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Perspective

From forests to factories: How modern slavery deepens the crisis of climate change

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ABSTRACT

Globally those in slavery, though small in absolute numbers (est. 40.2 million), contribute disproportionately to environmental destruction and carbon emissions. If modern slaves were a country, they would be the third largest emitter of carbon dioxide in the world, after China and the United States. Concurrently, anthropogenic changes to the global ecosystem have significant impacts on human life, creating vulnerability and displacement that drive modern slavery. This circular relationship is explored through the interaction of contemporary slavery with multiple anthropogenic processes recognized as "planetary boundaries." It is a key assertion that the study of human rights (and slavery in particular), and the study of anthropogenic impacts, have been falsely seen as distinct and separate issues. In this Perspective, we map an unfolding and extremely troubling nexus between slavery, environmental degradation, and carbon emissions. We break this challenge down into the interconnected processes of extreme weather, deforestation, biodiversity loss, and pollution from manufacturing and resource extraction. We discuss how climate change is a threat multiplier to slavery, but also how slavery is a threat multiplier to the causes of climate change. We conclude by offering compelling policy implications to address these threat multipliers, to help guide future research and policy pathways. Abolishing slavery is shown to be one of the most effective instruments for climate change mitigation, especially given that the costs of ending slavery seem on par to about $20 billion, or the expense of a single large nuclear power plant.

1. Introduction

Operating in the shadows, without regard for international laws, treaties, or environmental protections, slaveholders are decimating some of the planet's most ecologically vital places— the very ecosystems most critical for maintaining a stable climate, or potentially mitigating the impacts of global climate change. Modern slavery—defined as the subjugation (often through force or fraud) and possession of a person as if they are property including their control, use, management, and profit [1,2]— is placing under siege our national forests, wildlife preserves, and the protected homes and territories of indigenous peoples and endangered species. Whether slaves are extracting gold from Ghana, granite from India, or graphite from China, the impact of modern slavery on the natural climate is immense. From Eastern Congo to the Bangladeshi Sundarbans to the Brazilian Amazon, slave labor is routinely utilized by some of the most ecologically toxic industries on earth, like brick making, clear-cut deforestation, precious-woods logging, and strip mining.

Modern slaves are compelled to destroy their own livelihoods even as they undermine any chance of arresting global warming. As we will show in this Perspective, via manifold patterns of environmental destruction such as resource extraction, deforestation, manufacturing, and illegal logging, if modern slaves were a country, they would be the *third* largest emitter of carbon dioxide in the world, after China and the United States.

There are an estimated 40–46 million slaves in the world today, a number equivalent to a fairly small sized country such as Algeria [3]. But in practice this population of slaves is distributed widely around the world. Modern slaves are found in all countries except the smallest island nations, but with a widely varying prevalence - North Korea is estimated to have the largest proportion of its citizens in slavery (4.3% - most in state-sponsored slavery), and other high prevalence countries (for example, Cambodia, India, Pakistan, DRC) are likely to have around 1% of their population in slavery. [4] Even countries with well-functioning law enforcement and low levels of corruption (for example, Norway, the United Kingdom, or Canada) exhibit surprisingly

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Fig. 1. Global Population and Average Slavery Prices over the past Three Millenia (updated for inflation and to US$).

high rates of modern slavery, making its presence and pervasiveness not simply a problem for countries in the Global South.

One of the core drivers of slavery is, tragically, the falling costs of slaves. When slavery was widely practiced a few centuries ago, such as in the early 1800 s of the United States, a slave's average value or cost was equivalent to about US$40,000 (2021 USD). This was equivalent with the capital cost of 6 to 8 oxen – the prime agricultural motive force. However, as Fig. 1 indicates, the average acquisition cost of a person is now only about $90, less than one-fifth the cost of a single ox today in rural India. Using another comparator, in the Indian debt bondage slavery of today, the acquisition cost (price) of an enslaved worker is between 5% and 18.5% of the local annual wage rate for agricultural workers. Fig. 1 charts the fluctuation over time in the cost of slaves and the global population from 2000 BCE to the present [5].

This collapse in the acquisition cost of slaves, and its specific impact on the lives of slaves, as well as the profits of slaveholders, has had a transformative effect on the nature and practice of slavery. Put simply, when the cost of a human being falls to this level, they cease to be capital purchase items and instead become disposable inputs into economic processes or patterns of environmental rapaciousness. While the enslaved are put to a wide range of exploitative forms of work, very low levels of mechanization and high levels of pollution and environmental destruction mark that work. It is only relatively recently that the environmental impact of slave-based economic activity, in such enterprises as brick making, mining, and deforestation, has been investigated and measured. [6-8] Conflict, often driven by anthropic change, regularly results in forced migration of non-combatants, exacerbating their vulnerability to enslavement [9].

The implications of this radical diminution in the economic value of enslaved persons are significant – it leads to important changes in the way slaves are used and treated. Further, since this marked change in both the value and treatment of slaves has been caused by one of the central indicators of the Anthropocene, rapid population growth, it is reasonable to ask what might be the impact of other indicators or outcomes of the Anthropocene on global slavery.

