Development Review

An intervention-focused review of modern slave labor in Brazil's mining sector

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ABSTRACT

Mining constitutes an important sector in Brazil's economy and has a history of modern slave labor. Brazil is the second largest producer of iron ore and manganese, a major exporter of gold and copper, and holds 40% of the world's Tantalum reserves. The aim of this review is to summarize literature on modern slave labor in artisinal and small-scale mining in Brazil's gold mining sector. Peer-reviewed and gray literature were screened for relevance and a total of 60 articles were included based on the inclusion and exclusion criteria. Findings indicate that miners in modern slave labor are often seasonal migrants and the severity of exploitation depends on the size, formality, and legality of the mines. A range of factors influence modern slave labor in ASM, including socio-economic discrepancies, seasonal labor migration, informality, weak sanctions against companies that use modern slave labor, and inadequte reintegration programs for victims. The significance of this study lies in its contribution to limited peer-reviewed literature on modern slave labor in ASM and its insights for designing and implementing effective, environmentally-conscious, and gender-sensitive interventions. The study underscores the urgency for addressing modern slave labor in ASM, given its adverse impacts on the workers' well-being, mining communities, and the environment.

1. Introduction

What if you were lured into a job offer in a remote mine without pay, protection, and consent? This is the reality for millions of people around the world who are trapped in modern slavery - a form of labor exploitation that violates their freedom and dignity. Working under exploitative conditions, modern slave laborers can be subjected to long hours, hazardous working conditions, wage-theft, confinement, violence, coercion, and threats (Zimmerman & Kiss, 2017; Kiss & Zimmerman, 2019; Sahai et al., 2021). These working conditions can occur in various sectors, such as agriculture, mining, construction, and domestic servitude, especially prevlaent in low- and middle-income countries where there is high demand for cheap labor (Brewer, 2009; Raigrodski, 2016), laws are precarious or poorly enforced (GTZ, 2008; Zimmerman & Kiss, 2017), and labor contracts are often absent or informal (Zimmerman & Kiss, 2017).

Modern slavery is particularly pervasive and concealed within mining—an industry characterized by a high demand for low-cost labor,

hazardous working conditions, lax regulation, and intricate supply chains that hinder tracing and monitoring of labor practices (LeBaron et al., 2018). As a leading mineral exporter, Brazil produces nearly 80 different mineral commodities, including iron ore, gold, manganese, bauxite, copper, nickel, and tantalum (OECD, 2022). In the past decade, the mining sector has generated more than one million jobs each year (Ministério da Economia, 2020). Although mining is of major importance to the Brazilian economy, it is also presents significant environmental and social challenges, such as pollution, deforestation, loss of biodiveristy, natural disasters (Alves et al., 2017; Garcia et al., 2017; Salvador et al., 2020), and modern slavery.

The issue of modern slavery in Brazil's mining sector primarily affects the informal and illegal artisanal and small-scale mining (ASM) sub-sector which contributes to approximately 20% of Brazil's mineral production and employs approximately 500,000 people, both directly and indirectly (Seccatore, Veiga, Origliasso, Marin, & De Tomi, 2015). These ASM workers often operate outside formal legal frameworks which compromises their access to social protection, health care,

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education, and credit. Moreover, they are susceptible to labor exploitation by intermediaries who lure them with false promises of high wages and subsequently entrap them in debt bondage or other coercive situations (Cremers et al., 2013).

Despite the gravity of the problem, there is limited information on the extent and nature of modern slave labor in Brazil's ASM sector. Most cases remain hidden or underreported due to fear of retaliation or lack of awareness. In 2018, the Global Slavery Index estimatated that around 369,000 people were in modern slavery, ranking Brazil among the top ten countries with the highest prevalence. However, the index does not specify the number of individuals affected within the mining sector. Moreover, little is known about the social dynamics of ASM workers, such as labor recruitment practices, job structures, living and working conditions, occupational safety, and labor protection mechanisms. Additionally, few interventions have been implemented to address modern slave labor in Brazil's ASM sector and there is little evidence to inform interventions aimed at reducing labor exploitation in mining. Thus, this paper seeks to provide an analysis of the nature of modern slave labor in Brazil's mining sector, enabling factors, consequences, and prevention efforts.

Findings are intended to guide policy and programmatic initiatives to ensure that interventions are well-targeted, cost-effective, build on previous efforts, and avoid erroneous investments in poorly designed strategies. To our knowledge, this is the first study to present findings specifically guided by a framework for the development of complex interventions (Skivington et al., 2021) and for the purpose of unearthing published evidence to help design well-targeted and effective interventions to address modern slave labor in the Brazilian mining sector.

