacts of natural disasters by weakening the resilience of ecosystems and increasing vulnerability to harm, ultimately raising the risk of loss of life and property. For example, flooding— the world's most frequent natural disaster – kills thousands of people each year. The incidence of flooding has increased globally from the 1950s to the present, which can be partly attributed to the concentration of people living in coastal areas and to the destruction of wetlands, mangrove forests, floodplains, and other vegetated ecosystems that serve as natural 'sponges' for floodwater and shock absorbers that cushion the impact of coastal storms (Barbier et al. 2008; Ewel 2010). Catastrophic floods and resulting landslides in Bangladesh, India, the Philippines, Thailand, and Central America have been associated with extensive logging in upstream watersheds (**Figure 2 and ESM no. 18**) (Kundzewicz et al. 2014). Destruction of coastal mangrove forests is partially responsible for the severe devastation of the 2004 Indian Ocean tsunami, in which at least 250,000 people died (**Figure 2 and ESM no. 19**). The loss of wetlands and floodplain habitats has amplified flooding and property damage in several major U.S. disasters. These include Hurricane Katrina in 2005, which devastated New Orleans (**Figure 2 and ESM no. 20**); Hurricane Sandy in 2012, which caused $69 billion in damage along the New Jersey coast; and Hurricane Harvey in 2017, which inflicted US$125 billion in damage across Houston (Arkema et al. 2013; Costanza et al. 2021). A 2017 study commissioned by the insurance industry found that up to one-third of economic losses resulting from coastal storms could have been mitigated by expanding wetlands and natural flood barriers (Narayan et al. 2017).

Wildfires illustrate how ecological disruptions can elevate security risks and threaten to undermine domestic stability, not only through economic damage but also by straining emergency response systems, displacing communities, and eroding public trust in institutions. In 2024, California experienced a pronounced fire season that saw over 8,000 wildfires burn more than a million acres of land (**Figure 2 and ESM no. 21**). These fires destroyed or severely damaged 148 structures, caused over $3.5 billion in agricultural losses, and led to a $5 billion decline in tourism revenue. While multiple factors contributed to the fires, including weather conditions, climate change, and human ignition (accidental and arson), another key factor is the transformation of California's landscape by more than 100 invasive plant species. These plants have significantly increased the frequency and intensity of burns, making them more severe than they would have been under native vegetation regimes. Highly flammable trees such as Eucalyptus, introduced from Australia in the mid-19th century, and Salt cedar, introduced from Eurasia in the 1800s, are now widespread in California. Their oily leaves and papery bark ignite easily and help spread fire across landscapes (Brooks & Pyke 2000; Keeley 2000; Wolf & DiTomaso 2016). In addition, California is home to hundreds of invasive grass species from Europe that dry rapidly after their short life cycles, creating dense fuel beds that intensify wildfire risk (Fusco et al. 2019).

Environmental crime

Environmental crime poses a significant and growing threat to national security. Its total estimated value ranges from US$91 to US$258 billion annually, making it one of the largest criminal sectors globally, ranking just below drug trafficking (US$344 billion) and counterfeiting (US$288 billion), and on par with human trafficking (US$157 billion) (Nellemann et al. 2016). Among the various forms of environmental crime, illegal wildlife trade ranks as one of the most lucrative, with an estimated value between US$7 and US$24 billion per year (Sas-Rolfes et al. 2019). This puts illegal wildlife trade on par with illegal mining (US$12–48 billion), logging (US$9–26 billion), and fishing (US$11–24 billion) (Nellemann et al. 2016).

The primary driver of illegal wildlife trade is the exceptionally high black-market prices placed on rare species and their body parts. Tigers (*Panthera tigris*), whose body parts are used in traditional medicine, folk remedies, and increasingly as status symbols in some Asian cultures, can sell for up to US$50,000 each on the black market. Musk glands from musk deer, sought after for use in traditional medicines and high-end perfumes, can command prices as high as US$250,000 each. Rhinoceros horns, mistakenly believed to have medicinal or aphrodisiac properties, are the world's most valuable animal appendage, fetching up to US$65,000 per kg.

Poaching, illegal logging, and other forms of environmental crime are known to generate revenue for organized criminal networks, drug cartels and, in some cases, armed non-state actors. These activities often bypass local and international legal frameworks, fueling illicit trafficking and weapons distribution networks that can undermine governance and regional stability. In Somalia, for example, the jihadist group Al-Shabaab has reportedly financed its operations in part through illegal charcoal exports (**Figure 2 and ESM no. 22**). Charcoal produced through illegal logging and deforestation has become a lucrative sector in Somalia's informal economy, and especially important for Al-Shabaab (Petrich 2022). Profits from environmental crime have helped fund the group's operations, including bombings and suicide attacks targeting Somali government officials, peacekeepers, and perceived international allies of the Federal Government of Somalia. Al-Shabaab has also been responsible for major terrorist attacks outside Somalia, including the 2013 Westgate mall attack in Nairobi that killed sixty-seven people, and the 2015 Garissa University massacre in which 150 students were killed. These actions have had destabilizing effects across the Horn of Africa (Verhoeven 2018) and serve to illustrate how environmental crime intersects with terrorist financing.

Drug trafficking and cartel violence in Mexico offer another example of how environmental crime can fuel broader illegal activity and instability (**Figure 2 and ESM no. 23**). Since it began in 2006, Mexico's drug war has evolved into a prolonged conflict that has claimed hundreds of thousands of lives, fueled organized crime and terrorist networks, and created cross-border tensions with the United States and other counties. In response to intensified state crackdowns and competition from rival groups, many drug cartels adapted by diversifying their activities beyond narcotics. Increasingly, they turned to environmental crimes, including the theft of natural resources, poaching, and illegal deforestation, as alternative sources of revenue and territorial control. For example, some drug cartels shifted operations to illegal harvest of the totoaba (*Totoaba macdonaldi*), a species of marine fish endemic to Mexico's Gulf of California (Martínez & Alonso 2021). The swim bladder of the totoaba, commonly referred to as "maw", is highly prized in parts of Chinese cuisine a traditional medicine, where it is erroneously believed to treat fertility, circulatory, and skin problems (Morell 2017). Maw can fetch high prices that exceed $11,000 per pound on the black market, and several multi-million dollar seizures have been made recently (Customs 2022; Mark 2023). The activities of many other drug cartels and terrorist organizations are funded, in whole or part, by environmental crime (**Figure 2 and ESM no. 24-26**).

Common themes

The ecological foundations of national security have been underappreciated, in part, because ecological disruptions are "actorless threats" that lie outside the traditional 20th century doctrines on what constitutes national security. But recently, the 20th century doctrines have started to consider a broader landscape of threats that include, among others, anthropogenic forms of global environmental change. While most sovereign nations have considered anthropogenic climate change a security risk for decades, the role of ecological disruptions to the biological composition of ecosystems are just beginning to receive attention in national security planning (Pirages 2013; Schoonover et al. 2021). Ecological disruptions are also of growing interest in sustainable development initiatives at national and international scales. In 2020, for example, environmental concerns dominated the top long-term risks identified by the World Economic Forum for the first time (WEF 2020a). In 2024/2025 the top three decadal risks were judged to be extreme weather events, critical change to earth systems, and biodiversity loss and ecosystem collapse, outranking involuntary migration, cyber insecurity, and societal polarization (WEF 2024, 2025). Clearly, the older traditional view of national security, which focuses on military strength, secure borders, and state actors competing for land, resources, and economic market shares, is dangerously incomplete. National security must also include critical dimensions of human safety and well-being like protection from poverty, hunger, disease, natural disasters, and political violence (Bajpai 2003; UNDP 1994). These aspects of security often depend on the ability of a nation to maintain productive and stable ecosystems, resilient biological communities, and sustainable access to natural resources that underlie basic human needs (Díaz et al. 2018).

In most nations, governments play the most significant role in maintaining the natural resources required to meet basic human needs and prevent ecological disruptions. Collectively referred to as "natural infrastructure," the ecosystems and biological communities that underlie human well-being and security are analogous to a nation's physical infrastructure (**Figure 5**). Physical infrastructure like communication networks, electrical grids, and transportation networks control key aspects of economic, energy, food, and cyber-security. Physical infrastructure is needed for societies to thrive, as is obvious when the infrastructure is destroyed by increasingly frequent and intense disasters, cyberwarfare, and/or terrorism. While the importance of physical infrastructure to national security is well-accepted, we have shown that the role of natural infrastructure can also be critically important and warrants greater attention in security planning.

Loss of natural infrastructure tends to disproportionately impact poor countries. While developed nations are not immune to the consequences of infrastructure decay, wealthy nations are better able to (partially) buy their way out of ecological disruptions. For example, they often compensate with 'hard' engineering projects that compensate for disrupted natural processes using manufactured structures or materials. Wealthy nations can also better compensate for ecological disruptions by importing goods and services from elsewhere (e.g., water, food, energy, etc.). In contrast, developing nations typically cannot buy their way out of natural infrastructure decay or import the services lost. This compounds the vulnerability of the large populations of people living in poor nations that rely heavily on natural infrastructure for their food, water, building supplies, medicines, and livelihoods. When their natural infrastructure is destroyed or degraded, people fall deeper into poverty and desperation, triggering social and political instability, and often leading to environmental refugees and other humanitarian crises that spill across borders (**Figure 3**).

Loss of natural infrastructure can also magnify other threats to national security. In fact, ecological disruptions have sometimes been characterized as "threat multipliers" that make existing problems worse, or that push social and political unrest into the realm of security threats. For example, while climate change can affect national security directly (e.g., hurricanes), it can also interact with ecological disruptions, causing their impact on national security to become greater than that of either acting alone (**Figure 6**). The devastating 2024 fires in Los Angeles, California serve as an example. While the magnitude and intensity of the fires were partly driven by climate change, they were made far worse by the abundance of highly flammable invasive species like Eucalyptus and European grasses. Indeed, many impacts of climate change on national security are mediated through biological links whereby e.g., changing air temperature degrades biological systems through loss of agriculture or geographic shifts in commercial fisheries and, in turn, lead to social problems that cause even greater instability.

It has long been known that ecosystems and their biological communities provide important goods and services to people (Daily 1997). These have been collectively referred to as *ecosystem services* or *nature's contributions to people* (Díaz et al. 2018). The role that nature plays in enhancing national security can be considered another type of service that natural and managed ecosystems provide to society. As such, national security could and should be considered a goal of ecosystem management alongside other ecosystem services. Conservation, restoration, and ecological design are complementary forms of natural resource management that are used to manage ecosystems and their biological communities that provide important ecosystem services (Cardinale & Murdoch 2025). Conservation, which seeks to protect the natural infrastructure that currently exists, is usually the most effective and cost-efficient form of resource management. But it is an increasingly limited option in the modern era where so many ecosystems, biological communities, and ecosystem services have already been degraded or lost. Restoration is the adaptation strategy used to reverse the negative consequences of decaying natural infrastructure. Restoration practices that use 'soft engineering' -- the use of natural materials and principles of ecology to reverse environmental degradation – can be quite effective at restoring the services provided by natural infrastructure (Morris et al. 2018; Palmer et al. 1997). Examples include restoration of wetlands to improve water storage and flood protection (Arkema et al. 2013), or use of native plant communities to stabilize hillslopes that are prone to landslides or beaches and dunes that are prone to erosion from storms (Sigren et al. 2014; Stokes et al. 2014). Conservation and restoration can be complimented by principles of ecological design that are used to maximize the benefits of natural infrastructure in human-dominated habitats like urban environments (Cook et al. 2025). Examples include urban food gardens that enhance local food security (Barthel & Isendahl 2013), or use of green infrastructure to mitigate the impact of natural disasters (Chang & Mori 2021; Onuma & Tsuge 2018).

It is troubling that, just as we are coming to appreciate the key roles of nature for maintaining natural security, governments of some rich and otherwise well-informed nations (e.g., the United States) are actively dismantling the agencies, scientific expertise, and investments necessary to understand changes in, and therefore safeguard, critical natural infrastructure. Weakening these institutions undermines a nation's ability to meet the basic needs of its citizens, fueling grievances that erode trust in government and heighten instability within and among nations. Avoiding this fate requires that citizens demand leaders who recognize natural infrastructure as a public good and cornerstone of personal and social well-being, including national security, and reclaim the narrative to protect their well-being and the stability of society. The question is not whether natural infrastructure is important to security but whether the public will prioritize its importance and choose leaders who also recognize natural infrastructure as critical to national security and the well-being of society.