In this Perspective, we look closely at this nexus between slavery, environmental destruction, and climate change. There is a deadly triangular trade going on today that reaches from threatened villages and forests in the most remote parts of the earth all the way to our homes in America and Europe. It is a trade cycle that grinds up the natural world and crushes human beings to more cheaply churn out commodities like the cassiterite and other minerals we need for our laptops and cell phones. Nevertheless, Boyd et al. caution that while "modern slavery and climate change have emerged as concurrent crises in the

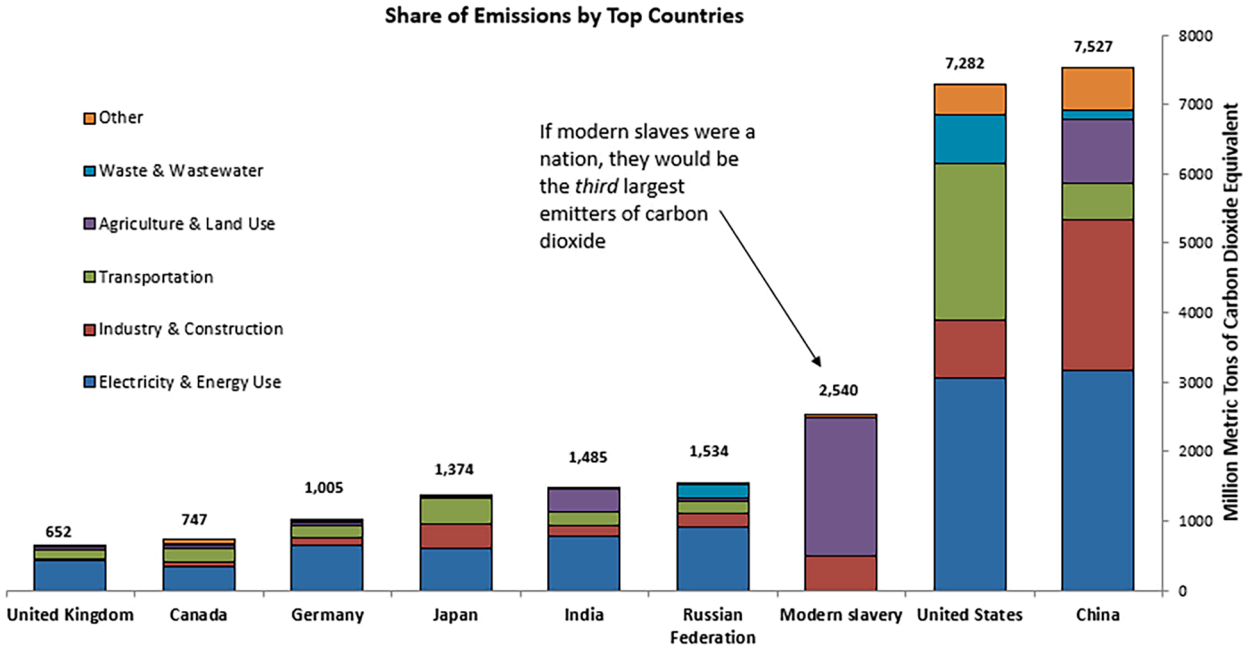

Fig. 2. The surprising contribution of modern slavery to global greenhouse gas emissions.

Table 1
Simple regression: Disasters and slavery.

Source |	SS	df	MS	Number of obs =167		
Model |	184.187311	1	184.187311	F(1, 165) = 60.97		
Residual |	498.417774	165	3.02071378	Prob > F = 0.0000		
				R-squared =0.2698		
				Adj R-squared = 0.2654		
Total |	682.605085	166	4.11207883	Root MSE = 1.738		
logGSI |	Coef.	Std. Err.	T	P>|t|	[95% Conf. Interval]	
disasters |	0.2274033	0.029122	**7.81**	**0.000**	0.1699034	0.2849032
_cons |	9.626986	0.1560641	61.69	0.000	9.318846	9.935126

contemporary world," they are studied in silos and "little discussion has taken place on the interconnections between them." [10] We break down this discussion into the interconnected processes of extreme weather, deforestation, biodiversity loss, and manufacturing and extraction. We examine how climate change is a threat multiplier to slavery, but also how slavery engenders a threat multiplier to the causes of climate change. We conclude by offering compelling policy implications to address these threat multipliers, to help guide future research and policy pathways. Although the role of slavery in ecological catastrophe is sobering, it also unleashes the prospective power of the abolition of slavery to preserve the natural world.

2. The slavery-environment-climate nexus

Altogether, the environmental cost of slavery is high—in contributing to climate change, deforestation, species loss, and even chemical and industrial pollution. Even a conservative estimate of all the CO_2 produced by illegal deforestation done with slave labor suggests that such actions are a major contributor to climate change. If slavery were a country it would have a population of some 40 million people and the gross domestic product of Angola, in global terms a relatively poor nation, but it would be the *third* largest emitter of CO2 (2.54 billion tons a year) after China (7.527 billion tons) and the United States (7.282 billion tons), numbers underscored by Fig. 2. If slavery were an American state it would have the population of California and the economic output of the District of Columbia, but it would be the world's third largest producer of carbon emissions. Moreover, the emissions from slavery are larger than the national emissions from Canada, Germany, and the United Kingdom *combined*.

The approximately 40 million people in slavery globally are a tiny fraction of the 7.8 billion people on the planet, but their environmental impact is inordinately large. They are forced to work in ways that are extremely destructive, not least because they are often enslaved in precisely those geographical areas that most needing safeguarding – protected areas of the Amazon, the Central African forests, and UNESCO World Heritage sites such as the Sundarbans mangrove forests on the India-Bangladesh coastline. How has modern slavery come to play such a huge role in the greenhouse gas emissions behind climate change? We explore four distinct patterns of the slavery-environment-climate nexus, which see slavery either contributing to greenhouse gas emissions or climate change exacerbating slavery.