2. Methods

The review was conducted as part of a larger mixed-methods formative assessment study to gather necessary evidence to design an intervention to reduce the prevalence of modern slave labor in Brazil's mining sector. Drawing on an Intervention Development Research (IDR) framework (Skivington et al., 2021), the research team developed a review protocol outlining the structure of the review, areas of inquiry, search strategy, selection criteria, and data extraction process. In consultation with subject experts, a comprehensive list of English and Portuguese search terms was developed to identify relevant articles on modern slave labor in the Brazilian mining industry. A variety of databses were searched for relevant articles, inclduing Science Direct, JSTOR, Google Scholar, Google, government websites, websites of stakeholders active in the mining sector, and news media outlets. In addition, bibliographies of identified sources were also scanned to find additional relevant sources of information.

Selected articles were uploaded to Zotero referencing software (Version 6.0.4) where articles were screened based on inclusion and exclusion criteria. Articles were eligible for inclusion if they met the following inclusion criteria: (1) conducted in Brazil; (2) focused on modern slave labor in the mining industry; (3) published between 2017 and 2022, with the exception of intervention evaluation reports that were published after 2010 and articles on the history of modern slave labor published after 2005; and (4) written in English or Portuguese. Articles were excluded from the review if they were op-eds, blogs, commentaries, and policy documents without empirical data.

Data concerning the labor conditions, recruitment practices, risk factors, supply chains, mining disasters, laws and regulations, and interventions were imported into Microsoft Excel. Shortlisted articles were analyzed using a detailed data extraction spreadsheet, which was developed using a thematic deductive approach. A total of 107 English and Portuguese articles were identified, of which 60 articles were included in the review after screening for relevance and removing duplicates.

3. Results

Findings are structured to align with the seven components of IDR methodology, applied to modern slave labor in the Brazilian mining sector. The seven components in include target problem, target group characteristics, risk and protective factors, modifiable determinants, economic implications, measurable indicators, and intervention evidence. The review is designed to address these components, which will then inform subsequent primary data collection to determine causal pathways and potential intervention mechanisms.

4. Target problem and contextual influences

4.1. Historical legacy of modern slave labor in Brazil

Brazil's role as a major player in the *trans*-Atlantic slave trade has left a deep and lasting impact on the country's labor practices. Being the last country in the Americas to formally abolish slavery in 1888 (The Brazilian Report, 2020), many workers in Brazil continue to face violations of their dignity and freedom. Many former slaves have entered into informal agreements with landowners that resemble slavery, especially in remote areas of the Amazon, resulting in debt bondage, physical violence, and other forms of exploitation since the 1960 s (Kaye, 2017; The Brazilian Report, 2020). Today, an estimated 370,000 people in Brazil live in these conditions even though more than 50,000 people have been rescued from slavery by Brazilian labor inspectors since 1995 (eCycle, 2021; SmartLab, n.d.).The artisanal mining sector in the Amazonian state of Pará is just one example of this ongoing struggle where workers face dire conditions and frequent violations of their rights. Although the precise number of modern slave laborers in mining mine workers without dignity or freedom is unclear, factors such as the nature of the industry, the isolation of mining sites suggest that there is a significant and concenrning number of exploited workers in this sector.

4.2. Definition of modern slave labor

The phenomenon of workers being held in conditions that violate their freedom and dignity is referred to as forced labor, slave labor, or modern slave labor in the literature (Belser, 2005; Gold, Trautrims, & Trodd, 2015; Crane, 2013). The United Nations and International Labor Organization conventions use the term "forced labor" and define it as work or service that is exacted from a person under the menace of any penalty and for which the person has not offered themselves voluntarily (ILO, 1930, n.29; ILO, 1957, n.105). This definition protects the worker's basic freedom to leave the workplace (Ruffini, 2019).

Brazil, on the other hand, has taken a broader approach to ensure worker protection. In 2003, the country formally recognized the importance of protecting both the freedom and dignity of workers (Phillips & Sakamoto, 2011). Brazil criminalized the reduction to a condition analogous to slavery, which includes practices such as forced labor, debt bondage, long working hours, and degrading or inhumane working conditions (Garreto, Baptista, & Mota, 2021). The types of conditions that are considered analogous to slavery include:

I. *Forced labor* is that which is required under threat of physical or psychological sanction and for which the worker has not offered himself or wishes to remain spontaneously.
II. *Long working hours* are any type of physical or mental work that, because of its scope or intensity, violates the worker's fundamental rights, particularly those related to safety, health, rest, and family and social interaction.
III. *Degrading working conditions* are any form of denial of human dignity caused by a violation of the worker's fundamental rights, particularly those guaranteed by labor protection and safety, hygiene, and health rules at work.

IV. Any *restriction of the worker's locomotion* due to debt is a limitation of the fundamental right to come and go or to terminate work due to a debt imputed by the employer or agent or the inducement to indebtedness to third parties (Brazil Penal Code, 1940).

This study uses the term 'modern slave labor' to refer to Brazilian workers who were recruited to work in mines under conditions that violated their freedom and dignity. This term is broader than slave labor (McGrath, 2013), which evokes the form of slavery that allowed owning people as property—a phenomenon that occurred in Brazil between the 16th and 19th centuries.