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References

Arkema, KK, et al. (2013) Coastal habitats shield people and property from sea-level rise and storms. Nature Climate Change 3: 913-918. https://doi.org/10.1038/nclimate1944

Arriagada, N. (2019). *Adaptive capacity in social-environmental crisis: The case of the red tide/salmon farming conflict in Chiloé (Chile)* [Dissertation, University of British Columbia]. British Columbia, Canada. https://open.library.ubc.ca/collections/24/items/1.0380286

Babar, TK (2023) Risks of Deserts Locust and Its Mitigation. In: Ahmed M & Ahmad S (eds) Disaster Risk Reduction in Agriculture. Springer, Singapore, pp 361-392

Bagley, JE, et al. (2014) Drought and deforestation: Has land cover change influenced recent precipitation extremes in the Amazon? Journal of Climate 27: 345-361. https://doi.org/10.1175/JCLI-D-12-00369.1

Bajpai, K (2003) The idea of human security. International Studies 40: 195-228. DOI:10.1177/002088170304000301

Barbier, EB, et al. (2008) Coastal ecosystem-based management with nonlinear ecological functions and values. Science 319: 321-323. DOI: 10.1126/science.1150349

Bargout, RN, & Raizada, MN (2013) Soil nutrient management in Haiti, pre-Columbus to the present day: Lessons for future agricultural interventions. Agriculture & food security 2: 11. https://doi.org/10.1186/2048-7010-2-11

Barthel, S, & Isendahl, C (2013) Urban gardens, agriculture, and water management: Sources of resilience for long-term food security in cities. Ecological Economics 86: 224-234. https://doi.org/10.1016/j.ecolecon.2012.06.018

Berazneva, J, & Lee, DR (2013) Explaining the African food riots of 2007–2008: An empirical analysis. Food Policy 39: 28-39. https://doi.org/10.1016/j.foodpol.2012.12.007

Bloem, JR, & Salemi, C (2021) COVID-19 and conflict. World Development 140: 105294. https://doi.org/10.1016/j.worlddev.2020.105294

Brooks, ML, & Pyke, DA (2000) Invasive plants and fire in the deserts of North America. Proceedings of the Invasive Species Workshop: The Role of Fire in the Control and Spread of Invasive Species. San Diego, California.

Brown, AE, et al. (2005) A review of paired catchment studies for determining changes in water yield resulting from alterations in vegetation. Journal of Hydrology 310: 28-61. https://doi.org/10.1016/j.jhydrol.2004.12.010

Brown, AR, et al. (2020) Assessing risks and mitigating impacts of harmful algal blooms on mariculture and marine fisheries. Reviews in Aquaculture 12: 1663-1688. https://doi.org/10.1111/raq.12403

Busby, J (2017) Water and U.S. National Security. Council on Foreign Relations, New York City, New York

Busby, JW (2007) Climate Change and National Security: An Agenda for Action. (CRS No. 32). Greenberg Center for Geoeconomic Studies, New York City, New York

Cardinale, BJ, & Murdoch, JD (2025) Chapter 17 - The Future of Conservation. Conservation Biology. Oxford University Press, New York, NY, pp 553-569

Cawthorn, D-M, & Hoffman, LC (2015) The bushmeat and food security nexus: A global account of the contributions, conundrums and ethical collisions. Food Research International 76: 906-925.

Chang, C-W, & Mori, N (2021) Green infrastructure for the reduction of coastal disasters: a review of the protective role of coastal forests against tsunami, storm surge, and wind waves. Coastal Engineering Journal 63: 370-385. 10.1080/21664250.2021.1929742

Chaplin-Kramer, R, et al. (2014) Global malnutrition overlaps with pollinator-dependent micronutrient production. Proceedings of the Royal Society B: Biological Sciences 281: 20141799. doi:10.1098/rspb.2014.1799

Chivian, E, & Bernstein, A (2008) Sustaining Life: How Human Health Depends on Biodiversity. Oxford University Press, New York, NY

Cook, EM, et al. (2025) Nature-based solutions for urban sustainability. Proceedings of the National Academy of Sciences 122: e2315909122. doi:10.1073/pnas.2315909122

Costanza, R, et al. (2021) The global value of coastal wetlands for storm protection. Global Environmental Change 70: 102328. https://doi.org/10.1016/j.gloenvcha.2021.102328

Costanza, R, et al. (2014) Changes in the global value of ecosystem services. Global Environmental Change 26: 152-158. http://dx.doi.org/10.1016/j.gloenvcha.2014.04.002

Customs, US (2022, October 17) Second Largest Seizure in Arizona of Protected Totoaba Swim Bladders Discovered in San Luis, Arizona Port of Entry https://www.cbp.gov/newsroom/local-media-release/second-largest-seizure-arizona-protected-totoaba-swim-bladders

Daily, GC (1997) Nature's Services: Societal Dependence on Natural Ecosystems. Island Press, Washington, D.C.

Díaz, PA, et al. (2019) Impacts of harmful algal blooms on the aquaculture industry: Chile as a case study. Perspectives in Phycology. http://doi.org/10.1127/pip/2019/0081

Diaz, RJ, & Rosenberg, R (2008) Spreading dead zones and consequences for marine ecosystems. Science 321: 926-929. DOI: 10.1126/science.1156401

Díaz, S, et al. (2018) Assessing nature's contributions to people. Science 359: 270-272. 10.1126/science.aap8826

Duffy, E, et al. (2017) Biodiversity effects in the wild are common and as strong as key drivers of productivity. Nature 549: 261-264. https://doi.org/10.1038/nature23886

Eilers, EJ, et al. (2011) Contribution of pollinator-mediated crops to nutrients in the human food supply. PLoS One 6: e21363. 10.1371/journal.pone.0021363

Evans, JD, & Chen, Y (2021) Colony Collapse Disorder and Honey Bee Health. In: Kane TR & Faux CM (eds) Honey Bee Medicine for the Veterinary Practitioner. Wiley Blackwell, Hoboken, New Jersey, pp 229-234

Everard, M, et al. (2020) The role of ecosystems in mitigation and management of Covid-19 and other zoonoses. Environmental Science & Policy 111: 7-17. https://doi.org/10.1016/j.envsci.2020.05.017

Ewel, KC (2010) Appreciating tropical coastal wetlands from a landscape perspective. Frontiers in Ecology and the Environment 8: 20-26. https://doi.org/10.1890/080090

Fa, JE, et al. (2003) Bushmeat and food security in the Congo Basin: linkages between wildlife and people's future. Environmental Conservation 30: 71-78. doi:10.1017/S0376892903000067

FAO (2022) The State of World Fisheries and Aquaculture 2022: Towards Blue Transformation. Food and Agriculture Organization of the United Nations, Rome, Italy

FAO (2023) Report of the FAO Commission for Controlling the Desert Locust in South-West Africa. Food and Agriculture Organization of the United Nations, Rome, Italy

FAO (2024) The State of World Fisheries and Aquaculture 2022: Blue Transformation in Action. Food and Agriculture Organization of the United Nations, Rome, Italy

Farzanegan, MR, & Gholipour, HF (2023) COVID-19 fatalities and internal conflict: Does government economic support matter? European Journal of Political Economy 78: 102368. https://doi.org/10.1016/j.ejpoleco.2023.102368

Fusco, EJ, et al. (2019) Invasive grasses increase fire occurrence and frequency across US ecoregions. Proceedings of the National Academy of Sciences 116: 23594-23599. https://doi.org/10.1073/pnas.1908253116

Geist, H (2017) The Causes and Progression of Desertification. Ashgate Publishing Limited, Hants, United Kingdom

Gleick, P (2017, June 15) Water and U.S Natonal Security War Room, United States Army College. https://warroom.armywarcollege.edu/articles/water-u-s-national-security/

Gleick, PH (1993) Water and conflict: Fresh water resources and international security. International Security 18: 79-112. https://doi.org/10.2307/2539033

Gleick, PH (2019) Water as a weapon and casualty of armed conflict: A review of recent water-related violence in Iraq, Syria, and Yemen. WIREs Water 6: e1351. https://doi.org/10.1002/wat2.1351

Hallmann, CA, et al. (2017) More than 75 percent decline over 27 years in total flying insect biomass in protected areas. PLoS One 12: e0185809. 10.1371/journal.pone.0185809

Hao, YJ, et al. (2022) The origins of COVID-19 pandemic: A brief overview. Transboundary and Emerging Diseases 69: 3181-3197. 10.1111/tbed.14732

Hedges, SB, et al. (2018) Haiti's biodiversity threatened by nearly complete loss of primary forest. Proceedings of the National Academy of Sciences 115: 11850-11855. doi:10.1073/pnas.1809753115

Hendrix, CS (2016) When Hunger Strikes: How Food Security Abroad Matters for National Security at Home. The Chicago Council on Global Affairs, Chicago, Illinois

Hendrix, CS, et al. (2023) Climate change and conflict. Nature Reviews Earth & Environment 4: 144-148. 10.1038/s43017-022-00382-w

Holmes, EC, et al. (2021) The origins of SARS-CoV-2: A critical review. Cell 184: 4848-4856. https://doi.org/10.1016/j.cell.2021.08.017

Hughes, AC, & Grumbine, RE (2023) The Kunming-Montreal Global Biodiversity Framework: What it does and does not do, and how to improve it. Frontiers in Environmental Science 11: 1281536.

Huntington, TG (2006) Evidence for intensification of the global water cycle: Review and synthesis. Journal of Hydrology 319: 83-95. https://doi.org/10.1016/j.jhydrol.2005.07.003

ICRC (2022) Food Security and Armed Conflict. International Committee of the Red Cross, Geneva, Switzerland

IPBES (2019) Global assessment report on biodiversity and ecosystem services of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services. Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services, Bonn, Germany

IPCC (2007) Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, New York City, New York

Jackson, MC, et al. (2016) Net effects of multiple stressors in freshwater ecosystems: A meta-analysis. Global Change Biology 22: 180-189. https://doi.org/10.1111/gcb.13028

Jones, KE, et al. (2008) Global trends in emerging infectious diseases. Nature 451: 990-993. http://www.nature.com/nature/journal/v451/n7181/suppinfo/nature06536_S1.html

Jones, N, & Sullivan, JP (2020) Climate change and global security. Journal of Strategic Security 13: 3-17.

Katsos, GE (2017a) The U.S. Government's Approach to Food Security. Joint Force Quarterly 87: 112-121.

Katsos, GE (2017b) The US Government's Approach to Health Security. Joint Force Quarterly 85: 66-75.

Keeley, JE (2000) Fire and invasive species in Mediterranean-climate ecosystems of California. Proceedings of the invasive species workshop: The role of fire in the control and spread of invasive species. San Diego, California.

Kennedy, N, et al. (2016) Adoption of soil and water conservation practices in central Haiti. Journal of Soil and Water Conservation 71: 83-90. https://doi.org/10.2489/jswc.71.2.83

Klein, AM, et al. (2007) Importance of pollinators in changing landscapes for world crops. Proceedings of the Royal Society B-Biological Sciences 274: 303-313. https://doi.org/10.1098/rspb.2006.3721

Kundzewicz, ZW, et al. (2014) Flood risk and climate change: global and regional perspectives. Hydrological Sciences Journal 59: 1-28. 10.1080/02626667.2013.857411

Lenzen, M, et al. (2021) Impacts of harmful algal blooms on marine aquaculture in a low-carbon future. Harmful Algae 110: 102143. https://doi.org/10.1016/j.hal.2021.102143

Leybold-Johnson, I. (2011, July 11). How a Swiss scientist saved 20 million people. Swissinfo, Archived from original on 6 December 2021.

Mardones, JI, et al. (2020) Estimating and mitigating the economic costs of harmful algal blooms on commercial and recreational shellfish harvesters. (59). PICES, Sidney, British Columbia

Marengo, JA, & Espinoza, JC (2016) Extreme seasonal droughts and floods in Amazonia: causes, trends and impacts. International Journal of Climatology 36: 1033-1050. doi:10.1002/joc.4420

Mark, M. (2023, Jul 18). Customs officers seized $2.7 million worth of endangered fish bladders hidden inside a shipment of frozen fish fillets. Business Insider. New York City, New York.

Martens, P, & Hall, L (2000) Malaria on the move: Human population movement and malaria transmission. Emerging Infectious Diseases 6: 103-109. DOI: 10.3201/eid0602.000202

Martínez, IA, & Alonso, AI (2021) Mexican organized crime and the illegal trade in totoaba maw. Trends in Organized Crime 24: 526-546. 10.1007/s12117-021-09436-9

Mbow, C, et al. (2019) Food security. In: P.R. Shukla, et al. (eds) Climate Change and Land: An IPCC Special Report on Climate Change, Desertification, Land Degradation, Sustainable Land Management, Food Security, and Greenhouse Gas Fluxes in Terrestrial Ecosystems. Cambridge University Press, Cambridge, United Kingdom, pp

Millington, N (2018) Producing water scarcity in São Paulo, Brazil: The 2014-2015 water crisis and the binding politics of infrastructure. Political Geography 65: 26-34. https://doi.org/10.1016/j.polgeo.2018.04.007

Montecalvo, I, et al. (2023) Ocean predators: Squids, Chinese fleets and the geopolitics of high seas fishing. Marine Policy 152: 105584. https://doi.org/10.1016/j.marpol.2023.105584

Morell, V (2017) World's most endangered marine mammal down to 30: Acoustic survey speeds last-ditch plans to round up the vaquita—for its own good. Science 355: 558-559. DOI: 10.1126/science.355.6325.558

Morris, RL, et al. (2018) From grey to green: Efficacy of eco-engineering solutions for nature-based coastal defence. Global Change Biology 24: 1827-1842. https://doi.org/10.1111/gcb.14063

Narayan, S, et al. (2017) The value of coastal wetlands for flood damage reduction in the northeastern USA. Scientific Reports 7: 9463. 10.1038/s41598-017-09269-z

Nazareno, AG, & Laurance, WF (2015) Brazil's drought: Beware deforestation. Science 347: 1427-1427. 10.1126/science.347.6229.1427-a

Needham, K, & Craymer, L. (2024, April 10). US Coast Guard says boardings of Chinese fishing vessels in South Pacific legal. Reuters, Thomson Reuters, London, United Kingdom. https://www.reuters.com/world/us-coast-guard-says-boardings-chinese-fishing-vessels-south-pacific-legal-2024-04-10/

Nellemann, C, et al. (2016) The Rise of Environmental Crime: A Growing Threat to Natural Resources, Peace, Development and Security. United Nations Environment Programme (UNEP), Nairobi, Kenya

NIC (2012) Global Water Security. (ICA 2012-08). National Intelligence Council, Washington, D.C.