2.1. Extreme weather and climate change

Extreme weather events, now accelerated or intensified by climate change, create conditions in which the vulnerability to enslavement increases. Globally, extreme weather events currently cause more casualties than other catastrophes [11]. Previous tropical cyclones and their damage to cities and coastal settlements have been known to drive refugees, destroy infrastructure, and render large numbers of people homeless and destitute. For example, cyclone Odisha generated a storm surge of six meters on the Indian coast in 1999; this led to some 15,000 fatalities and 1.6 million people made homeless. Hurricane Katrina struck the southern US states of Louisiana and Mississippi in 2005 killing 1,836 and making 500,000 homeless. In Peru, more than one-third of the country's glaciers have melted since 1970, causing floods and water scarcity that has seen a great migration of Peruvians into city areas to look for work, placing them at increased risk of exploitation [12]. More recently in Bolivia in the mid-2010 s, climate change contributed to the disappearance of the second largest lake in the country which then forced farming communities and indigenous communities to face a state of emergency and water rationing for hundreds of thousands of people in the cities of La Paz and El Alto [12].

This rapid forced migration creates refugees at rates similar to outbreaks of armed conflict. Given that Category 4 and 5 storms are expected to double in frequency by the end of the century [13,14],

increasing numbers of people will be pressed into increased vulnerability – which includes an increased vulnerability to enslavement. The same applies to a predicted increase in the frequency of great floods [15] that damage settlements, disrupt agriculture and ignite public health crises. The effects of climate change on water supplies in the armed conflict Yemen have been linked to 55,000 unnecessary deaths [12].

Changing weather patterns also mean disruption to food production. This can come about through an increased frequency and severity of fires, loss of alpine forests and other habitats, movement of vegetation zones and disruption to agriculture [16]. The impact on vulnerable populations is threefold. Firstly, food insecurity presses families into desperate decisions, including precarious migration and being drawn into job "recruitment" which is a conduit into enslavement. Secondly, lack of suitable nutrition saps the productive capacity of families, and stunts the human capital of youth, increasing their vulnerability to exploitation. Thirdly, food insecurity coupled with the movement of vegetation zones contributes to mass migration and converts many permanent populations into refugees. The famously documented plight of migrant "dust bowl Okies" of the 1930 s [17] is being replayed today in many diverse but damaged ecosystems. Future extreme weather and natural disasters could lead to worse patterns, not better ones. By 2050, it is estimated that there could be more than 140 million climate migrants—mostly from South Asia, Sub-Saharan Africa, and Latin America [18].

In Table 1 we use data derived from the Global Slavery Index[1] as well as other data sources to provide nation-state level information for 167 countries on the link between natural disasters and contemporary slavery. Looking at the simple relationship between human trafficking/slavery and natural disasters in Table 1, we see what appears to be a strong link. Table 1 presents the bivariate relationship between the *prevalence* of slavery in 167 countries and whether these countries had suffered a *natural disaster* within recent years. In this simple two-variable example, regressing the natural log of the GSI *slavery prevalence* measure on the number of *disasters* by country suggests the occurrence of a natural disaster dramatically increases the prevalence of slavery[2], and that disasters might explain up to 27% of the variance or difference in the prevalence of slavery across countries. We note that there are multicollinear effects when variables such as pandemic/epidemic disease and armed conflict are introduced. The precise estimation of these individual variables in specific countries or regions rests on the untangling of the nexus between environmental destruction and slavery, including armed conflict, disease, and natural disaster we describe in this Perspective.

2.2. Deforestation and land use change

Globally, after the burning of fossil fuels, deforestation is the second largest emitter of CO_2, and slave-based deforestation contributes a significant portion of those emissions [19]. When unregulated slave-based production in brick kilns, mining, quarrying, fishing, and agriculture are added, the volume of CO_2 emissions from slavery equals or exceeds that of many countries and industries. Without further exploration of the deeply forged links between the violations of human rights, and slavery in particular, on one hand, and illegal and/or tolerated environmental destruction on the other, appropriate solutions to the larger challenges of anthropogenic impacts will be elusive and amelioration unlikely.

The problems of land system change and slavery are tightly intertwined. Climate change drives land use change, making some landscapes untenable for agriculture and opening others to more intensive cultivation. Population pressure pushes land into use, and the resulting loss of biodiversity and carbon sequestration in forests exacerbates the negative influences of climate change. Specifically, the loss of protected forests to criminal logging using enslaved workers is extensive and releases large amounts of CO_2 into the atmosphere. Forest loss also promotes flooding and can be catastrophic for coastal communities experiencing storm surges from hurricanes and cyclones or tsunami.

Stocks of "wild" land that might be appropriately converted to cultivation are expected to be exhausted between 2020 and 2050 [20]. This conversion of ecosystems from "wild" to cultivated increases the power of other negative factors. Combined with climate change and poor cultivation techniques this can lead to, for example, forests in transition to deserts. Conversion of the rich and complex Amazonian forests to cattle grazing produces compacted soils that cannot absorb the extensive rainwater or support a lush ecosystem. Deforestation results in a denuded and eroded watershed, which then fails the communities that have depended on a constant flow of groundwater. This cycle of climate driven change is intensified by the effects of land use change and dislodges families and communities, reduces their productive and subsistence outputs, and increases their vulnerability to exploitation.