4.3. Overview of mining sector

The mining industry in Brazil can be classified into two categories: artisanal small-scale mining (ASM) and large-scale mining. ASM is the dominant form of mining in Brazil, accounting for about 70% of mining activity in the country and employing approximately 450,000 people, making Brazil the largest ASM worker population in South America (Souza et al, 2021; Springer et al, 2020; Intergovernmental Forum, 2021). This type of mining is often informal, unregistered, and carried out with little or no mechanization, requiring more human labor. In the case of gold mining, ASM only produces 20% of the output, but employs 80% of the workforce. In contrast, large-scale mining is a formal and registered process, producing 80% of the gold outputand employing only 20% of the workforce. The Tapajós River Basin, which is the world's largest ASM district, hosts Brazil's rapidly expanding ASM sector in the Amazon (Amazon Aid Foundation, 2021).

4.4. Environmental and social impacts of mining

Brazil is one of the world's leading mineral producers with a rich endowment of iron ore, gold, copper, tin, nickel, bauxite, and manganese. However, mining these resources entails considerable environmental and social costs for the Amazon region and its inhabitants. Mining activities have caused deforestation, biodiversity loss, atmospheric and water pollution, health issues, and human rights violations (Sonter et al., 2017; FBI, 2019). One major environmental challenge is the expansion of gold mining in the Amazon, especially in Pará state. According to MapBiomas (accessed 2022), the gold mining area in Brazil doubled from 99 thousand hectares to 196 thousand hectares between 2010 and 2021. Most of this expansion (91.6%) occurred in the Amazon region, with Pará state alone accounting for 113,777 ha of gold mining. Gold mining poses a serious threat to protected areas, such as indigenous lands and conservation units, where it often operates illegally and violently.

The main environmental impact of gold mining is deforestation. Mining requires clearing large areas of forest land which reduces forest cover and biodiversity. According to Sonter et al. (2017), mining constituted 9% of the total Amazon forest loss between 2005 and 2015 which amounts to 11,670 km2 of forest clearing. Brazil is the largest country in the Amazon region and is responsible for half of its deforestation, which could cost up to $35 trillion USD in social and economic losses over the next thirty years (Abdenur et al., 2020).

Another severe environmental impact of mining is mercury pollution. Mercury is commonly used to recover gold, which can contaminate water sources and cause serious environmental damage (Springer, Peregovich, & Schmidt, 2020). Mercury contamination also poses a health risk for Indigenous communities who live in the Amazon and rely on fish as a staple food source. A study of the Munduruku people in 2020 found that 58% of participants had mercury levels above safe limits in their blood, compelling them to reduce or stop eating fish which compromises their nutrition and cultural practices (Wanderley et al., 2021; Risso & Sekula, 2021). Moreover, mining activities often encroach on Indigenous lands which has led to increased conflict and violence between miners and Indigenous people, consequently threatenening their culture and identity.

5. Target group Characteristics, needs and preferences

5.1. Worker characteristics

The hidden nature of modern slave labor in ASM makes it difficult to determine exact prevalence of workers in exploitative conditions. However, in general, marginalized groups such as Indigenous Peoples, religious minorities, and members of the LGBTQIA + community are reportedly at higher risk of becoming victims of modern slave labor (ILO, n.d., Hickman, 2021). Historically, mine workers in the Amazon region are single or separated men, with low levels of education, and migrating from the Northeast region of Brazil (Sonter et al., 2017). The SmartLab Initiative estimates that, among rescued mine workers between 2003 and 2020, 30% of victims were between the ages of 18 and 29, 23% between ages 30 and 45, and 45% were older than age 45. Although over 90% of individuals in each age group were male, it should be noted that many peripheral groups around modern slave labor who are predominantly female, such as sex workers, care givers, and domestic workers may not have been found in these rescue operations. Additionally, almost half of all rescued workers identified as "brown" or mixed race, and one in three workers were illiterate (SmartLab, n.d.). Interest in working in ASM is driven by individuals in need of quick income because mining requires lower levels of education compared to employment in the formal sector (Springer et al, 2020). The prevalence of child miners is difficult to measure, but growing evidence points to an increase in child laborers to meet increasing global demand for mined materials (Ray, 2018).

5.2. Living and working conditions of workers who are recruited in modern slave labor

Brazilian miners in modern slave labor face harsh and unsafe living and working conditions that violate their freedom and dignity. In terms of living conditions, workers live in overcrowded and unsanitary shacks without clean water, toilets, electricity, or ventilation. They also lack other basic necessities such as food, medicine, education, communication, and personal protective equipment (PPE) such as hard hats, eye protection, hearing protection, respiratory devices, or self-contained self-rescue equipment (Aranha, 2018; Springer et al, 2020). Many workers are trapped in these exploitative situations through debt bondage—an arrangement where they are only permitted to spend their wages inside of the mining village and are often subjected to arbitrary fees that exceed their earnings. For example, they must buy all food, PPE (when available), and other necessary products from the local store at prices 5 to 10 times higher than in the city.