NIC (2015) Global Food Security. (ICA 2015-04). U.S. National Intelligence Council, Washington, D.C.

NIC (2016) Implications for US National Security of Anticipated Climate Change. (NIC WP 2016-01). National Intelligence Council, Washington, D.C.

NIC (2017) Global Trends: Paradox of Progress. U.S. National Intelligence Council, Washington, D.C.

NIC (2021a) Climate Change and International Responses Increasing Challenges to US National Security Through 2040. (NIC-NIE-2021-10030-A). National Intelligence Council, Washington, D.C.

NIC (2021b) Global Trends 2040: A More Contested World. (NIC 2021-02339). U.S. National Intelligence Council, Washington, D.C.

NIE (2000) National Intelligence Estimate: The Global Infectious Disease Threat and Its Implications for the United States. (NIE 99-17D). National Intelligence Estimate Washington, D.C.

Norgaard, RB (1988) The biological control of Cassava Mealybug in Africa. American Journal of Agricultural Economics 70: 366-371. 10.2307/1242077

O'Connor, T (April 3, 2017) War over water: ISIS and U.S. battle over massive dam that could shape Syrian conflict http://www.newsweek.com/us-isis-war-water-syria-rebels-retreat-army-advance-578625

O'Neill, DW, et al. (2018) A good life for all within planetary boundaries. Nature Sustainability 1: 88-95. https://doi.org/10.1038/s41893-018-0021-4

Onuma, A, & Tsuge, T (2018) Comparing green infrastructure as ecosystem-based disaster risk reduction with gray infrastructure in terms of costs and benefits under uncertainty: A theoretical approach. International Journal of Disaster Risk Reduction 32: 22-28. https://doi.org/10.1016/j.ijdrr.2018.01.025

Paleczny, M, et al. (2015) Population trend of the world's monitored seabirds, 1950-2010. PLoS One 10: 11. 10.1371/journal.pone.0129342

Palmer, MA, et al. (1997) Ecological theory and community restoration ecology. Restoration Ecology 5: 291-300.

Paskett, CJ, & Philoctete, CE (1990) Soil conservation in Haiti. Journal of Soil and Water Conservation 45: 457-459. https://doi.org/10.1080/00224561.1990.12456518

Peng, W, et al. (2020) A review of historical and recent locust outbreaks: Links to global warming, food security and mitigation strategies. Environmental Research 191: 110046. https://doi.org/10.1016/j.envres.2020.110046

Petrich, K (2022) Cows, charcoal, and cocaine: Al-Shabaab's criminal activities in the Horn of Africa. Studies in Conflict & Terrorism 45: 479-500. 10.1080/1057610x.2019.1678873

PI (2024) Water Conflict Chronology Pacific Institute. https://www.worldwater.org/water-conflict/

Pirages, DC (2013) Ecological security: A conceptual framework. In: Matthew RA, et al. (eds) Handbook of Environmental Security. Routledge, Milton Park, England, pp 139-153

Póvoa, MM, et al. (2003) Malaria vectors, epidemiology, and the re-emergence of Anopheles darlingi in Belém, Pará, Brazil. Journal of Medical Entomology 40: 379-386. https://doi.org/10.1603/0022-2585-40.4.379

Ritchie, H, & Roser, M (2024) Fish and Overfishing. https://ourworldindata.org/fish-and-overfishing

Rockstrom, J, et al. (2009) A safe operating space for humanity. Nature 461: 472-475. https://doi.org/10.1038/461472a

Romm, JJ (1993) Defining National Security: The Nonmilitary Aspects. Council on Foreign Relations, New York, NY

Sachs, J, & Malaney, P (2002) The economic and social burden of malaria. Nature 415: 680. https://doi.org/10.1038/415680a

Sas-Rolfes, M, et al. (2019) Illegal wildlife trade: Scale, processes, and governance. Annual Review of Environment and Resources 44: 201-228. 10.1146/annurev-environ-101718-033253

Savary, S, et al. (2019) The global burden of pathogens and pests on major food crops. Nature Ecology & Evolution 3: 430-439. 10.1038/s41559-018-0793-y

Schlesinger, WH, & Jasechko, S (2014) Transpiration in the global water cycle. Agricultural and Forest Meteorology 189-190: 115-117. https://doi.org/10.1016/j.agrformet.2014.01.011

Schoonover, R (2022) Societal and Security Implications of Ecosystem Services Declines. Part 1: Pollination and Seed Dispersal. The Council on Strategic Risks: Ecological Security Program of the Converging Risks Lab, Washington, D.C.

Schoonover, R, et al. (2021) The Security Threat That Binds Us: The Unraveling of Ecological and Natural Security and What the United States Can Do About It. The Converging Risks Lab, an institute of The Council on Strategic Risks, Washington, D.C.

Sigren, J, et al. (2014) Coastal sand dunes and dune vegetation: Restoration, erosion, and storm protection. Shore & Beach 82: 5-12.

Singh, D, & Yi, SV (2021) On the origin and evolution of SARS-CoV-2. Experimental & Molecular Medicine 53: 537-547. https://doi.org/10.1038/s12276-021-00604-z

Smith, MR, et al. (2022) Pollinator deficits, food consumption, and consequences for human health: A modeling study. Environmental Health Perspectives 130: 127003. doi:10.1289/EHP10947

Smith, SDP, et al. (2015) Rating impacts in a multi-stressor world: a quantitative assessment of 50 stressors affecting the Great Lakes. Ecological Applications 25: 717-728. https://doi.org/10.1890/14-0366.1

Steinsson, S (2016) The Cod Wars: A re-analysis. European Security 25: 256-275. 10.1080/09662839.2016.1160376

Steinsson, S (2017) Neoclassical realism in the North Atlantic: Explaining behaviors and outcomes in the cod wars. Foreign Policy Analysis 13: 599-617. 10.1093/fpa/orw062

Stokes, A, et al. (2014) Ecological mitigation of hillslope instability: ten key issues facing researchers and practitioners. Plant and Soil 377: 1-23. 10.1007/s11104-014-2044-6

Tennesen, M. (2018, August 6). Blowing Up Illegal Fishing Boats Helps Indonesian Fishers. Scientific American. New York, NY.

UNDP (1994) Human Development Report 1994 (Programme UND, Ed.). Oxford University Press, New York, New York

Vass, A (2002) Over half the world will face water shortages by 2032. BMJ 324: 1293. 10.1136/bmj.324.7349.1293

Verhoeven, H (2018) Environmental Politics in the Middle East: Local Struggles, Global Connections. Oxford University Press, Oxford, United Kingdom

Verma, AK, & Prakash, S (2020) Impact of Covid-19 on environment and society. Journal of Global Biosciences 9: 7352-7363. DOI: www.mutagens.co.in/jgb/vol.09/05/090506.pdf

Vittor, AY, et al. (2006) The effect of deforestation on the human-biting rate of *Anopheles darlingi,* the primary vector of falciparum malaria in the Peruvian Amazon. The American Journal of Tropical Medicine and Hygiene 74: 3-11. https://doi.org/10.4269/ajtmh.2006.74.3

Vittor, AY, et al. (2009) Linking deforestation to malaria in the Amazon: Characterization of the breeding habitat of the principal malaria vector, *Anopheles darlingi*. The American Journal of Tropical Medicine and Hygiene 81: 5-12.

Vogler, A (2023) Tracking climate securitization: Framings of climate security by civil and defense ministries. International Studies Review 25: viad010. https://doi.org/10.1093/isr/viad010

von Hein, M. (2016, March 3). 'Islamic State' using water as a weapon. DW News, Deutsche Welle, Berlin, Germany. https://www.dw.com/en/islamic-state-using-water-as-a-weapon/a-19093081

von Lossow, T (2016) The rebirth of water as a weapon: IS in Syria and Iraq. The International Spectator 51: 82-99. https://doi.org/10.1080/03932729.2016.1213063

Wagner, DL, et al. (2021) Insect decline in the Anthropocene: Death by a thousand cuts. Proceedings of the National Academy of Sciences 118: e2023989118. doi:10.1073/pnas.2023989118

Warren, MS, et al. (2021) The decline of butterflies in Europe: Problems, significance, and possible solutions. Proceedings of the National Academy of Sciences of the United States of America 118. 10.1073/pnas.2002551117

WEF (2020a) The Global Risks Report 2020. World Economic Forum, Geneva, Switzerland

WEF (2020b) Nature Risk Rising: Why the Crisis Engulfing Nature Matters for Business and the Economy. World Economic Forum, Geneva, Switzerland

WEF (2024) The Global Risks Report 2024. World Economic Forum, Geneva, Switzerland

WEF (2025) The Global Risks Report 2025. World Economic Forum, Geneva, Switzerland

WHO (2016) World Malaria Report 2016. World Health Organization, Geneva, Switzerland

Wolf, KM, & DiTomaso, J (2016) Management of blue gum eucalyptus in California requires region-specific consideration. California Agriculture 70. 10.3733/ca.v070n01p39

Wright, JS, et al. (2017) Rainforest-initiated wet season onset over the southern Amazon. Proceedings of the National Academy of Sciences 114: 8481-8486. doi:10.1073/pnas.1621516114

Zhang, HZ (2024) The South China Sea fishing crisis: The overlooked role of Chinese subnational governments. Pacific Review 37: 1090-1119. 10.1080/09512748.2024.2304805

Figure legends

Figure 1. Nature's role in national security. Anthropogenic changes to nature can generate ecological disruptions that increase social and political stress and, in turn, pose risks to national security.

Figure 2. Examples of ecological disruptions that affect key aspects of national security. The five aspects of national security are shown in the key at top. The type of ecological disruption is color coded as indicated on left. Note the disruption of habitat loss includes multiple disruptions that stems from mismanagement of habitats, such as deforestation, wetland/ mangrove loss, soil degradation/erosion, and desertification. While several examples in this figure are discussed in the text, all are described in the Supplemental Information and can be cross-referenced using the number in parentheses. Color codes: **Habitat loss (green)**, **overharvesting (orange)**, **pest / disease outbreaks (red)**, **invasive species (blue)**, **biodiversity loss (purple)**.

Figure 3. Examples of how ecological disruptions influence national security. (A) A 2019 outbreak of desert locusts in the Horn of Africa spread quickly and jeopardized food security in a region where 24 million people already face food shortages. The outbreak led several countries to declare national emergencies and rely on international aid. (B) Demonstrators protest in São Paulo, Brazil during the 2014 drought that forced the government to invoke water rations. The drought was exacerbated by climate change and rampant deforestation in the Amazon that reduced plant transpiration. (C) A Center for Disease Control worker is decontaminated after visiting an Ebola isolation ward. The 2014-16 Ebola epidemic started after humans contracted the virus from a wild animal, likely fruit bats, that were collected for bushmeat. The epidemic caused 11,325 deaths in West Africa and spread to other countries like the U.S., leading the World Health Organization to declare an International Health Emergency. (D) The 2004 Indian Ocean Tsunami was one of the worst natural disasters in recorded history, killing more than 250,000 people in 14 countries and displacing millions more. Countries that had destroyed coastal habitats like mangroves that provide flood protection were the hardest hit. (E) Kenyan soldiers prepare for a rescue operation near the Westgate Mall in Nairobi, Sept. 23, 2013 after the terrorist organization Al Shabaab stormed the shopping center, took hostages, killed 62 individuals and injured 175 others. Al Shabaab's activities were partly, if not mostly, funded from revenues such as charcoal from illegal logging and poaching, both environmental crimes.

Figure 4. Trends in water conflicts by type from 2000 to 2023. Trigger: Water as a trigger or root cause of conflict, or underlying cause of ongoing tension that is contributing to conflict, where there is a dispute over the control of water or water systems or where economic or physical access to water, or scarcity of water, triggers violence. Weapon: Water as a weapon of conflict, where water resources, or water systems themselves, are used as a tool or weapon in a violent conflict. Casualty: Water resources or water systems as a casualty of conflict, where water resources, or water systems, are intentional or incidental casualties or targets of violence. Source: https://pacinst.org/wp-content/uploads/2024/08/Water-Conflict-Chronology_Fact-Sheet.pdf.

Figure 5. Both physical and natural infrastructure provide security-relevant services for people and nations.

Figure 6. Ecological disruptions as threat multipliers. Direct and indirect pathways by which nature influences national security.