For the last twenty years, the amount of land and forests especially set aside as reserves and protected spaces has significantly increased. In the developing world this has meant a decrease in legal logging, but a dramatic increase in illegal smash and grab cutting. Put simply, criminals rushed into the vacuum created by new environmental treaties. Not caring about people or nature, they destroyed both in the process. Sometimes this attack was aimed at cutting and selling timber, but was often in support of lucrative slave-based commodities such as gold, minerals for electronics (such as cell phones or laptops), shrimp, or fish.

Both forest loss and coastal flooding can result in abrupt and dangerous migration. Small farming communities, with declining state support and facing increased marketisation in agriculture are more vulnerable to exploitative labor practices and human trafficking. Farming communities in particular are more likely to use informal, dangerous, or risky migratory channels following a natural disaster or environmental shock; agrarian communities are also more susceptible after such shocks to exploitation by criminal traffickers [21].

With the profits flowing back down the supply chain from our purchases of phones, computers, jewelry, and food for both our pets and ourselves, slave-using criminals make big profits from ripping up the earth's forests. A good example is the Sundarbans UNESCO World Heritage Site covering 4,000 square miles (10,000 square kilometers) of mangrove forest at the bottom of Bangladesh and India. Protected since the late 1970 s, this is the largest carbon sink in Asia, one of the largest mangrove forests in the world, and the special refuge and breeding grounds of the Bengal Tiger and many other endangered species. Here slaveholders cut the forest and install fish processing camps using child slaves, or clear and excavate the land to put in shrimp farms. The result is coastal villages, once protected by the mangrove forests, are now inundated when cyclones hit, causing widespread deaths and ruining the land for future farming. Meanwhile, pushed from their territories, Bengal tigers prey on the only small mammals left – the child slaves [19].

In Ghana, criminals force slaves to dig for gold in protected forests, and in doing so saturate the ecosystem with mercury, a poison and pollutant so potent that the land, plants, insects, animals and people living there will be affected for decades to come. The gold produced through slave labor flows into the global market and ends up in our wedding rings, jewelry and electronics. In Eastern Congo, armed gangs enslave whole villages to dig coltan and cassiterite for our computers and phones, or to cut and burn the Virunga Forest, Africa's oldest protected park and home of the mountain gorillas, to sell as charcoal.

In the Amazonian rainforest, debt-bonded labor and deforestation are intimately linked via illegal logging, to the production of charcoal (used primarily by the Brazilian export steel industry), as well as the cattle and palm oil industries that rely upon an exploited workforce. All of these activities lead to the clearing of the Amazonian forest, especially in the "deforestation arch" in the Northern parts of Brazil [21].

[1] *Global Slavery Index*, Walk Free Foundation, 2016

[2] Specifically, that a one-unit increase in disasters corresponds to a 22.7% increase in trafficking/enslavement.

Table 2
Type and number of species in two ecosystems.

Type of Species	Arctic Environment	Amazon Basin
Insects	3,000	2,500,000
Land Mammals	48	427
Reptiles	1	378
Amphibians	5	greater than400
Plants	1,700	greater than40,000

2.3. Loss of biodiversity

Species diversity is a biological resource – the more diverse and numerous the species within an ecosystem, the more resilient it will be. When rich, diverse forest habitats are clear-cut and the land is then burned over to remove other foliage, the environmental niches of thousands of species are destroyed and their existence becomes untenable. For most animals and birds this leads to displacement into neighboring ecosystems and increased competition with others of their species. For some insects, amphibians, and plants this is extirpation if not extinction. The potential for sustainable human use declines even as the land is brought into cattle or agriculture production. Table 2 points to the range of biodiversity catalogued by ecologists from the Amazonian maximum to the Arctic minimum (even the Sahara Desert has more species than the Arctic, especially reptiles), and helps to quantify potential biodiversity loss. Note the precarious nature of arctic environments and the relatively unknown complexity and extent of the equatorial rainforests – highly different but both equally vulnerable to anthropogenic damage.

A key characteristic of the transitions between past geological epochs has been species loss, and when more than 75% of species are lost over a geologically short time period, this is referred to as a "mass extinction." The current rate of species loss, though severe, has not yet reached a point to suggest that we are currently undergoing the planet's sixth mass extinction. However, the increasing rate of biodiversity loss, if unchecked, could achieve that dubious distinction in the relatively near future. This rate of loss is supported, as noted earlier, by the ongoing processes of ocean acidification, climate change, changes in atmospheric CO_2 levels, and habitat loss [22,23].