In terms of working conditions, miners are exposed to various health risks, especially those in ASM. They have an increased risk of respiratory problems due to high levels of airborne toxins in the dust generated by mining, mercury poisoning from gold extraction, malaria and parasitosis from contaminated water, and snake bites (Souza et al, 2021; Springer et al, 2020; Nascimento et al, 2019). Although the use of PPE is mandatory for mine workers in Brazil by Law n. 11,685, many workers are not provided with essential PPE or are forced to buy their own (de Araújo Freitas Leão et al, 2020). This not only leads to additional workplace injuries and illnesses for those who cannot afford adequate protective gear, but also increases workers' debt burden (Aranha, 2018; Souza et al., 2021).

6. Risks and protective factors

6.1. Enabling environment

Modern slave labor in Brazil's mining sector is facilitated by socio-economic discrepancies between areas with mining operations versus

those without mining activities. Despite negative externalities, such as environmental degradation, pollution, and biodiversity loss, gold mining operations bring wage jobs, infrastructure, and local development to areas in which they operate. For example, some miners can achieve social mobility by gaining experience and becoming owners or entrepreneurs with political influence (Kligerman et al, 2001). The sparsity of wage jobs in non-mining areas intensifies migration to mining areas, consequently amplifying workers' vulnerability to exploitation due to factors such as pressure to send remittances home and lack of social networks around mining sites. The lack of alternative wage jobs further undermines workers' leverage and choice (Monteiro et al, 2019). Additionally, the remote location of gold mines means that workers are far from urban areas where police and law enforcement authorities are typically located, facilitating modern slave labor in areas with few governing structures in place. Further, access roads are precarious in these areas and communication infrastructure is extremely limited (Arbex et al, 2018; Springer et al, 2020; ILO, n.d.).

6.2. Barriers for government intervention

One of the main barriers for government intervention to address modern slave labor in the gold mining sector of Brazil is the lack of a clear and consistent definition of what constitutes this phenomenon. According to Arbex and colleagues (2018), investigators, law enforcement, judges, and other stakeholders have varying and confusing interpretations of the minimum conditions for decent work (Brandão, 2021; Mendes & Mesquita, 2018). This ambiguity makes it difficult to identify and prosecute cases of modern slave labor in the mining industry.

Another barrier is the limited resources and capacity of government agencies responsible for enforcing existing policies and regulations. The Special Mobile Inspection Group (GEFM), which has been operating since 1995 to combat modern slave labor, has only 17 auditors working in groups of 4 as of 2020 (Angelo, 2020). The Federal Police which collaborates with GEFM on raids, has also faced constraints due to COVID-19 and staffing shortages. Although satellite imagery can help locate illegal mining sites, law enforcement institutions lack the necessary resources to conduct effective operations and curb illegal mining (MapBiomas, 2019). Moreover, some private sector agents who seek to expand mining operations often receive support from law enforcement to settle land conflicts in their favor, disregarding the interests and rights of local communities (Amaral & Hauradou, 2020).

A third barrier is the political influence of the mining industry at the national level. Wanderley et al (2021) argue that the mining lobby has been able to pressure the government to relax some measures against illegal mining. For example, in September 2019, the government agreed to stop destroying machinery found in illegal mining operations which previously served as a deterrent for illegal miners. This decision was criticized by environmentalists and human rights activists who claimed that it would encourage more illegal mining and exploitation (Wanderley et al., 2021). Other media outlets such as eCycle, InSight Crime, and Reuters have also reported on how the mining sector's political influence undermines initiatives to combat modern slave labor. These sources provide credible evidence of the challenges faced by the government to regulate the mining sector and protect workers' rights.

6.3. Labor Recruitment, contracts and formalization

One of the main characteristics of the Brazilian mining sector is the prevalence of informal ASM operations which involve *donos de garimpo* (managers or owners of the mines) and *garimpeiros* (workers). According to Springer et al (2020), workers do not have formal employment contracts and are paid in a percentage of the extracted gold which is shared among groups of approximately five people. This remuneration system originated in the 1970 s as a way of giving workers a stake in productivity. However, this arrangement became more exploitative in the 1980

s with the mechanization of mining which increased workers' dependency on the owners' capital investment and reduced their shares from 50% to 40% or 30%. The mechanization of mining also exacerbated working conditions, leading to more accidents, restrictions on freedom, and violence (Wanderley, 2015). This means that workers face financial insecurity because wages depend on how much gold they extract. In some remote Amazon locations, this situation can also result in modern slave labor where workers are trapped in debt bondage (de Araújo Freitas Leão et al., 2020).