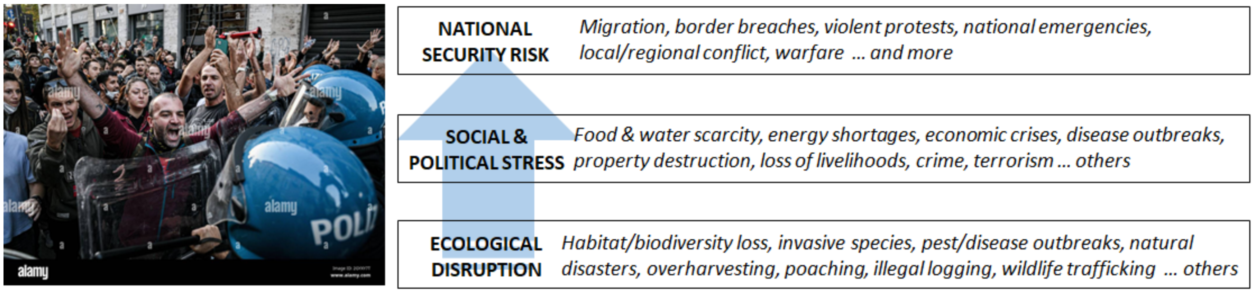
NATIONAL SECURITY RISK
Migration, border breaches, violent protests, national emergencies, local/regional conflict, warfare ... and more
SOCIAL & POLITICAL STRESS
Food & water scarcity, energy shortages, economic crises, disease outbreaks, property destruction, loss of livelihoods, crime, terrorism ... others
ECOLOGICAL DISRUPTION
Habitat/biodiversity loss, invasive species, pest/disease outbreaks, natural disasters, overharvesting, poaching, illegal logging, wildlife trafficking ... others

Figure 1.

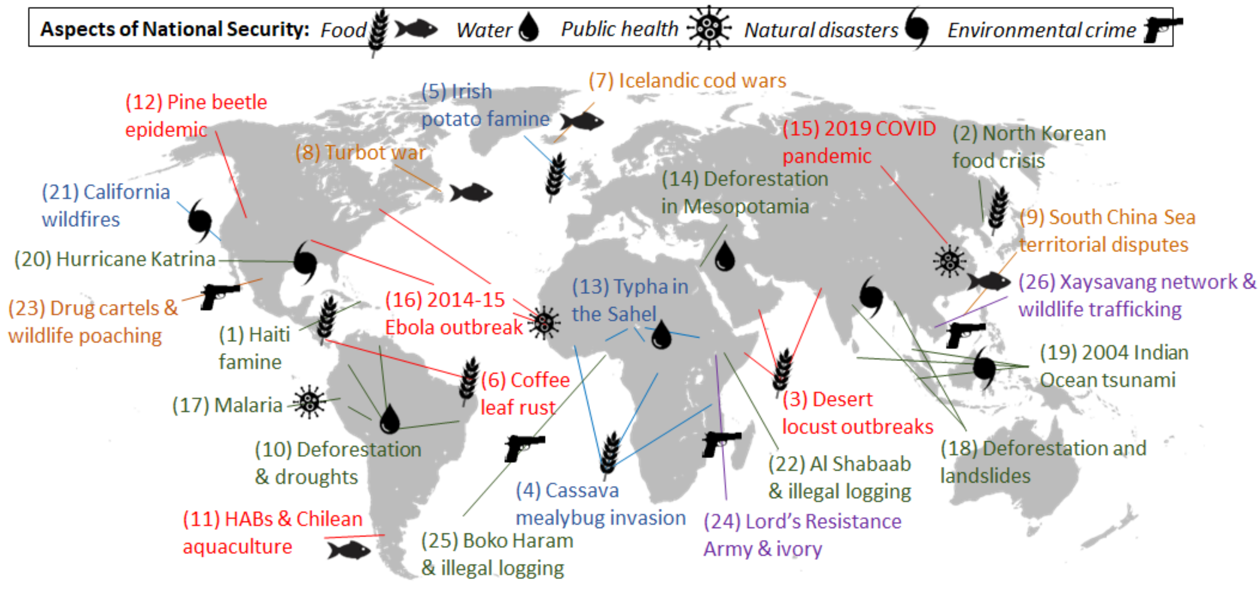
Aspects of National Security: Food
Water
Public health
Natural disasters
Environmental crime
(1) Haiti famine
(2) North Korean food crisis
(3) Desert locust outbreaks
(4) Cassava mealybug invasion
(5) Irish potato famine
(6) Coffee leaf rust
(7) Icelandic cod wars
(8) Turbot war
(9) South China Sea territorial disputes
(10) Deforestation & droughts
(11) HABs & Chilean aquaculture
(12) Pine beetle epidemic
(13) Typha in the Sahel
(14) Deforestation in Mesopotamia
(15) 2019 COVID pandemic
(16) 2014-15 Ebola outbreak
(17) Malaria
(18) Deforestation and landslides
(19) 2004 Indian Ocean tsunami
(20) Hurricane Katrina
(21) California wildfires
(22) Al Shabaab & illegal logging
(23) Drug cartels & wildlife poaching
(24) Lord's Resistance Army & ivory
(25) Boko Haram & illegal logging
(26) Xaysavang network & wildlife trafficking

Figure 2.

This paper is a non-peer reviewed EarthArXiv preprint

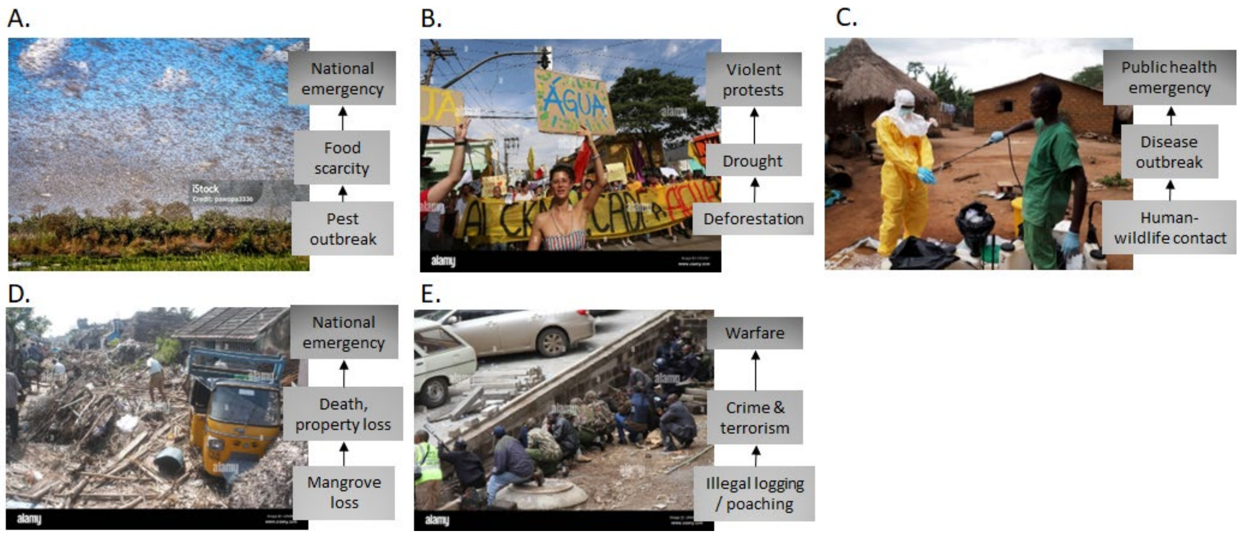

Figure 3.

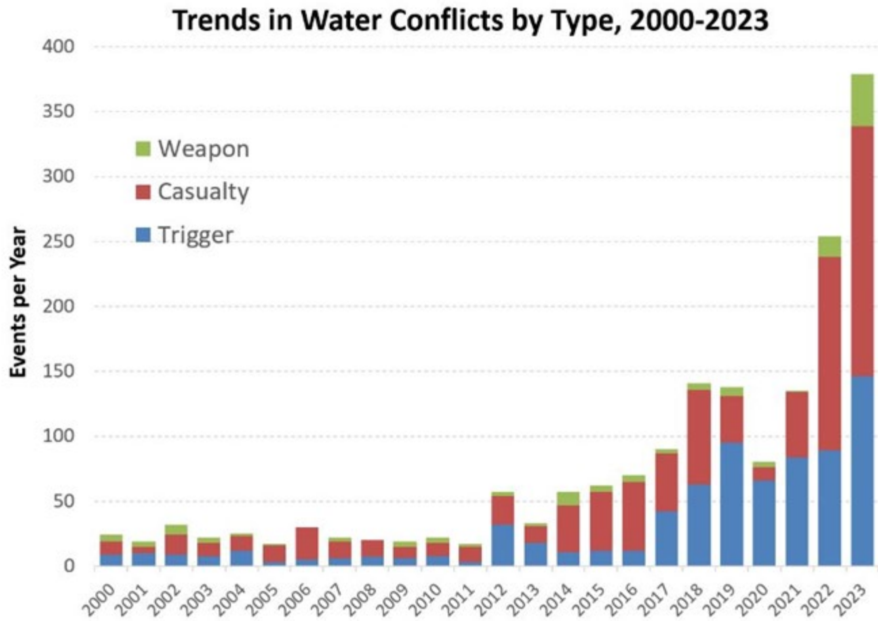
Trends in Water Conflicts by Type, 2000-2023
Events per Year
Weapon
Casualty
Trigger
400
350
300
250
200
150
100
50
0
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021
2022
2023

Figure 4.

Physical Infrastructure	Security-relevant service provided
Military bases	Land/coastal defense
Border walls	Border protection
Cybersecurity data centers	Information integrity
Dams, ports, roads	Water, trade security
Satellite constellations	Strategic situational awareness

Natural Infrastructure	Security-relevant service provided
Mangroves, coral reefs	Coastal protection, food security
Forests, wetlands	Water regulation, disease buffering
Pollinators	Food, trade security
Healthy soils, aquifers	Water security
Biodiversity	Resilience to stress/shocks

Figure 5.

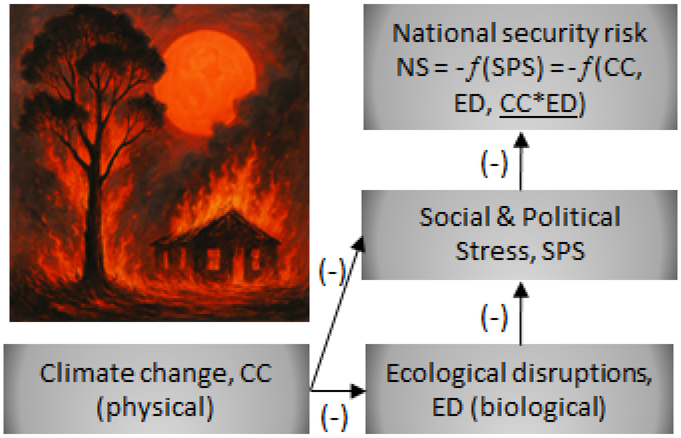
National security risk
NS = -ƒ(SPS) = -ƒ(CC, ED, CC*ED)
(-)
Social & Political Stress, SPS
(-)
(-)
Climate change, CC (physical)
(-)
Ecological disruptions, ED (biological)

Figure 6.

Electronic Supplemental Material, ESM

This SI provides examples of how anthropogenic changes to nature lead to ecological disruptions that increase national security risk. Example numbers correspond to those in Figure 2 of the paper.

Color code	Aspect of national security
Habitat loss (green)	Food
Overharvesting (orange)	Water
Pest / disease outbreaks (red)	Public health
Invasive species (blue)	Natural disasters
Biodiversity loss (purple)	Environmental crime

Food Security

(1) **Haiti famine**. Haiti illustrates how a country's mismanagement of its forested ecosystems can lead to widespread starvation, civil unrest, and strained international relations. Centuries of deforestation for agricultural production and fuelwood have reduced Haiti's forest cover from 80% to less than 1% (Bargout & Raizada 2013; UNCT 2008). The removal of forest cover, combined with steep topography and overexploitation of marginal farm land, has driven widespread erosion and large scale soil infertility where only one-sixth of the land currently in production is actually suitable for farming (Paskett & Philoctete 1990; UNCT 2008). Soil infertility and erosion have reduced crop yields below local demand, prompting Haiti's reliance on imports for more than 50% of all food and 80% of rice, the main staple (Bargout & Raizada 2013; Kennedy et al. 2016; UNCT 2008). Haiti's dependence on food imports has made the country vulnerable to food price fluctuations, worsening the already dire food security situation. Prices of beans and rice rose by 50% during the 2007-2008 global food crisis, provoking widespread protests that turned into violent riots (UNCT 2008). In April 2008, the unrest prompted the Haitian Senate to oust Prime Minister Alexis. The political stalemate that followed weakened the government's decision-making power and delayed Haiti's response to the food crisis (UNCT 2008). The toppled government, ongoing starvation, and social unrest fueled attempts for refugees to immigrate to the U.S., putting a strain on U.S. Coast Guard resources and raising national security concerns (Hendrix 2016).

(2) **North Korean Food Crisis**. North Korea is a volatile single-party state widely viewed as vulnerable to potential regime collapse in the foreseeable future (Bennett 2013). A potential collapse of the North

Korean government could result in substantial internal violence, and elevate the risk that weapons of mass destruction could be used, either by competing domestic factions or by non-state actors seeking to exploit the instability (Bennett 2013). Part of North Korea's volatility stems from chronic food insecurity, which in turn has been exacerbated by widespread habitat destruction. Following the collapse of the Soviet Union in the early 1990s,oil imports to North Korea declined by 60%, forcing much of the population to rely on firewood for household energy (McKenna). Between 1990 and 2005, North Korea lost 25% of its forest cover, with deforestation occurring at a rate of nearly 2% per year (Doak 2000). This rapid loss of tree cover contributed to severe soil erosion and widespread flooding. Those environmental stressors were among the contributing factors to the catastrophic 1990s famine, which is estimated to have caused between 1 to 2.5 million deaths (Bennett 2013; McKenna). North Korea continues to face chronic food insecurity, as severely degraded soils and persistently low crop yields remain insufficient to meet the population's subsistence needs (Bennett 2013; McKenna ; Stone 2012a). An estimated 18 million people (72% of the population) suffer from chronic food insecurity (Mishra 2017). The nation's food scarcity was so severe that in 2012, the government hosted its first-ever international science conference, inviting scientists from eight countries to focus on ecological restoration. International experts collaborated with North Korean scientists to explore strategies for improving food security through restoring natural infrastructure (Stone 2012b). This rare engagement by North Korea's typically isolationist government underscored the gravity of the country's intertwined environmental and humanitarian crises.