Although it is very difficult to calculate the impact of modern slavery and the loss of biodiversity, we do know that bonded labor is often used in overfishing and illegal, unregulated or unreported fishing, such acts

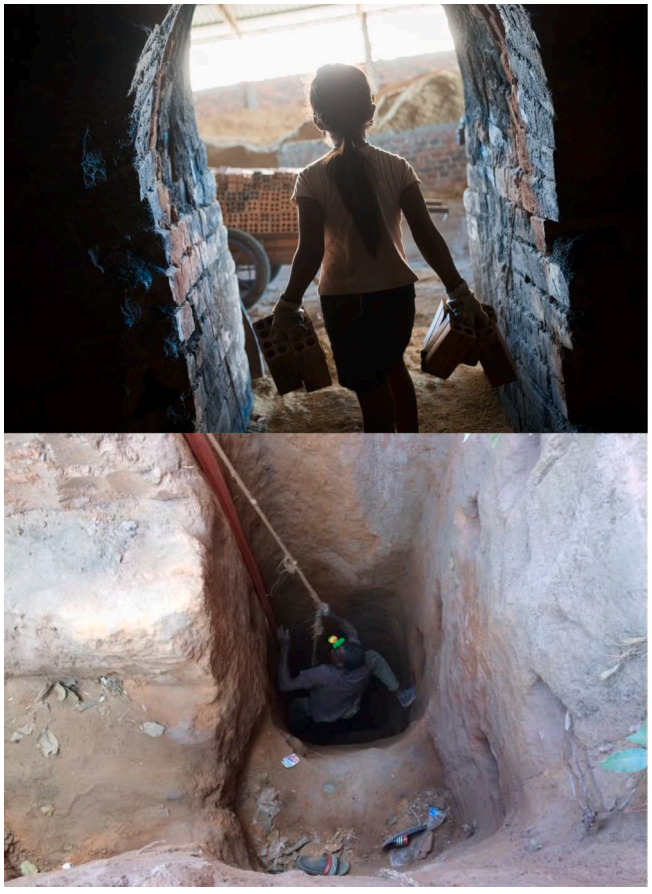

Fig. 3. Contours of modern slavery across Cambodia and the Democratic Republic of the Congo. Source: Authors including data from the Rights Lab. The authors thank Thomas Cristofoletti, Ruom. Copyright©2018 Royal Holloway, University of London, for permission to use the top image. Note: The top panel shows a 10 year old girl carrying fired bricks out of a kiln in Cambodia. Children that grow up on the kilns often end up taking on their parents' debt when they reach adulthood, making debt bondage intergenerational. The bottom panel shows a young cobalt miner indebted to a mining boss in the Democratic Republic of the Congo. Many young miners become permanently trapped into debt bondage through "subterranean" slavery.

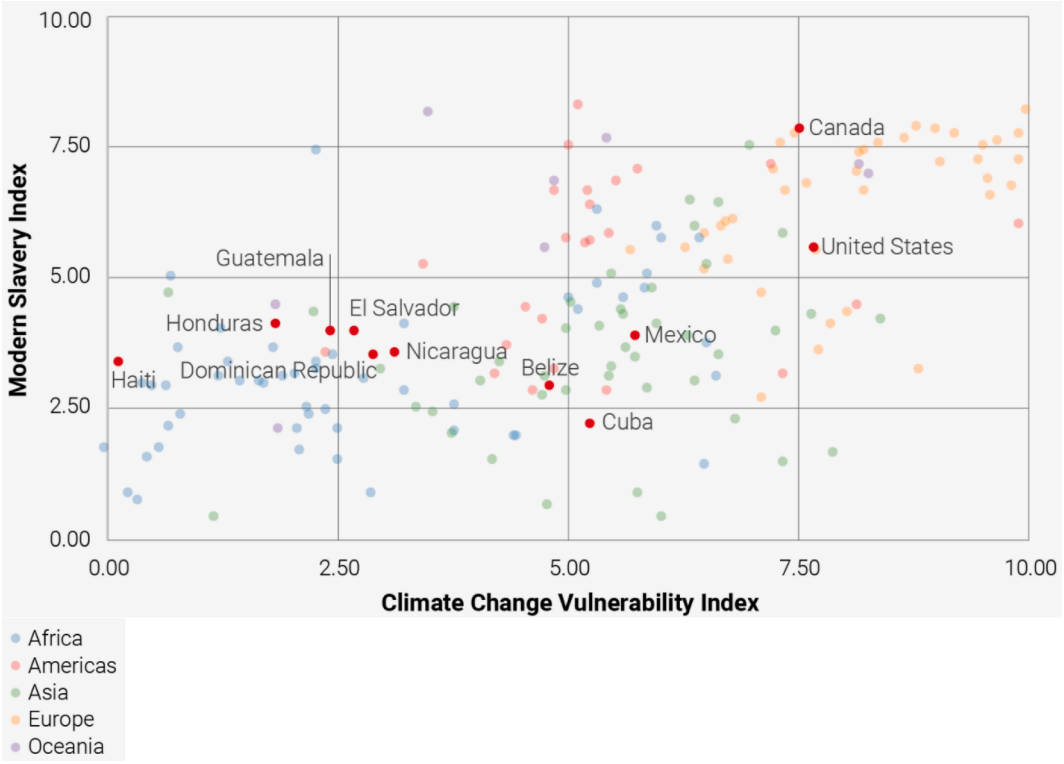

Fig. 4. Climate change vulnerability and modern slavery risks are strongly interlinked.
Source: [18]

which have led to the collapse of marine ecosystems around the world; such marine vessels are also a meaningful source of transit for human traffickers [24]. Roughly one-third of global fish catch is currently unsustainably caught, and slave labor and debt bondage are rife in the fishing sector. In Thailand, for instance, illegal fishing vessels depend on cheap and debt-bonded labor in order to survive, masking the actual economic costs of ecosystem decline and of months-long, long-haul fishing operations [21]. Modern slavery is also interconnected with patterns of displacement and forced migration, loss of subsistence, and the death of species around the world's forests and farms.