Another factor that contributes to informality in the mining sector is the difficulty of obtaining legal permits from the Agência Nacional de Mineração (ANM) which was established in 2017 to regulate the sector. Many *donos de garimpo* are illiterate or have low levels of education that hinder their ability to file claims with ANM. It is estimated that only about 10% of ASM in the Tapajós Region in the Amazonian state of Pará is legal. However, some *garimpeiros* prefer to work informally, as they value their freedom to leave at any time and the option of becoming wealthy quickly if they strike gold. On the other hand, informal contracts lack adequate protection, such as guaranteed income, compensation for illness or accidents, and job security (Springer et al., 2020). It is important to note that informality is not unique to the gold mining sector; it affects almost half of the Brazilian workforce across different sectors. According to a 2020 survey by the Instituto Brasileiro de Geografia e Estatística, 47.1% of employment in Brazil is informal (IBGE, 2020).

6.4. Debt bondage and movement restrictions

Debt bondage constitutes one of the main forms of modern slave labor in Brazil's mining sector. Miners are recruited by *empreiteiros* or *gatos* (intermediaires) who target rural workers in need of income during periods of low agricultural activity or drought (Harnoncourt, 2020; Issa, 2017). Workers are transported to distant gold mining sites where they are immediately trapped in debt bondage and forced to purchasefood, tools, protective gear, and housing, despite having already paid substantial recruitment fees. Workers are not only confined to mining estates until they pay off their debts, but are also subjected to confiscation of their identity documents and work permits which further prevents them from leaving (Free the Slaves, n.d.; Newell, 2020; Al Jazeera, 2020). Moreover, some workers face physical threats, humiliation, or punishment by armed guards if they try to escape before clearing their debt.

6.5. Modifiable determinants

In this section, we explore literature on potentially modifiable factors that may be targeted through appropriate interventions to prevent and reduce modern slave labor, and support individuals in leaving and recovering from exploitative work conditions. We also highlight local resources identified in the literature that could be useful in addressing modern slave labor in Brazil.

6.6. Labor protection

Brazil's legal and judicial system presents a formidable challenge for combating modern slave labor in Brazil is the legal and judicial system. Currently, there are three types of modern slave labor cases that most frequently move through the court system: i) degrading conditions; ii) degrading conditions and debt servitude, and iii) degrading conditions, weapons and surveillance (Hickman, 2021). In an analysis of all modern slave labor or exploitation cases in court systems between 2008 and 2020, 84% of cases were categorized as degrading conditions, 13% were degrading conditions and debt servitude, and about 3% were degrading conditions, weapons and surveillance. Debt servitude is perhaps the easiest element of modern slave labor exploitation to prove because employers often keep physical workbooks tracking the debts (Hickman,

2021). However, although workbooks can help track debts, some judges require evidence of lack of freedom associated with the debt to convict an individual for perpetuating modern slave labor (Garcia, 2020).

Another challenge for combating modern slave labor in Brazil is the lack of effective sanctions against companies that use modern slave labor. One of the most notable initiatives to address this issue is the Dirty List. Established in 2004 by the former Ministry of Labor and Employment, the Dirty List includes the names of companies that use modern slave labor as identified by the Labor Inspection Secretariat. Firms remain on the list for two years during which they cannot access government credit or condcut business with Brazilian and international companies. However, labor rights advocates note that injunctions can be temporarily removed from the Dirty List and modern slave labor cases can take up to 10 years to reach a verdict (Newell, 2020), underscoring the need for more transparency and accountability in the Dirty List mechanism.

When a worker is rescued from modern slave labor, one of the primary concerns is the victim's reintegration into the Brazilian labor market. The government provides some assistance to rescued workers, such as three installments of Unemployment Insurance, where each installment is equivalent to the minimum wage amount as defined by Law n. 10.608/2002 and Bolsa Familia—a social program that provides financial assistance to families living in poverty or extreme poverty (according to the Decree N. 177 of June 16, 2011). However, these benefits are often insufficient or inaccessible for many workers who face difficulties in finding alternative employment, accessing education or training, or obtaining legal or psychological support—all of which highlights the need for more comprehensive and tailored reintegration programs for victims of modern slave labor.

Brazil is a founding member of the International Labor Organization and has ratified 96 International Labor Conventions. However, some of these conventions are not fully implemented or enforced in Brazil (e.g., Convention No. 29 on Forced Labor and Convention No. 105 on the Abolition of Forced Labor), emphasizing the need for better alignment and compliance between Brazil's national laws and international standards on modern slave labor. Relatedly, it is also crucial to recognize that women engage in various tasks within ASM, including domestic work and sexual services (Buss et al., 2019). By acknowledging the multifaceted roles that women play in ASM, we can shed light on the potential vulnerabilities they face, such as exploitation and modern slave labor. Ratifying Convention No. 189 on Decent Work for Domestic Workers can serve as an essential step towards protecting the rights and well-being of millions of domestic workers, mitigating the risk of modern slave labor and exploitation in this sector.

Another possible point for intervention is the role of trade unions in protecting workers' rights and preventing modern slave labor. Trade unions can help workers organize, bargain collectively, access legal assistance, report abuses, and demand better working conditions (Alves et al., 2021). However, trade unionism in Brazil is weak and fragmented, especially in rural areas and the mining sector where workers are often isolated and vulnerable.