(3) **Desert locust outbreaks**. The 2019-20 desert locust (*Schistocerca gregaria*) infestation was one of the most severe pest outbreaks of the 21^{st} century. This transcontinental crisis devastated crops, triggered extensive economic losses, and jeopardized the food security of millions of people across East Africa, the Arabian Peninsula, and the Indian subcontinent. The locust outbreak originated in the Arabian Peninsula, where heavy rains from 2018's Cyclone Mekuna produced heavy rains created ideal breeding conditions. Desert locusts rank among the world's most destructive migratory pests, with swarms capable of travelling up to 90 miles a day and consuming as much food per day as 35,000 people (Babar 2023). The infestation quickly spread north to Iran, Pakistan, and India and south across the Horn of Africa (FAO 2023). By the end of 2019, swarms of 80 million locusts or more had destroyed crops, trees, and pastureland throughout Ethiopia, Eritrea, Somalia, Kenya, Saudi Arabia, Yemen, Egypt, Oman, Iran, India, and Pakistan (Peng et al. 2020). Around 2.25

million hectares of land were infested (Curtis et al. 2020), further threatening food security in an area where 20 million people were already facing acute food shortages and where 8 million people have already been displaced (WB 2020). Several nations (e.g., Pakistan and Somalia) were forced to declare national emergencies in response to the locust outbreaks, and 110,000 households in seven countries were targeted for rapid livelihoods protection (FAO 2020). The World Bank estimated that in Africa alone, losses could amount to as much as US$8.5 billion (WB 2020).

(4) **Cassava mealybug**. The case of the cassava mealybug (*Phenacoccus manihoti*) in Africa illustrates how invasive or introduced species can threaten food security on a regional scale, affecting millions of people across an entire continent(?). Cassava (*Manihot esculenta*) is a shrubby plant cultivated for its starchy tuberous root and serves as a vital source of calories in tropical regions. Introduced to Africa from South America roughly 300 years ago, cassava had become a staple food for more than 200 million people in sub-Saharan Africa by the mid-twentieth century. In the 1970s, the cassava mealybug was accidentally introduced to Africa from South America. Lacking natural predators in its new environment, the pest spread rapidly across the continent. By the 1980s, it had become a major agricultural pest in Africa, causing yield losses of up to 50% in cassava crops (Norgaard 1988). In response, biologists initiated a search in the mealybug's native range in South America for effective natural enemies. This effort led to a small parasitic wasp (*Epidinocarsis lopezi*) that showed strong potential as a biological control agent. With support from the International Fund for Agricultural Development, scientists at Nigeria's International Institute of Tropical Agriculture developed methods for mass rearing and distribution techniques of the wasp. By 1987, *E.lopezi* had been intentionally released and successfully established in 90% of the cassava-growing regions of Africa (Norgaard 1988). Losses caused by mealybug were almost immediately brought under control, and the efforts were later recognized by the World Food Prize for saving millions of lives and preventing billions of dollars of economic losses across the continent. By averting widespread food shortages and potential civil unrest, this intervention underscored the often-overlooked role of ecological resilience in maintaining human and national security.

(5) **Irish potato famine**. The Irish Potato Famine, or Great Hunger, was a period of mass starvation, disease, and emigration in Ireland triggered by the introduction of an invasive fungal pathogen. Between 1845 and 1849, a potato blight caused by the water mold *Phytophthora infestans* decimated potato crops, the staple food for much of the Irish population, leading to one of the most

devastating food crises in modern European history (Donnelly Jr 2002; Woodham-Smith 1992). Genome sequencing has revealed that the *P. infestans* strain responsible for the famine, known as HERB-1, originated in Mexico's Toluca Valley in the early 19th century and was likely introduced to Europe in the 1840s via ships transporting infected potatoes or plant material (Goodwin et al. 1994; Yoshida et al. 2013). In Ireland's moist climate, the pathogen spread quickly, devastating nearly three-quarters of the potato crop within just a few years. The resulting agricultural collapse led to the deaths of more than one million people from starvation and famine-related diseases (McLean 2019).In addition, an estimated 1 to 2 million emigrated from Ireland to destinations in England, Scotland, South Wales, and North America, where the influx of Irish migrants permanently reshaped regional ethnic demographics (Nusteling 2009). Although the British government deployed the British Navy to deliver food and medical aid, the relief efforts were grossly insufficient to prevent mass starvation. The inadequate response to the famine deepened existing political and cultural tensions, fueling resentment towards British rule and accelerating the rise of Irish nationalism. This would become a major factor in Ireland's protracted struggle for independence from Great Britain (Donnelly Jr 2002; Woodham-Smith 1992).

(6) **Coffee leaf rust in Central America**. Coffee leaf rust (CLR), caused by the fungus *Hemileia vastatrix*, has been a major plant disease affecting coffee crops in Central America since its first appearance in 1976 (Avelino et al. 2015; Koutouleas 2023). The pathogen infects the leaves of coffee plants, causing premature yellowing and defoliation, which in turn reduces both yield and bean quality. In 2012, a particularly severe outbreak of CLR swept across Central America and southern Mexico, severely impacting coffee production and threatening the livelihoods of thousands of farm workers. The outbreak affected 70% of farms in Guatemala, 64% in Costa Rica, 37% in Nicaragua, and 25% in Honduras. Regionally, coffee production declined by 16% in Central America, with select countries like Colombia experiencing losses as high as 31% (Avelino et al. 2015). In response, Costa Rica, Honduras, and Guatemala declared states of emergency between 2012 and 2013 and launched national initiatives to contain the disease (Koutouleas 2023). The economic consequences have been substantial; CLR has inflicted an estimated $1–2 billion in annual losses on the coffee industry (Wellman 1953), led to the loss of more than 250,0000 farm jobs (Rey Mallén 2014), and triggered mass labor migration as displaced agricultural workers sought new sources of income (Dupre et al. 2022).

(7) **Icelandic cod wars**. More than 3.2 billion people worldwide rely on fisheries as a primary source of protein (FAO 2024). Given this critical dependence, the overexploitation of marine fisheries has frequently served as a driver of civil strife and international conflict (Hendrix & Glaser 2011; Spijkers et al. 2019). One notable example occurred In the 1970s, when tensions between the United Kingdom and Iceland over access to declining cod stocks in the North Atlantic., Unsustainable overfishing had severely depleted the Icelandic cod fisheries, prompting the Icelandic government to impose a ban and extend its exclusive fishing zone (Steinsson 2016). British trawlers continued to operate in the contested waters, leading to repeated confrontations with Icelandic gunboats. In response, the British Royal Navy was deployed to protect the trawlers, sparking a series of clashes known as the "Cod Wars." The conflict severely strained diplomatic relations, prompting Iceland to threaten to withdraw from the North Atlantic Treaty Organization (NATO) and consider closing a key U.S. military base (Steinsson 2017).

(8) **Turbot War**. The Turbot War was an international fishing dispute between Canada and Spain over access to Greenland turbot (*Reinhardtius hippoglossoides*) stocks in the Northwest Atlantic Ocean (Soroos 1997). Canada had long contended that European Union (EU) factory ships were overfishing turbot on the Grand Banks, just beyond its 200-nautical mile Economic Exclusive Zone (EEZ). In March 1995, tensions escalated when Canadian patrol vessels fired warning shots, seized a Spanish fishing trawler, and cut the nets of another Spanish boat for allegedly violating fishing quotas in international waters (Wiener 2016). Spain and the EU condemned Canada's actions as a breach of international law, accusing it of piracy for seizing a foreign ship outside its EEZ. Spain responded by mobilizing its own gunboats, and the EU threatened economic sanctions against Canada. The crisis was ultimately defused through diplomatic negotiations that led to the 1995 Straddling Stocks Agreement, a landmark treaty that strengthened international cooperation over the management of migratory and transboundary fish stocks of shared economic and ecological importance (Colburn 1996).

(9) **South China Sea territorial disputes**. China's overexploitation of its own coastal fisheries has contributed to expansive and aggressive fishing activities beyond its territorial waters. These include territorial assertions in the South China Sea and the extension of fishing fleets to the coasts of Africa and South America, actions that have heightened both economic and political instability in multiple regions (Zhang 2024). In response to repeated incursions, Indonesia has taken a hardline approach

by destroying more than 40 Chinese vessels accused of illegal fishing within its Exclusive Economic Zone and claiming annual losses exceeding $4 billion a year in stolen fisheries revenue (Tennesen 2018). To counter illegal, unreported, and unregulated (IUU) fishing, the United States, Australia, New Zealand and the United Kingdom have stepped up navy patrols across the Pacific. These patrols have led to direct confrontations with Chinese Coast Guard vessels that frequently escort fleets operating unlawfully in other nations' waters. In 2024, the U.S. Coast Guard and Argentine Navy began joint exercises in the Atlantic Ocean aimed at deterring illegal Chinese fishing (Embassy 2024). The escalation of coordinated military activities highlights the extent to which ecological disruptions to an important biological resource (e.g., fisheries) can generate international conflict and reshape national security priorities.

Water scarcity

(10) **Deforestation and drought in South America**. From 2014 to 2017, a prolonged rainfall deficit triggered a severe drought across southeastern Brazil, affecting major urban centers such as São Paulo, home to over 20 million people (Millington 2018). The crisis was partially driven by a Pacific Ocean El Niño–Southern Oscillation (ENSO) event but was significantly exacerbated by widespread deforestation throughout the Amazon Basin. The loss of forest cover reduced plant transpiration, which in turn diminished regional precipitation (Bagley et al. 2014; Marengo & Espinoza 2016; Nazareno & Laurance 2015). During the drought, millions of São Paulo residents faced daily water shutoffs and rationing, with poorer communities suffering the most due to limited access to bottled water and storage infrastructure. These acute shortages triggered social unrest and protests against the government, some of which escalated into violence. Similar water-related protests have occurred in Venezuela, Columbia, and Peru (PI 2024). Because plant transpiration plays a central role in regulating climate (Wright et al. 2017) and governs the recharge of both surface and groundwater systems (Huntington 2006), land-use practices that destroy vegetation (e.g., deforestation) can have far-reaching effects on regional water availability (Brown et al. 2005).

(11) **HABs harming aquaculture in Chile**. A major driver of degraded water quality worldwide is nutrient pollution, which occurs when poorly managed agricultural and waste systems release excessive fertilizer runoff into freshwater and marine ecosystems. This influx of nutrients, commonly nitrogen and phosphorus compounds, promotes harmful algal blooms (HABs), which have contributed to the formation of hypoxic "dead zones" in over 400 coastal habitats worldwide, covering an estimated

245,000 km^2 (Diaz & Rosenberg 2008). These oxygen-depleted zones can trigger mass mortality events, rapidly killing entire populations of fish and other marine life. Dead zones frequently lead to the collapse of commercial and recreational fisheries and force the closures of aquaculture operations (Brown et al. 2020; Lenzen et al. 2021; Mardones et al. 2020). For example, in 2016 an exceptionally large HAB developed in Chile's Patagonian fjords, killing 39,000 tons of farmed salmon and trout generating estimated economic losses of over US$800M (Díaz et al. 2019). Beyond the economic damage, the event sparked widespread social unrest in coastal communities, eroded public trust in national institutions, and exposed deep vulnerabilities in Chiles' food system, rural employment base, and maritime governance. As aquaculture becomes an increasingly strategic sector for economic development and food security in Chile (and elsewhere), recurrent HABs now pose not only ecological and economic threats but also risks to the country's internal stability and national security.

(12) **Pine beetle epidemic.** Southern and Mountain Pine Beetles are bark beetles that infest and kill pine trees across North America (Aukema et al. 2008). Although native to the continent, these beetles have rapidly expanded their range northward, and over the past fifteen years, they have caused the death of nearly 50% of mature pine trees in some regions (Long & Lawrence 2016). This widespread tree mortality has resulted in billions of dollars in timber losses and has negatively affected forestry-related employment and local economies (Pye et al. 2011). Beyond economic impacts, beetle-induced tree mortality has significantly altered the hydrologic cycle in Rocky Mountain forests by reducing plant transpiration and ground evaporation (Bearup et al. 2014). These ecological changes have, in turn, increased the availability of combustible material, contributing to more frequent, intense, and prolonged wildfires. The resulting fires have led to t loss of life and property, and have posed growing threats to critical infrastructure, including regional power grids (Hicke et al. 2012).