2.4. Resource extraction, manufacturing and pollution

Modern slavery often involves toxic materials or hazardous working conditions that can also accelerate environmental destruction and decline. Slaves can be required to use synthetic organic compounds such as pesticides, defoliants, and fuel additives to undertake their work. Other compounds are produced through mining and other processes, such as radioactive materials and highly poisonous cadmium, lead, and mercury, which are subsequently spread widely across the environment. Added to these is the atmospheric dispersion of nitrogen and sulfur oxides, a product of burning fossil fuels, which have health effects and contribute to acidification.

Biomagnification, the process by which the concentration of a substance is increased as it moves up the food chain, means that a pollutant like mercury increases in predator species such as spiders, birds, and some species of fish such as shark, swordfish, or mackerel, and then flows from them into the apex species - human beings. The resultant mercury poisoning, common among enslaved gold miners, is a weakening of resistance to disease and damage especially to the brain, nervous system, and organs. Taken together, the impact of these pollutants ranges from the trivial to the catastrophic and deadly – such as the Bhopal industrial disaster. For workers already enslaved in mining or other highly polluted workplaces, without protection against inhalation or absorption, their forced labor can become a death sentence [25]. Such exploitative and physically damaging conditions result not only in pollution, but often the ongoing impoverishment of families and increased vulnerability to a host of other problems including enslavement.

Other forms of modern slavery are deeply embedded into manufacturing or industrial processes. The production of bricks and operation of kilns throughout South Asia and Southeast Asia, especially the "brick belt" of India, Nepal, and Pakistan, or Cambodia, are well known for relying on debt or bonded labor [21]. Such brickmaking activities often use low-grade coal, charcoal, or other combustible materials such as tires to fire clay bricks. As a result, such kilns are highly polluting, contributing not only to greenhouse gases but also local air pollution and the global circulation of black carbon, a highly potent aerosol. In India particularly, for instance, Bull's Trench Kilns are one of the largest consumers of coal, where they require about 35 million tons annually and have a corresponding emissions profile of about 525,000 metric tons of carbon dioxide per year. In India, smallholder farmers often become ensnared as bonded laborers, along with vulnerable rural–urban migrants. In Cambodia, climate change has also worsened the income insecurity of small farmers, leading them to acute indebtedness, and in turn, debt-bonded labor in brick kilns, where their work is so dangerous their activities are often termed "blood bricks" [26]. Fig. 3 shows one young girl working in these kilns.

The extractive industries, especially the mining sectors, are also prone to recurrences of both slave labor and child labor [27]. In the Democratic Republic of the Congo, for instance, mining teams that extract much needed copper and cobalt (for mobile phones but also batteries for electric vehicles) report very high rates of child labor. One civil society group estimated that between 800,000 and 1 million miners were children under the age of 18. Patterns of exploitation and bondage are apparent, with one Congolese expert noting that "system benefits from a cheap workforce with little rights, access to information, markets, and protections" and that it reduces miners to "just workers and cogs in a

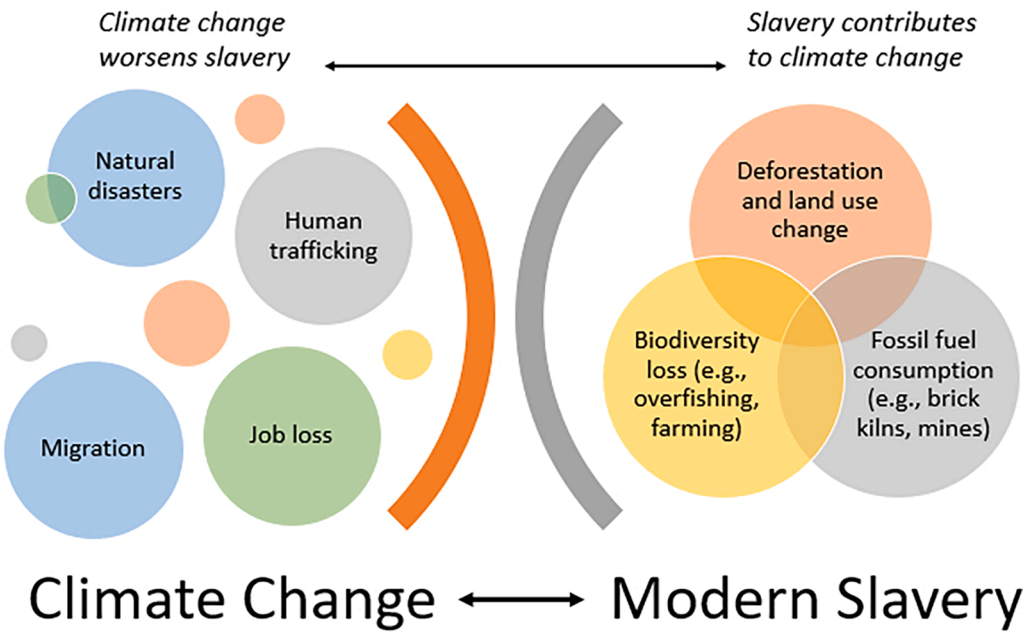

Fig. 5. Depicting the interlinked threats of modern slavery and climate change. Source: Authors.

machine, sort of like slaves." [27] Miners often speak about how their lives are no longer their own, and that they have become the property of their bosses or traders. One such miner is shown in Fig. 3.