6.7. Labor inspections

Labor inspections are key to influence modern slave labor outcomes in Brazil. Various officials are tasked with inspecting mines and workplaces to enforce standards, combating illegal mining, and rescuing victims. These officials include the Special Mobile Inspection Group (GEFM), the National Mining Agency (ANM), and military-run protection outposts in Indigenous Reservations to combat illegal mining (Hernandez et al., 2020).

GEFM is a government task force that rescues modern slave labor victims in collaborationother agencies (e.g. Federal Police, Public Ministry of Labor, Federal Prosecutor's Office). GEFM also participates in intelligence-sharing to build cases and receive reports from environmental agencies like the Brazilian Institute of Environment and Renewable Natural Resources (IBAMA) and Chico Mendes Institute for Biodiversity Conservation (ICMBio). However, GEFM's labor inspection efforts are thwarted by resource constraints and political interference. GEFM's limited staff capacity of only 17 auditors considerably restricts their efforts, indicating their potential for much greater impact with increased investment and support.

ANM is tasked with preventing modern slave labor and ensuring that legal mining companies stay within their production quotas and use approved technologyHowever, the director of ANM recently stated that illegal mining operations are quick to reappear once authorities leave the area. As of 2021, ANM employs just 250 inspectors to monitor about 35,000 mining sites across the country. Inspection efforts were further compromised during the COVID-19 pandemic (Jones, 2021), highlighting the need for better oversight and accountability.

7. Economic and cost implications

7.1. Supply chain and corporate practices

The use of modern slave labor in mining varies depending on the size and level of formalization of mining operations in Brazil. Informal and artisanal mines operate outside the government's control, while large-scale and transnational corporations can be held accountable for the negative impacts of their operations. ASM workers do not have employment contracts and earn wages based on a percentage of substances that they are able to extract (Springer et al, 2020). These substances are sold to refiners or processors, who then sell to wholesalers for retail in domestic and international markets.

7.2. Relationship between legal and illegal actors

Modern slave labor prevention initiatives should consider economic realities that vary between illegal and legal mining operations, and consequently affect the type of workers recruited, recruitment practices, payment methods, and working conditions. Understanding the legality of operations also helps practitioners find the best entry points for interventions along the supply chain. For example, although gold is significant export commodity from Brazil's northern most state of Roraima, there are no legally registered mining operations in Roraima. Most of the gold in the state is believed to be on the Yanomami reservation and is being extracted illegally, with much of it being exported to India (Hernandez et al., 2020). Illegally extracted gold can enter the supply chain if it mixes with legal gold at certain collection points. According to a study by Manzolli et al (2021), there are two major ways in which this happens. First, the seller uses a current mining title to present the gold, after which the buyer can register the transaction using legal mining titles and without verifying its true origin. Another option is for the miner to declare that he extracted the gold based on a mining title in effect in a specific location, even if the gold did not originate there (Manzolli et al, 2021). A deeper understanding of the mechanisms for masking the illegal source of minerals can inform initiatives to disrupt them.

Indigenous Peoples have been resisting the pressures of mining on their lands for decades and continue to push for the removal of illegal mines from their territories. Overall, Brazilian law forbids mining on Indigenous lands except under certain conditions. Although according to Federal Constitution articles, mining on Indigenous land requires approval of the Congress in the form of legal provisions, there is no constitutional regulation.

7.3. Measurable indicators

Initiatives addressing modern slave labor in Brazil's mining sector require context-relevant measurement approaches and indicators to assess impact and progress. However, measurement approaches largely depend on locally used definitions of modern slave labor. The Brazilian legal definition of work conditions analogous to slavery is more

comprehensive than the ILO definition of forced labor and includes specific components, such as debt bondage, degrading conditions, long hours, and restriction of freedom, some of these components are easier to measure than others.

Potential outcome indicators may vary depending on the type of initiative and the definition of modern slave labor used. For instance, the Social Life Cycle Assessment (SLCA) is a method that can be used to assess the social aspects of products or services along their life cycle, such as the working conditions of miners. SLCA can estimate both positive and negative impacts and can be used for initiatives like the one conducted by Springer et al. (2020) to assess the social impacts of ASM sector in the Tapajós Region in Pará. However, SLCA may not capture all the elements of modern slavery that are relevant for prosecutions.

The ILO has the longest history of conducting prevalence estimation research in Brazil and considers the country as an international reference for fighting modern slavery. The ILO used its 'Harder to See, Harder to Count' method to measure prevalence in 2017 for Maranhão state in Brazil. This method combines different sources of data, such as surveys, administrative records, and media reports, to estimate the number and profile of victims of modern slave labor and child labor. In addition to exploring current evidence, this study collected mixed-methods data from rescued workers, public agents, and researchers involved in the fight against slave labor.