(13) **Typha in the Sahel.** *Typha domingensis* (cattails) is an aggressive invasive plant species that has rapidly proliferated across the Sahel region of Africa, particularly in the Senegal River basin and wetlands such as Nigeria's Hadejia-Nguru system (Mukhtar & Abdullahi 2020). As Typha colonizes irrigation canals, drainage ditches, and river channels, it obstructs the flow of water needed for agriculture, reduces access to fishing grounds, and impedes availability of drinking water. These disruptions to local hydrology and ecosystem services have directly undermined agricultural productivity, fishing yields, and livestock grazing, thereby intensifying livelihood insecurity across

rural communities (Ringim et al. 2015). The resource scarcity induced by Typha, particularly water shortages and loss of productive land, creates the conditions for conflict by intensifying competition among user groups (FMOE 2015). Farmer-herder conflicts, which have historically been driven by disputes over land and water access, are further inflamed by the spread of Typha (FMOE 2015; Turner 2004). Armed groups operating in the region have been known to exploit such tensions, using local grievances related to environmental stress and economic marginalization to bolster recruitment or destabilize governance structures. Moreover, invasive species management can itself become a flashpoint. In some communities, Typha is used for traditional purposes or biomass harvesting, creating contested views over whether it should be eradicated, controlled, or integrated (Mukhtar & Abdullahi 2020). Such disagreements over resource governance, especially when state-led interventions are perceived as unjust or exclusionary, can heighten mistrust and contribute to social friction.

(14) **Deforestation in Mesopotamia**. In Mesopotamia and the Levant, the relationship between deforestation and water scarcity have shaped human societies for more than 9000 years, often contributing to water-related conflicts (Gleick 2017). In ancient Mesopotamia, early human populations engaged in widespread clearing of deciduous oak forests to support agriculture and settlement expansion (Chew 2001). This deforestation led to a cascade of environmental consequences: lowered water tables, reduced regional rainfall, increased soil erosion, and intensified desertification These effects exacerbated water scarcity in an already arid or semi-arid landscape, undermining the sustainability of agriculture and human habitation (Chew 2001). As demand for irrigation water grew alongside increasing scarcity, disputes over water access intensified. Mesopotamian city-states frequently clashed over the diversion and control of water from the Tigris and Euphrates Rivers, with upstream communities sometimes restricting water flow to those downstream (Chew 2001; Gleick 2017). These disputes represent some of the earliest documented cases of water-related conflicts in history.

Public health

(15) **COVID-19.** SARS-CoV-2 – the coronavirus responsible for the 2019 COVID-19 global pandemic – illustrates how close human-wildlife contact can facilitate the direct transmission of zoonotic diseases from animals to humans. Epidemiological and genetic studies strongly suggest that SARS-CoV-2 first spilled over to humans via wild animals sold in the Huanan live animal market in Wuhan,

China (Hao et al. 2022; Holmes et al. 2021). Although the specific animal that served as the original host is still under investigation, bats and other mammals are considered the likely natural reservoirs of SARS-CoV-2 because they harbor other coronaviruses with closely related genomes (Singh & Yi 2021). Following the initial zoonotic spillover event, the virus spread rapidly across the globe, killing more than 7 million people and causing acute disruptions not only to global markets and supply chains but also to social cohesion and political stability (Verma & Prakash 2020). Countries with high COVID-19 mortality rates had elevated levels of civil disorder and fatalities caused by political violence as the trust of citizens in the ability of governments to protect them eroded (Bloem & Salemi 2021; Farzanegan & Gholipour 2023). The pandemic thus underscored the profound security implications of zoonotic disease emergence, especially in contexts marked by weak governance and strained state-society relations.

(16) **Ebola Epidemic**. The 2014-2016 Ebola epidemic served as a stark reminder of the horrors that can result from a fast-moving and lethal infectious disease outbreak. Declared a Public Health Emergency of International Concern by the World Health Organization, the epidemic primarily affected Guinea, Liberia, and Sierra Leone in West Africa, and ultimately triggered an international humanitarian response when the virus spread to seven countries outside of the three-country epidemic zone (Bell BP 2016). In all, the outbreak resulted in 28,652 reported cases and 11,325 deaths, far exceeding the cumulative case count of all 20 previous Ebola outbreaks since the virus was first identified in 1976. Public alarm escalated in the United States following the confirmation of four Ebola cases, including one death, in Texas and New York. The Centers for Disease Control and Prevention (CDC) led the U.S. response, mounting the largest emergency operation in the agency's history. More than 4,000 CDC personnel were mobilized, with nearly half deployed to West Africa, where they worked alongside 3,000 U.S. military personnel to construct Ebola treatment units and support field response operations. (Bell BP 2016). The U.S. government contributed $2.4 billion to the global Ebola response, accounting for a significant portion of the $3.6 billion total international effort (Prevention 2016). Although multiple factors contributed to the rapid spread of the virus, the fruit bat is widely suspected to be the primary natural reservoir of the Ebola virus, with handling for bushmeat trade serving as the human transmission route (Bell BP 2016).

(17) **Malaria**. Malaria offers a compelling case study of the intersection between human health, natural infrastructure, and national security. Once considered to be under control—and even eradicated in

some regions, malaria has reemerged over the past five decades as one of world's most deadly infectious diseases. The World Health Organization estimated that in 2015, 212 million people contracted malaria and nearly a half million died, primarily in sub-Saharan Africa (90% of cases). Of those who died, 70% were children under 5 years old (WHO 2016). The resurgence and continued spread of malaria are driven by a complex set of environmental and socioeconomic factors. These include deforestation, increased human migration, poorly designed irrigation and water storage systems, inadequate housing, poor sanitation, and growing resistance to antimalarial drugs and insecticides (Martens & Hall 2000; NIE 2000; Sachs & Malaney 2002). The role of natural infrastructure loss, particularly the degradation of forest ecosystems, has become a central focus in understanding malaria's comeback and its broader public health and security implications. Some of the most striking examples of this relationship come from the Amazon Basin. In the northern Amazon region of Peru, rapid population growth during the late twentieth century drove rural expansion into previously unsettled land. Subsistence agriculture and road creation drove deforestation, which peaked from 1983-1995. At the same time, the area experienced a dramatic rise in malaria, which had previously been low following eradication efforts in the 1960s. Studies demonstrated that the ecological alterations from progressive deforestation promoted the presence and increased the biting rate of South America's most significant malaria vector, *Anopheles darlingi*. The changes in shade, vegetation, and hydrology resulting from deforestation and road construction, combined with the creation of artificial water bodies such as wells and fish farms, created ideal habitat conditions for the disease vector to thrive (Vittor et al. 2006; Vittor et al. 2009). In the Brazilian Amazon, a similar increase in malaria and reappearance of *A. darlingi* was attributed to urban encroachment on surrounding forest lands (Póvoa et al. 2003).

Disaster mitigation

(18) **Landslides in Southeast Asia**. Landslides are recurring natural disasters in many regions of the world, particularly where intense rainfall during the monsoon season triggers slope instability. Between 2004 and 2016, nearly 60,000 people were killed in 4,862 distinct landslide events (Froude & Petley 2018). Most of these events occurred in Southeast Asia, particularly in the hilly areas of Bangladesh, India, the Philippines, and Thailand. The frequency and severity of landslides in these areas have been increased by widespread deforestation, unplanned construction, mining, and other human activities that have contributed to destabilization of hillslopes (Lehmann et al. 2019). Aside from high fatality rates, the economic costs of landslides are staggering, with losses amounting to

more than $20 billion per year in property losses and damage to national infrastructures (e.g. road, bridges, railways, and utilities) (Kjekstad & Highland 2009). Landslides exacerbate social conflict as they lead to displacement and resource scarcity (Alcántara-Ayala 2025; Turner 2018).

(19) **Indian Ocean tsunami**. The 2004 Indian Ocean tsunami, one of the deadliest natural disasters in recorded history, illustrates how the loss of natural habitat can intensify the impacts of a disaster and contribute to cascading national security challenges. In December 2004, a 9.3 magnitude earthquake in the Indian Ocean triggered a series of destructive tsunamis that impacted the coasts of nearly all bordering landmasses, killing at least 250,000 people in 14 countries and displacing millions more (Srinivas & Nakagawa 2008). A humanitarian disaster ensued from the widespread damage of infrastructure, water and food shortages, and concerns over the potential for epidemics. Secondary impacts of the tsunami included soil and water contamination from salinization, sewage, debris, and hazardous or toxic substances, threatening drinking water supplies and agricultural yields (Srinivas & Nakagawa 2008). The tsunami exacerbated several secessionist conflicts that were ongoing in the region (Billon & Waizenegger 2007) and required a worldwide relief response that included more than $350 million in U.S. aid and U.S. Navy dispatch (Margesson 2005). Following the event, analysis of the distribution and severity of impacts revealed the compounding effect of natural infrastructure loss and the vulnerabilities it creates for human populations. In areas where natural features such as seagrass beds, mangrove forests, coral reefs, and sand dunes had been previously destroyed by human activity, damage to human-made structures was substantially greater (Chatenoux & Peduzzi 2007; Cochard et al. 2008; Srinivas & Nakagawa 2008). Areas in Thailand and Sri Lanka where mangroves had been converted to shrimp farms or other land uses experienced far more damage than areas with large mangrove forests (Dahdouh-Guebas et al. 2005; Srinivas & Nakagawa 2008). In Sumatra, Indonesia, areas where coral reefs had been destroyed by dynamite fishing suffered 70% greater wave heights than areas with intact reefs (Fernando et al. 2005). Areas in Sri Lanka that have suffered from coral mining also experienced intensified tsunami damage (Liu et al. 2005). Conversely, on the island of Maldives, human causalities were relatively low, which some attribute to intact coral reefs reducing the strength of the tsunami wave (Srinivas & Nakagawa 2008).

(20) **Hurricane Katrina**. As the most catastrophic natural disaster in U.S. history, Hurricane Katrina exemplifies how domestic natural disasters intensified by the loss of natural infrastructure can pose serious challenges to national security. Costing 1,833 lives and $161 billion, Hurricane Katrina's

widespread devastation demonstrated the vulnerability of U.S. coastal communities (Day et al. 2007; NOAA 2018). Heavy rains, a 30 foot storm surge, and failed levees left 80% of New Orleans under water and displaced over a million people from the Gulf Coast region (Plyer 2015). A year later, half of New Orleans' population had not returned and by ten years after the hurricane, the population of New Orleans was still only 80% of what it was prior to the hurricane (Plyer 2015). Critical infrastructure was severely affected, including crude oil refineries that were off-line for an unprecedented length of time (Busby 2007). Existing vulnerabilities converged with natural infrastructure losses to exacerbate the impact of Hurricane Katrina on New Orleans. The eroding coastline, wetland destruction, fragile levee system, and socio-economic status of the affected residents compounded the hurricane's effects and led to mass devastation. Wetlands south of New Orleans have been disappearing for decades, taking with them the city's buffer against hurricanes. Altered hydrology due to dams and levees throughout the Mississippi River basin have decreased sediment deposition on the delta, resulting in a loss of up to 100 km^2 per year of wetlands and their storm attenuating function (Day et al. 2007; Travis 2005). Faced with an extreme storm surge, several earthen levees collapsed and sent a massive amount of water into the city, which is situated largely below sea level (Travis 2005). The severe flooding disproportionally affected neighborhoods in extreme poverty, adding complexity to the rescue and relief effort (Fussell et al. 2010). Over 72,000 active-duty, National Guard, and Army Reserve soldiers were mobilized in response to the disaster (Wombwell 2011). Displacement of large numbers of New Orleans residents led some cities to experience significant post-Katrina increases in various forms of serious crime (Varano et al. 2010).

(21) **California wildfires**. Over the past decade, California has faced a marked increase in the frequency and severity of wildfires. The 2018 Camp Fire stands as the deadliest wildfire in the state's history, destroying the town of Paradise and killing 85 people. In 2020, 4.3 million acres of land burned. The 2024 fire season was characterized by >8,000 wildfires that burned more than 1 million acres of land, destroyed or damaged 2,148 structures, produced agricultural losses exceeding $3.5 billion, and cost the tourism industry $5 billion. Wildfires have also been associated with increases in crimes like looting, leading the California Governor to deploy the National Guard to protect homes and property (Newsom 2025). While many factors contributed to the fires (weather, climate change, human ignition), California has >100 invasive species of plants that have accelerated the frequency and intensity of burns, making them far worse than they would have historically been under native regimes of plant species. Trees like Eucalyptus (introduced from Australia in the mid-19th century)

and Salt cedar (introduced from Eurasia in the 1800's) are now common species that are highly flammable due to their oily leaves and papery bark that catch fire easily and spread it further (Brooks & Pyke 2000; Keeley 2000; Wolf & DiTomaso 2016). California also has hundreds of species of grass that are invasive from Europe, which dry out quickly after their life cycle and create dense layers of fuel for wildfires (Fusco et al. 2019).

Environmental crime

(22) **Al Shabaab and illegal logging.** Al Shabaab, a Jihadist military group in Somalia, exemplifies how terrorist organizations can finance their operations through environmental crime. In Somalia, charcoal produced from illegal logging and deforestation is a lucrative part of the economy and has become one of the most important revenue streams for terrorist groups like Al-Shabaab (Petrich 2022), which Al- has used this funding to execute bombings and suicide attacks in Mogadishu and Somalia that targeted Somali government officials, peacekeepers, and perceived allies of the Federal Government of Somalia. Al-Shabaab was responsible for the 2013 Westgate mall attack in Nairobi that killed 67 Kenyan and non-Kenyan nationals, as well as the 2015 massacre of 150 university students in Garissa, Kenya. Al-Shabaab's terrorist activities have destabilized the entire Horn of Africa (Verhoeven 2018).