These mining activities, similar to brick kilns, are also devastating to the environment and climate. They involve greenhouse gas emissions associated with land clearing, transport, and mining excavation, but also biodiversity loss and the destruction of natural habitats through mines and disposal sites. Air pollution occurs through emissions and discharges, especially from diesel engines, and siltation of wetlands and riparian areas from processing slimes is common. Mining waste often leads to changes in river ecology due to pollution, sedimentation, and flow modification, and abandoned mines contribute to soil erosion, land instability and ground subsidence [28].

3. Addressing climate change and modern slavery threat multipliers

Modern slavery, then, acts as a "threat multiplier" to climate change, something that takes existing causes or threats and multiplies them or makes them worse, impinging on global security [29]. These threats are felt most severely among the poor and disempowered in the developing world. The tensions and challenges cross and degrade multiple "planetary boundaries" [20,30] in ways that drive vulnerability and exploitation, such as armed conflict, forced displacement, political policies that increase discrimination, and exclusion based on ethnic, religious, or political difference. Also linked to this tension is political malfeasance and land and water "grabs" through which multinational and national corporations buy up or seize control of scarce land and water resources in poor communities, thus further alienating residents from natural resources. [31] Modern slavery becomes interlinked with other social and political threats, including high levels of corruption; the lack of economic and democratic freedoms; legal and social discrimination based on race, ethnicity, and/or gender; and extreme poverty.

Troublingly, when data from the Modern Slavery Index is plotted alongside the Climate Change Vulnerability Index (CCVI), the results shown in Fig. 4 are striking. The risks of modern slavery are most severe in the particular areas where climate change risks are also acute; in other words, all but one of the 20 most at risk countries in the CCVI are ranked as having a "high" or "extreme" risk for modern slavery. Furthermore, modern slavery risks are also "very significant" in countries along the main slavery migration routes into North America, especially Honduras, Guatemala, and El Salvador, the so-called "Northern Triangle" of human trafficking [18]. This suggests not only that modern slavery is a threat multiplier to climate change, but that climate change is also a threat multiplier to modern slavery.

Interestingly, there is a temporal dimension to the relationship between climate change and slavery as well. When a natural disaster occurs in a location or the impacts of climate change begin to unfold, they bring to an end the existing patterns of criminal trafficking and slavery. As with all other activities, in the wake of a cyclone or tsunami, there is an end to "business as usual" – including the criminal businesses of human trafficking and enslavement. Criminal enterprises rely on much of the same infrastructure of buildings, communications, and transport links as legitimate businesses. Criminal traffickers will flee before catastrophe arrives just as others do. The well-being of the people they control and exploit is another question, so their victims may be moved away from the threat, or abandoned to their fates.

However, for virtually all people who remain in the disaster zone or impact area, and many who flee, there is an onset of extreme vulnerability. The loss of public services, of water, power, sewage, transport, medical help, law enforcement, and food supplies can lead quickly to serious danger. Public health is threatened, and infectious diseases may spread rapidly. In the absence of health services even minor injuries and illnesses can become life-threatening. Without law enforcement crimes against the person can be committed with impunity. Virtually all people within the disaster zone will have dramatically increased vulnerability to any or all of these threats. So, while they may not be caught up in human trafficking, the average person is made more vulnerable to subsequent trafficking and enslavement. Disaster increases the pool of people who might be exploited through reducing protections and safeguards.

Moreover, criminal businesses and slaveowners are adaptable, innovative, and quick to respond to changing situations. The levels of risk criminal enterprises experience are rather greater than that of legitimate businesses, so they are familiar with rapid contingency planning and response. In the event of a natural disaster, criminals are just as likely as other residents to evacuate the area; and being criminals, they are more likely to have secure transport available and portable financial resources. In addition to their own personal safety they will be looking to preserve or remove needed equipment and tools as well as key

human assets. Once they have achieved self-preservation, they will consider and adapt to whatever opportunities they might perceive within the disaster and its aftermath. If the focus of their criminal enterprise has been exploiting people, they are likely to recognize the potential for the "recruitment" of prime workers in the context of heightened vulnerability.

Finally, those involved in trafficking and enslavement may adapt to the changing conditions brought by the natural disaster, altering or adapting the type of exploitation they practice. The situation in New Orleans after Hurricane Katrina is a good example. While pre-Katrina New Orleans was thought to have a significant number of people trafficked into commercial sexual exploitation, the market for that commerce ended abruptly with the demise of the tourist and convention trade. Immediately, however, there was an urgent demand for workers to clear wreckage, repair infrastructure, and re-build. The individuals needed to fulfil these jobs were mostly different to those who had been used in commercial sexual exploitation. So, a key result of natural disaster is the high likelihood that criminals are likely to change the types of exploitation they practice, if not the methods by which they "recruit" and control the individuals they intend to exploit.

Fortunately, this dualism of linkages between climate change, natural disasters and modern slavery means that addressing one also brings a co-benefit in terms of remediating the other. There is, for example, a possible two-step and relatively low-cost process that might mitigate the extent of both the continuing destruction of ecosystems and the rising levels of CO_2. The first step would be the adequate enforcement of international and national laws against slavery and related crimes. Abolition of slavery, after all, is a *jus cogens* legal standard within international law – meaning that its enforcement is required of all countries at all times – in the same way that the international law against genocide is also a *jus cogens* standard. The resources needed to enforce such laws and free slaves would be significant, but likely much less expensive than other proposed actions to limit carbon emissions such as the cost of expanding nuclear power generation or making large-scale changes to transport infrastructure.