7.4. Intervention evidence

In this section, we argue that current interventions to address modern slave labor in Brazil's mining sector are insufficient and ineffective, and that more comprehensive and coordinated actions are needed to tackle the root causes and consequences of this problem. We base our arguments on a review of the existing literature and initiatives implemented by private sector, international institutions, and non-governmental organizations, as well as on some emerging mechanisms that have potential to improve the situation. We evaluate the strengths and weaknesses of these interventions from an impact and sustainability perspective.

7.5. Private sector

Historically, mining companies in Brazil have implemented corporate social responsibility (CSR) initiatives through which they establish company towns that provide housing, education and health services for workers and their families around their facilities, and simulatenously also invest in public infrastructure (e.g., roads, lighting, and sanitation). According to Cornejo and colleagues (2010), this "philanthropic and paternalistic" approach has led to dependency on these companies and huge disparities between these areas and surrounding municipalities. For example, the S11D iron mine led to improvements in many socio-economic indicators, but also created inequality within surrounding areas that attract migrants who are then vulnerable to modern slave labor (Matlaba et al, 2017). This suggests that CSR initiatives are not enough to prevent or reduce modern slave labor in the mining sector. In fact, they may even create or exacerbate some of the factors that contribute to modern slave labor, such as poverty, lack of opportunities, and social exclusion.

Outside of this older CSR model, private sector actors are now focused on supporting formalization of the mining sector. Some gold cooperatives are participating in the Garimpo 4.0 project. Sponsored by the National Gold Association, the project promotes formalization, training, environmental conservation, legal compliance, and using traceability to help miners get better gold prices (Intergovernmental Forum, 2021). Formalization is a key step to improve the working conditions and protect human rights of miners, as well as to reduce the environmental impacts of mining. However, formalization alone is not sufficient to address modern slave labor in the mining sector, as it does not guarantee fair wages, decent work standards, social protection, or

access to justice for workers. Moreover, formalization may face resistance from some actors who benefit from the informality and illegality of mining, such as criminal networks or corrupt officials.

7.6. International institutions

International institutions, including the United Nations Office on Drugs and Crime (UNODC), Intergovernmental Forum (IGF), and International Labour Organization (ILO), have implemented large-scale interventions addressing modern slave labor in Brazil, either generally or specifically in the mining sector. UNODC'sTRACK4TIP initiative is a three-year (2019–2022), US $3 million initiative that designed an online platform to provide trainings on human trafficking and modern slave labor to build the capacity of GEFM (UNODC, 2020). In 2018, the IGF ran a capacity-building program for Brazilian officials that presented a step-by-step process for governments to develop, implement, and monitor an effective ASM management strategy. Following the workshop, Brazil's Ministry of Mines and Energy created anASM taskforce that is leading the government's drive for formalization and environmental, social, and economic sustainability in the sector (Intergovernmental Forum, 2021).

Funded by the United States Department of Labor (USDOL) and implemented by the ILO, "Consolidating and Disseminating Efforts to Combat Modern Slave Labor in Brazil and Peru" was a US $6.8 million technical trilateral cooperation initiative from 2009 to 2015. The intervention consisted of a wide variety of components, including strengthening Brazil's National Committee for Eradicating Modern Slave Labour (CONATRAE), building government capacity to develop municipal indicators of decent work, facilitating socio-economic reintegration of rescued workers, and producing technical documents and facilitating knowledge exchange.

However, an independent evaluation of this intervention found that despite concerted efforts to promote knowledge sharing and build communities of practice, disconnects between different intervention approaches weakened the potential for tripartite collaboration between the three stakeholder groups. The siloing of intervention arms to create social dialogues on modern slave labor, improve government's capacity to implement public policy around modern slave labor, and engage the private sector and employer's organizations to combat modern slave labor highlights missed opportunities for synergies between stakeholders. In addition, the evaluation found that althought the intervention positively influenced the availability and quality of information on modern slave labor in Brazil, there was low uptake of some products (Digital Observatory, Direct Beneficiary Monitoring System) and limited institutional capacity to disseminate information to different vulnerable groups (Femenía & Sprandel, 2019).

7.7. Non-Governmental organizations (NGOs)

There are several important NGO initiatives addressing modern slave labor in Brazil that do not have publicly available evaluations. Launched by Reporter Brazil, *Escravo, Nem Pensar!* is one of the largest coordinated efforts educational programs. Though this is a primarily advocacy-based initiative, the program also developed a social assistance program in which professionals working in the Single Social Assistance System/O Sistema Único de Assistência Social (SUAS) contribute to the elimination of modern slave labor by supporting socioeconomically vulnerable people (Reporter Brasil, 2021). Free the Slaves implemented a project from 2009 to 2016 that included three components: educating rural workers living in vulnerable communities about the threat of slave labor; advocating for the inclusion of modern slavery survivors and vulnerable communities in government run programs; and advocating for the enactment of new anti-modern slavery laws and policies at the federal, state and municipal levels, in particular regulations for the private sector such as the Dirty List (Free the Slaves, n.d.).