(23) **Mexican drug cartels.** The escalation of organized crime and violence in Mexico since 2006 illustrates how environmental crimes can intersect with broader criminal economies, threatening national security. Armed groups involved in drug trafficking have increasingly turned to activities such as illegal logging, wildlife poaching, and unregulated mining to diversify their revenue streams. These practices not only degrade ecosystems but also fund violence, undermine governance, and contribute to regional instability, including tensions along the U.S.-Mexico border. Soon after the beginning of the so-called war on drugs, many drug cartels adapted to state repression and increased competition with peers by diversifying from drug trafficking to environmental crimes that included theft of natural resources, poaching, and illegal deforestation. For example, some Mexican drug cartels shifted operations to illegal harvest of the totoaba (*Totoaba macdonaldi*), a marine fish endemic to the Gulf of California in Mexico (Martínez & Alonso 2021). The swim bladder of the totoaba, commonly referred to as "maw", is a considered a delicacy in Chinese cuisine as it is erroneously believed to be a treatment for fertility, circulatory, and skin problems (Morell 2017). Maw can fetch prices exceeding $11,000 per pound on the black market, and several multi-million

dollar seizures have been made recently (Customs 2022; Mark 2023). The activities of many other drug cartels and terrorist organizations are funded, in whole or part, by environmental crime [e.g., the Islamic Jihadist militant group Boko Haram (Onuoha 2022), the Lord's Resistance Army extremist militant group in Uganda (Barron 2015), the Xaysavang network in Southeast Asia (Bergenas & Knight 2015), and more].

(24) **Lord's Resistance Army in Uganda**. The Lord's Resistance Army (LRA), an extremist militant organization founded by warlord Joseph Kony in 1987, has financed its operations through transnational environmental crimes, including ivory trafficking. The group initially formed as a rebellion against the Ugandan government under then President Yoweri Museveni with the goal of fighting government oppression and establishing a state based on Christian fundamentalism and Acholi traditionalism (Nellemann et al. 2016). The LRA is infamous for its brutality, including attacks on civilian populations, killings, mutilation, sexual violence, and the widespread abduction of children (Vinci 2005). They have forcibly recruited children to serve as soldiers, sex slaves, and porters (Eichstaedt 2009). The LRA has financed much of its operations through environmental crime, notably illegal ivory poaching from elephants in places like Garamba National Park. LRA rebels reportedly killed forest elephants under Joseph Kony's orders, trading tusks on the black market for arms and logistics support (Nellemann et al. 2016).

(25) **Boko Haram**. Boko Haram is a violent Islamist extremist group based in northeastern Nigeria that has waged an insurgency across the broader Lake Chad Basin region. The group is known for its brutal attacks on civilians and has caused a severe humanitarian crisis, leading to displacement and hardship for millions of people. Boko Haram partially funds its militant activities from illegal timber trade, particularly illegally harvested rosewood, which is valued at billions of dollars annually. The group operates in Nigeria's forest reserves (notably Sambisa, Kainji, Kamuku, and Alawa), used by insurgents as hiding grounds and bases to engage in industrial-scale illegal logging and small-scale mining to generate revenue. Boko Haram then takes advantage of weakened law enforcement, widespread corruption among public officials, and the complicity of some locals in the illegal timber trade. The Nigerian Hunters & Forest Security Service now plays a role in anti-insurgency operations, helping to track insurgents through terrain and disrupt their environmental crime networks.

(26) **Xaysavang network in Southeast Asia**. The Xaysavang Network -- an international wildlife trafficking syndicate led by Lao national, Vixay Keosavang -- traffics ivory, rhino horn, pangolins, and other illicit exports of wildlife parts across Asia and to Africa. Xaysavang associates smuggle illegally taken wildlife from countries in Africa and Asia into Laos and then export them to countries such as Vietnam and China. Affiliates are suspected to be active in South Africa, Mozambique, Thailand, Laos, Malaysia, Vietnam, and China. The Xaysavang Network has been linked to several major seizures of wildlife products. Investigations have revealed overlap with corrupt officials and organized criminal networks across borders, undermining wildlife governance and fueling broader criminal ecosystems (Rademeyer 2014). In November 2013, then U.S. Secretary of State John Kerry announced the first-ever reward—up to US $1 million—for information leading to the dismantling of the Laos-based Xaysavang Network (DoS 2013).

References

Alcántara-Ayala, I (2025) Landslides in a changing world. Landslides 1-15. https://doi.org/10.1007/s10346-024-02451-1

Aukema, BH, et al. (2008) Movement of outbreak populations of mountain pine beetle: influences of spatiotemporal patterns and climate. Ecography 31: 348-358. https://doi.org/10.1111/j.0906-7590.2007.05453.x

Avelino, J, et al. (2015) The coffee rust crises in Colombia and Central America (2008-2013): impacts, plausible causes and proposed solutions. Food Security 7: 303-321. 10.1007/s12571-015-0446-9

Babar, TK (2023) Risks of Deserts Locust and Its Mitigation. In: Ahmed M & Ahmad S (eds) Disaster Risk Reduction in Agriculture. Springer, Singapore, pp 361-392

Bagley, JE, et al. (2014) Drought and deforestation: Has land cover change influenced recent precipitation extremes in the Amazon? Journal of Climate 27: 345-361. https://doi.org/10.1175/JCLI-D-12-00369.1

Bargout, RN, & Raizada, MN (2013) Soil nutrient management in Haiti, pre-Columbus to the present day: Lessons for future agricultural interventions. Agriculture & food security 2: 11. https://doi.org/10.1186/2048-7010-2-11

Barron, DH (2015) How the illegal wildlife trade is fueling armed conflict. Georgetown Journal of International Affairs 16: 217-227.

Bearup, LA, et al. (2014) Hydrological effects of forest transpiration loss in bark beetle-impacted watersheds. Nature Climate Change 4: 481-486. 10.1038/nclimate2198

Bell BP, DI, Jernigan DB, Kenyon TA, Nichol ST, O'Connor JP, Tappero JW (2016) Overview, control strategies, and lessons learned in the CDC response to the 2014–2016 Ebola epidemic. MMWR Supplements 65: 4-11. http://dx.doi.org/10.15585/mmwr.su6503a2

Bennett, BW (2013) Preparing for the possibility of a North Korean collapse. Rand Corporation, Santa Monica, California

Bergenas, J, & Knight, A (2015) Green terror: Environmental crime and illicit financing. SAIS Review of International Affairs 35: 119-131. https://dx.doi.org/10.1353/sais.2015.0004

Billon, PL, & Waizenegger, A (2007) Peace in the wake of disaster? Secessionist conflicts and the 2004 Indian Ocean tsunami. Transactions of the Institute of British Geographers 32: 411-427. https://doi.org/10.1111/j.1475-5661.2007.00257.x

Bloem, JR, & Salemi, C (2021) COVID-19 and conflict. World Development 140: 105294. https://doi.org/10.1016/j.worlddev.2020.105294

Brooks, ML, & Pyke, DA (2000) Invasive plants and fire in the deserts of North America. Proceedings of the Invasive Species Workshop: The Role of Fire in the Control and Spread of Invasive Species. San Diego, California.

Brown, AE, et al. (2005) A review of paired catchment studies for determining changes in water yield resulting from alterations in vegetation. Journal of Hydrology 310: 28-61. https://doi.org/10.1016/j.jhydrol.2004.12.010

Brown, AR, et al. (2020) Assessing risks and mitigating impacts of harmful algal blooms on mariculture and marine fisheries. Reviews in Aquaculture 12: 1663-1688. https://doi.org/10.1111/raq.12403

Busby, JW (2007) Climate Change and National Security: An Agenda for Action. (CRS No. 32). Greenberg Center for Geoeconomic Studies, New York City, New York

Chatenoux, B, & Peduzzi, P (2007) Impacts from the 2004 Indian Ocean Tsunami: analysing the potential protecting role of environmental features. Natural Hazards 40: 289-304. 10.1007/s11069-006-0015-9

Chew, SC (2001) World Ecological Degradation: Accumulation, Urbanization, and Deforestation, 3000 BC-AD 2000. Altamira Press, Landham, Maryland

Cochard, R, et al. (2008) The 2004 tsunami in Aceh and Southern Thailand: A review on coastal ecosystems, wave hazards and vulnerability. Perspectives in Plant Ecology, Evolution and Systematics 10: 3-40. https://doi.org/10.1016/j.ppees.2007.11.001

Colburn, JE (1996) Turbot wars: Straddling stocks, regime theory, and a new UN agreement. Journal of Transnational Law and Policy 6: 323.

Curtis, B, et al. (2020, January 25). ‘This is huge': Locust swarms in Africa are worst in decades. Associated Press, New York, NY.

Customs, US (2022, October 17) Second Largest Seizure in Arizona of Protected Totoaba Swim Bladders Discovered in San Luis, Arizona Port of Entry https://www.cbp.gov/newsroom/local-media-release/second-largest-seizure-arizona-protected-totoaba-swim-bladders

Dahdouh-Guebas, F, et al. (2005) How effective were mangroves as a defence against the recent tsunami? Current Biology 15: R443-R447. https://doi.org/10.1016/j.cub.2005.06.008

Day, JW, et al. (2007) Restoration of the Mississippi Delta: Lessons from Hurricanes Katrina and Rita. Science 315: 1679-1684. DOI: 10.1126/science.1137030

Díaz, PA, et al. (2019) Impacts of harmful algal blooms on the aquaculture industry: Chile as a case study. Perspectives in Phycology. http://doi.org/10.1127/pip/2019/0081

Diaz, RJ, & Rosenberg, R (2008) Spreading dead zones and consequences for marine ecosystems. Science 321: 926-929. DOI: 10.1126/science.1156401

Doak, P (2000) Population consequences of restricted dispersal for an insect herbivore in a subdivided habitat. Ecology 81: 1828-1841. https://doi.org/10.1890/0012-9658(2000)081[1828:PCORDF]2.0.CO;2

Donnelly Jr, JS (2002) The great Irish potato famine. The History Press, Gloucestershire, United Kingdom

DoS (2013) Xaysavang Network Transnational Organized Crime Rewards Program U.S. Department of State. Retrieved July 22, 2025 from https://www.state.gov/transnational-organized-crime-rewards-program-2/xaysavang-network/

Dupre, SI, et al. (2022) The impact of coffee leaf rust on migration by smallholder coffee farmers in Guatemala. World Development 156: 105918. https://doi.org/10.1016/j.worlddev.2022.105918

Eichstaedt, PH (2009) First Kill Your Family: Child Soldiers of Uganda and the Lord's Resistance Army. Chicago Review Press, Chicago, Illinois

Embassy, US (2024) U.S. Coast Guard Cutter James to Arrive in Buenos Aires, Agentina U.S. Embassy in Argentina. https://ar.usembassy.gov/u-s-coast-guard-cutter-james-to-arrive-in-buenos-aires-argentina/

FAO (2020) Desert Locust Crisis: Appeal for Rapid Response and Anticipatory Action in the Greater Horn of Africa. Food and Agriculture Organization of the United Nations, Rome, Italy

FAO (2023) Report of the FAO Commission for Controlling the Desert Locust in South-West Africa. Food and Agriculture Organization of the United Nations, Rome, Italy

FAO (2024) The State of World Fisheries and Aquaculture 2022: Blue Transformation in Action. Food and Agriculture Organization of the United Nations, Rome, Italy

Farzanegan, MR, & Gholipour, HF (2023) COVID-19 fatalities and internal conflict: Does government economic support matter? European Journal of Political Economy 78: 102368. https://doi.org/10.1016/j.ejpoleco.2023.102368

Fernando, HJS, et al. (2005) Coral poaching worsens tsunami destruction in Sri Lanka. Eos, Transactions American Geophysical Union 86: 301-304. 10.1029/2005EO330002

FMOE (2015) National Biodiversity Strategy and Action Plan, 2016-2020. Federal Republic of Nigeria, Abuja, Nigeria

Froude, MJ, & Petley, DN (2018) Global fatal landslide occurrence from 2004 to 2016. Nat. Hazards Earth Syst. Sci. 18: 2161-2181. 10.5194/nhess-18-2161-2018

Fusco, EJ, et al. (2019) Invasive grasses increase fire occurrence and frequency across US ecoregions. Proceedings of the National Academy of Sciences 116: 23594-23599. https://doi.org/10.1073/pnas.1908253116

Fussell, E, et al. (2010) Race, socioeconomic status, and return migration to New Orleans after Hurricane Katrina. Population and Environment 31: 20-42. 10.1007/s11111-009-0092-2

Gleick, P (2017) Water resources, climate change, and the destabilization of Modern Mesopotamia. Water, Security and US Foreign Policy 149-167.