At the current averaged rates of expenditure needed to remove people from slavery, the cost of freeing 40 million slaves is in the order of $20 billion over a ten to twenty-year period [32,33] . To put this figure into context, it is the current price tag of building a large nuclear power plant (the current estimate for Turkey's 4,800 megawatt Akkuyu plant, set to come online in 2023) [34]. Because slaves are used in work that is especially destructive to the environment, this expenditure would support the interdiction of environmental crimes and support the reinstatement of protections for ecosystems essential to carbon sequestration and species diversity. This estimated cost can be compared to the overall estimate that with the aggressive pursuit of "all of the low-cost abatement opportunities currently available, the total global economic cost [of mitigating climate change] would be €200-350 billion *per year* by 2030" [35].

The second step in this process would be the employment of freed slaves (who choose to participate) to rebuild, replant, support, and protect the natural areas they have been previously forced to exploit and destroy. A current key challenge in the liberation and reintegration of freed slaves is finding sufficient and appropriate employment – but reforestation and forest management can provide long-lasting employment for workers. Further, there is a potential funding source for such employment in the sale of carbon credits linked to reforested areas. That carbon credits could support reforestation of illegally cut forests, as well as support the re-entry of survivors of slavery into paid employment, creates a virtuous circle across the slavery-environment nexus.

Since the 1990s there has been steady upward growth in the size, diversity, resources, and skill base of antislavery work in both governmental and non-governmental sectors. The rates of growth and the spread of the participants and approaches are increasing. While the economic and human resources estimated to be required for a major reduction of slavery worldwide have not been achieved, the trend is positive and local eradication efforts have been successful.

If we project those trends, and assume adequate investment in antislavery activity, three clear outcomes obtain. Firstly, *slavery diminishes*, slowly and then more rapidly, leading to a fall over the next 30 years in the number of enslaved people worldwide from the currently estimated 40 million to something under one million, with the remaining slaves spread widely in small pockets of criminality or cultural oppression.

Secondly, the restoration of ex-slaves to lives that include productivity and increased consumption support a *freedom dividend* paid to local and national economies. This dividend is afforded not just in increased wages, capital formation, and consumption, but also in improved public health, education levels, decreased corruption levels, and increased political participation.

Thirdly, CO_2 emissions could eventually fall by an estimated 2.5 to 3 billion tons per annum, as illegal deforestation slows with a concomitant prevention of species loss. The employment of freed slaves in the replanting of forests they were forced to cut would also support increased carbon sequestration in woodlands. For the surrounding community such activity could create an *environmental dividend* for their societies, in terms of livelihoods *not* lost to changing landscapes, and decreased burdens on public health. Ending slavery would have a beneficial impact far beyond the fundamental human rights achieved, mitigating environmental loss and climate change, slowing the march toward the collective negative impact of human activity on environmental viability.

4. Conclusion

The link between slavery and environmental destruction and climate change has been shown to be circular, compelling, and calamitous. Climate change drives environmental outcomes that increase the risk of enslavement. Slaves are commonly forced into work highly destructive to the environment, which then increases the pressures on vulnerable populations. Slavery is also a burden upon economies; it removes people from the opportunity of education and human capital formation, while it springs from and supports corruption and conflict.

As Fig. 5 depicts, climate change is a threat multiplier to slavery, but slavery is also a threat multiplier to the causes of climate change. The transgression of planetary boundaries also creates conditions that increase vulnerability to enslavement, conditions in which vulnerable people can be tricked, lured, captured, or forced into slavery. Climate disasters lead to increased risks of trafficking, and that trafficking and slavery in turn leads to activities that degrade the environment or emit greenhouse gases.

Moreover, up until now, the study of human rights (and slavery in particular), and the study of its anthropogenic impacts on the climate have been falsely seen as distinct and separate issues and areas of inquiry. Human rights, however, do not exist in isolation from the natural environment; and the detrimental impact of anthropogenic change on the natural environment can be exacerbated by the diminution of human rights. This separation of the *cultural, social, and legal* from the *natural and environmental* is a false and potentially fatal dichotomy, one that only entrenches "climate precarity" [36]. The nascent idea of their interrelatedness may be clear within some policy frameworks, but where it has failed to gain traction is at the sharp end of both human rights violations and environmental destruction. It is in the crucible of enslavement that workers are being forced to commit, for example, large-scale illegal deforestation or dangerously polluting open-cast mining. These two violations of international human rights and environmental law reinforce each other and in doing so multiply their negative impacts.

When it comes to global warming, slaveholders outpace all but the very biggest polluters. Adding together their slave-based deforestation and other CO_2-producing crimes leads to a sobering realization. Slavery, one of the world's largest greenhouse gas producers, is hidden from us.

Environmentalists are right to call for laws, treaties and actions that will apply to the community of nations and global industries, but that is not enough. We also have to understand that criminal slaveholders—who don't adhere to those laws and treaties—are a leading cause of the natural world's destruction. And to stop them, we don't need more laws. We need to end slavery.

Remarkably, these figures offer more reason for hope than despair. Slavery is fundamentally illegal in every country, it is not debatable in the way climate change is sometimes treated in less educated or enlightened countries. And unlike fossil fuels, trees can be replanted and quickly resume their work of sweeping carbon from the air. What's more, freed slaves can be paid to replant the forests they've been forced to destroy, and the cost can be covered through carbon credits sold on the basis of the new forest's carbon sequestration. If one looks closely at slavery and climate change, it miraculously opens up new ways to reduce both.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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