Goodwin, SB, et al. (1994) Panglobal distribution of a single clonal lineage of the Irish potato famine fungus. Proceedings of the National Academy of Sciences 91: 11591-11595. doi:10.1073/pnas.91.24.11591

Hao, YJ, et al. (2022) The origins of COVID-19 pandemic: A brief overview. Transboundary and Emerging Diseases 69: 3181-3197. 10.1111/tbed.14732

Hendrix, CS (2016) When hunger strikes: how food security abroad matters for national security at home. Chicago Council on Global Affairs, Chicago, IL

Hendrix, CS, & Glaser, SM (2011) Civil conflict and world fisheries, 1952–2004. Journal of Peace Research 48: 481-495. 10.1177/0022343311399129

Hicke, JA, et al. (2012) Effects of bark beetle-caused tree mortality on wildfire. Forest Ecology and Management 271: 81-90. https://doi.org/10.1016/j.foreco.2012.02.005

Holmes, EC, et al. (2021) The origins of SARS-CoV-2: A critical review. Cell 184: 4848-4856. https://doi.org/10.1016/j.cell.2021.08.017

Huntington, TG (2006) Evidence for intensification of the global water cycle: Review and synthesis. Journal of Hydrology 319: 83-95. https://doi.org/10.1016/j.jhydrol.2005.07.003

Keeley, JE (2000) Fire and invasive species in Mediterranean-climate ecosystems of California. Proceedings of the invasive species workshop: The role of fire in the control and spread of invasive species. San Diego, California.

Kennedy, N, et al. (2016) Adoption of soil and water conservation practices in central Haiti. Journal of Soil and Water Conservation 71: 83-90. https://doi.org/10.2489/jswc.71.2.83

Kjekstad, O, & Highland, L (2009) Economic and Social Impacts of Landslides. In: Sassa K & Canuti P (eds) Landslides – Disaster Risk Reduction. Springer Berlin Heidelberg, Berlin, Heidelberg, pp 573-587

Koutouleas, A (2023) Coffee leaf rust: Wreaking havoc in coffee production areas across the tropics. Plant health cases 2023: phcs20230005. https://doi.org/10.1079/planthealthcases.2023.0005

Lehmann, P, et al. (2019) Deforestation effects on rainfall-induced shallow landslides: Remote sensing and physically-based modelling. Water Resources Research 55: 9962-9976. https://doi.org/10.1029/2019WR025233

Lenzen, M, et al. (2021) Impacts of harmful algal blooms on marine aquaculture in a low-carbon future. Harmful Algae 110: 102143. https://doi.org/10.1016/j.hal.2021.102143

Liu, PLF, et al. (2005) Observations by the International Tsunami Survey Team in Sri Lanka. Science 308: 1595-1595. 10.1126/science.1110730

Long, JA, & Lawrence, RL (2016) Mapping percent tree mortality due to mountain pine beetle damage. Forest Science 62: 392-402. https://doi.org/10.5849/forsci.15-046

Mardones, JI, et al. (2020) Estimating and mitigating the economic costs of harmful algal blooms on commercial and recreational shellfish harvesters. (59). PICES, Sidney, British Columbia

Marengo, JA, & Espinoza, JC (2016) Extreme seasonal droughts and floods in Amazonia: causes, trends and impacts. International Journal of Climatology 36: 1033-1050. doi:10.1002/joc.4420

Margesson, R (2005) Indian Ocean Earthquake and Tsunami: Humanitarian assistance and relief operations. Library of Congress Congressional Research Office, Washington, D.C.

Mark, M. (2023, Jul 18). Customs officers seized $2.7 million worth of endangered fish bladders hidden inside a shipment of frozen fish fillets. Business Insider. New York City, New York.

Martens, P, & Hall, L (2000) Malaria on the move: Human population movement and malaria transmission. Emerging Infectious Diseases 6: 103-109. DOI: 10.3201/eid0602.000202

Martínez, IA, & Alonso, AI (2021) Mexican organized crime and the illegal trade in totoaba maw. Trends in Organized Crime 24: 526-546. 10.1007/s12117-021-09436-9

McKenna, P (March 6, 2013) Inside North Korea’s Environmental Collapse PBS. http://www.pbs.org/wgbh/nova/next/nature/inside-north-koreas-environmental-collapse/

McLean, D (2019) Famine on the coast: The Royal Navy and the relief of Ireland, 1846–1847. The English Historical Review 134: 92-120. 10.1093/ehr/cez004

Millington, N (2018) Producing water scarcity in São Paulo, Brazil: The 2014-2015 water crisis and the binding politics of infrastructure. Political Geography 65: 26-34. https://doi.org/10.1016/j.polgeo.2018.04.007

Mishra, T (2017) 2017 DPR Korea Needs and Priorities. United Nations Office for the Coordination of Humanitarian Affairs (OCHA), Humanitarian Country Team, New York, NY

Morell, V (2017) World's most endangered marine mammal down to 30: Acoustic survey speeds last-ditch plans to round up the vaquita—for its own good. Science 355: 558-559. DOI: 10.1126/science.355.6325.558

Mukhtar, A, & Abdullahi, I (2020) Typha biomass energy for sustainable management of Typha domingensis L. in affected communities of Northern Nigeria. Dutse Journal of Pure and Applied Sciences 6: 246-252.

Nazareno, AG, & Laurance, WF (2015) Brazil's drought: Beware deforestation. Science 347: 1427-1427. 10.1126/science.347.6229.1427-a

Nellemann, C, et al. (2016) The Rise of Environmental Crime: A Growing Threat to Natural Resources, Peace, Development and Security. United Nations Environment Programme (UNEP), Nairobi, Kenya

Newsom, G (2025, January 9) Governor Newsom deploys California National Guard to Los Angeles fires: ‘Looting will not be tolerated’ https://www.gov.ca.gov/2025/01/09/governor-newsom-deploys-california-national-guard-to-los-angeles-fires-looting-will-not-be-tolerated/

NIE (2000) National Intelligence Estimate: The Global Infectious Disease Threat and Its Implications for the United States. (NIE 99-17D). National Intelligence Estimate Washington, D.C.

NOAA (2018) U.S. Billion-Dollar Weather and Climate Disasters NOAA National Centers for Environmental Information (NCEI) https://www.ncei.noaa.gov/access/billions/

Norgaard, RB (1988) The biological control of Cassava Mealybug in Africa. American Journal of Agricultural Economics 70: 366-371. 10.2307/1242077

Nusteling, HPH (2009) How many Irish Potato Famine deaths? Toward coherence of the evidence. Historical Methods 42: 57-80. 10.3200/hmts.42.2.57-80

Onuoha, FC (2022) The terrorism-organized crime nexus in the Boko Haram insurgency in Nigeria. The Nexus Between Organized Crime and Terrorism. Edward Elgar Publishing, pp 366-390

Paskett, CJ, & Philoctete, CE (1990) Soil conservation in Haiti. Journal of Soil and Water Conservation 45: 457-459. https://doi.org/10.1080/00224561.1990.12456518

Peng, W, et al. (2020) A review of historical and recent locust outbreaks: Links to global warming, food security and mitigation strategies. Environmental Research 191: 110046. https://doi.org/10.1016/j.envres.2020.110046

Petrich, K (2022) Cows, charcoal, and cocaine: Al-Shabaab's criminal activities in the Horn of Africa. Studies in Conflict & Terrorism 45: 479-500. 10.1080/1057610x.2019.1678873

PI (2024) Water Conflict Chronology Pacific Institute. https://www.worldwater.org/water-conflict/

Plyer, A (2015) Facts for features: Katrina impact Retrieved 2/2/18 from https://www.datacenterresearch.org/data-resources/katrina/facts-for-impact/

Póvoa, MM, et al. (2003) Malaria vectors, epidemiology, and the re-emergence of Anopheles darlingi in Belém, Pará, Brazil. Journal of Medical Entomology 40: 379-386. https://doi.org/10.1603/0022-2585-40.4.379

Prevention, CfDCa (2016) Cost of the Ebola Epidemic Retrieved February 5, 2018 from https://www.cdc.gov/vhf/ebola/outbreaks/2014-west-africa/cost-of-ebola.html

Pye, JM, et al. (2011) Economic impacts of the southern pine beetle. In: Coulson RK, KD (ed), Southern Pine Beetle II. US Department of Agriculture Forest Service, Southern Research Station, Asheville, North Carolina, pp 213-222

Rademeyer, J. (2014, February 14). Untouchable? Wildlife crime kingpin Vixay Keosavang. EIA, Environment Investigation Agency, Washington, D.C. https://eia-international.org/blog/vixay-keosavang-an-untouchable-kingpin-of-wildlife-crime/

Rey Mallén, P. (2014, May 21). Coffee rust has claimed $1 B in losses and 250,000 jobs in Central America, US fears increase of migration. International Business Times. New York, NY.

Ringim, A, et al. (2015) Implication of invasive plant Typha domingensis on biodiversity: An ecological study of the Hadejia-Nguru wetlands, Nigeria. Scholarly Journal of Biological Science 4: 40-46.

Sachs, J, & Malaney, P (2002) The economic and social burden of malaria. Nature 415: 680. https://doi.org/10.1038/415680a

Singh, D, & Yi, SV (2021) On the origin and evolution of SARS-CoV-2. Experimental & Molecular Medicine 53: 537-547. https://doi.org/10.1038/s12276-021-00604-z

Soroos, MS (1997) The turbot war: resolution of an international fishery dispute. Conflict and the Environment. Springer, pp 235-252

Spijkers, J, et al. (2019) Global patterns of fisheries conflict: Forty years of data. Global Environmental Change 57: 101921. https://doi.org/10.1016/j.gloenvcha.2019.05.005

Srinivas, H, & Nakagawa, Y (2008) Environmental implications for disaster preparedness: Lessons Learnt from the Indian Ocean Tsunami. Journal of Environmental Management 89: 4-13. https://doi.org/10.1016/j.jenvman.2007.01.054

Steinsson, S (2016) The Cod Wars: A re-analysis. European Security 25: 256-275. 10.1080/09662839.2016.1160376

Steinsson, S (2017) Neoclassical realism in the North Atlantic: Explaining behaviors and outcomes in the cod wars. Foreign Policy Analysis 13: 599-617. 10.1093/fpa/orw062

Stone, R (2012a) Seeking cures for North Korea's environmental ills. Science 335: 1425-1426.

Stone, R (2012b) Seeking cures for North Korea's environmental ills. Science 335: 1425-1426. 10.1126/science.335.6075.1425

Tennesen, M. (2018, August 6). Blowing Up Illegal Fishing Boats Helps Indonesian Fishers. Scientific American. New York, NY.

Travis, J (2005) Scientists' Fears Come True as Hurricane Floods New Orleans. Science 309: 1656-1659. 10.1126/science.309.5741.1656

Turner, AK (2018) Social and environmental impacts of landslides. Innovative Infrastructure Solutions 3: 70. https://doi.org/10.1007/s41062-018-0175-y

Turner, MD (2004) Political ecology and the moral dimensions of "resource conflicts": the case of farmer–herder conflicts in the Sahel. Political Geography 23: 863-889. https://doi.org/10.1016/j.polgeo.2004.05.009

UNCT (2008) Haiti: Food crisis report Jul 2008. Haiti United Nations Country Team in Haiti,

Varano, SP, et al. (2010) A tale of three cities: Crime and displacement after Hurricane Katrina. Journal of Criminal Justice 38: 42-50. https://doi.org/10.1016/j.jcrimjus.2009.11.006

Verhoeven, H (2018) Environmental Politics in the Middle East: Local Struggles, Global Connections. Oxford University Press, Oxford, United Kingdom

Verma, AK, & Prakash, S (2020) Impact of Covid-19 on environment and society. Journal of Global Biosciences 9: 7352-7363. DOI: www.mutagens.co.in/jgb/vol.09/05/090506.pdf

Vinci, A (2005) The strategic use of fear by the Lord's Resistance Army. Small Wars & Insurgencies 16: 360-381. https://doi.org/10.1080/09592310500221336

Vittor, AY, et al. (2006) The effect of deforestation on the human-biting rate of *Anopheles darlingi,* the primary vector of falciparum malaria in the Peruvian Amazon. The American Journal of Tropical Medicine and Hygiene 74: 3-11. https://doi.org/10.4269/ajtmh.2006.74.3

Vittor, AY, et al. (2009) Linking deforestation to malaria in the Amazon: Characterization of the breeding habitat of the principal malaria vector, *Anopheles darlingi*. The American Journal of Tropical Medicine and Hygiene 81: 5-12.

WB (2020) The World Bank Group and the Locust Crisis The World Bank. Retrieved July 21, 2025 from https://www.worldbank.org/en/topic/the-world-bank-group-and-the-desert-locust-outbreak#1

Wellman, FL (1953) Americans face up to the threat of coffee rust. Foreign Agric 27: 1-7.

WHO (2016) World Malaria Report 2016. World Health Organization, Geneva, Switzerland

Wiener, A (2016) Contested norms in inter-national encounters: The 'Turbot War'as a prelude to fairer fisheries governance. Politics and Governance 4: 20-36.

Wolf, KM, & DiTomaso, J (2016) Management of blue gum eucalyptus in California requires region-specific consideration. California Agriculture 70. 10.3733/ca.v070n01p39

Wombwell, JA (2011) Army support during the Hurricane Katrina disaster. Combat Studies Institute Press, Fort Leavenworth, Texas

Woodham-Smith, C (1992) The Great Hunger: Ireland 1845-1849. Penguin Group, London, United Kingdom

Wright, JS, et al. (2017) Rainforest-initiated wet season onset over the southern Amazon. Proceedings of the National Academy of Sciences 114: 8481-8486. doi:10.1073/pnas.1621516114

Yoshida, K, et al. (2013) The rise and fall of the Phytophthora infestans lineage that triggered the Irish potato famine. eLife 2: e00731. 10.7554/eLife.00731

Zhang, HZ (2024) The South China Sea fishing crisis: The overlooked role of Chinese subnational governments. Pacific Review 37: 1090-1119. 10.1080/09512748.2024.2304805