8. Discussion

The review synthesizes evidence on the nature of modern slave labor in Brazil's mining sector, enabling facors, consequences, and prevention efforts to inform the design of well-targeted and effective interventions. Findings indicate that modern slave labor is a common, yet hidden phenonmenon in Brazil's ASM sector, affecting thousands of workers, especially those in remote and informal mining sites. Seasonal labor migration brings workers to remote sites where they face debt bondage, movement restrictions, degrading living and working conditions, violence, and coercion. Intermediaries recruit workers with false promises of high wages and trap them in debt cycles or other coercive mechanisms. Modern slave labor in the ASM sector not only compromsises workers' occupational health and safety, but also poses severe environmental and social threats to mining communities.

Findings from this review underscore the importance of context-specific definitions of modern slave labor both for actions to protect workers and to develop relevant measurement indicators for prevalence surveys and intervention evaluations. Research and programming efforts should also consider the size, formality, and legality of the mining operations. Large-scale interventions that work with the formal private sector must consider the history of CSR initiatives in Brazil and their unintended consequences, such as creating high levels of inequality between mining areas and neighboring communities that intensify migration and migrants' vulnerability for working conditions analogous to slavery. Interventions that target informal ASM in Brazil should consider the hurdles that mine operators need to overcome to formalize their operations and whether they are located on Indigenous lands.

Importantly, although formalization is viewed as a means to control the ASM sector and manage social and environmental impact, interventions promoting formalization should be carefully developed and implemented. Numerous examples from other geographic contexts illustrate the pitfalls of formalization initiatives. For instance, although formalization is the precursor to cleaner production, researchers found that formalized operations in Colombia were not using cleaner methods (Veiga & Marshall, 2019). In Peru, despite years of promotion and planning, the government managed to formally register only half the number of artisanal and small-scale miners, highlighting their lack of technical capacity (Veiga et al., 2014). Similarly, in Ghana, the cost incurred in registering a mineral deposit and the lengthy bureaucratic process deterred miners from formalization. (Hilson et al, 2017). Moreover, Buss and colleagues (2019) indicate that the formalization process puts women at particular disadvantage. As a result of disproportionate household and care responsibilities, women have limited access to mining knowledge, training, and networks, limiting their mining work and corresponding income. Consequently, women are often excluded as license holders and decision-makers in mining cooperatives (Buss et al. 2019). These findings highlight the need to develop holistic and gender-sensitive interventions to overcome barriers to formalization.

The review also underscores the importance of applying an intersectional lens for researching and designing interventions to combat modern slave labor in Brazil. Current forced labor measurement challenges have led to certain populations being 'invisible' in research and programming. Despite their presence around mining sites and their role in the mining supply chain, women are often overlooked in male-dominated labor sectors. When invisible to service programs, women and girls are at risk of abuse from criminal gangs, law enforcement, and mine workers, as well as at high risk of sexually transmitted infections which are highly transmissible in mining communities (Steele, 2013). There is little research on women's activities in Brazil's mining areas, although a 2019 study established that women in mines in the Tapajós region of Pará work as cooks and sex workers (Mendes & Mesquita, 2018). Given the considerable involvement of marginalized groups in the mining sector, using an intersectional lens will contribute to our understanding of the different lived experiences of exploited workers and inform appropriate intervention design.

With respect to identification and reporting, Sethumadhavan (2021) suggests that technological advancements such as satellite imagery, AI-powered chatbots, machine-learning algorithms, and blockchain-based traceability systems can be leveraged to detect, monitor, and report modern slave labor cases. Other researchers emphasize the importance of strengthening public–private partnerships that combine resources and expertise of different actors, such as government agencies, international institutions, NGOs, CSR initiatives, trade unions, mining companies, and consumers. The design and implementation of coordinated and integrated interventions can address the multiple drivers and dynamics of exploitation and vulnerability (Pinsent Masons, 2013). Awareness campaigns to educate workers, employers, consumers, and the community about the risks and consequences of modern slave labor in ASM and how to report or avoid exploitation can be a beneficial starting point (Chandra et al., 2021).

9. Conclusion

Although the review provides valuable insights into Brazil's ASM industry, the study is not without limitations. It is possible that the temporal limitations could have excluded relevant articles that were published before 2017. It is also possible that some interventions do not have publicly available documents and were consequenlty left out of the review. Additionally, although we included a broad range of sources, including web pages and news media articles, findings are limited in scope because we excluded some other potential sources of information such as videos, radio or television interviews, or social media posts. Moreover, findings may not be generalizable because the review focuses on one region of Brazil. However, despite such limitations, the review presents important findings to inform our understanding of modern slavery in ASM and calls action to urgent evidence-based intervention.

There is little doubt that mining is a hazardous livelihood which exposes individuals to numerous health hazards and exploitative work conditions. Given the magnitude of the problem and growing concerns about conditions analogous to slavery in Brazil, it is a propitious time to draw on intervention-focused evidence to develop well-targeted and context-appropriate interventions to improve working conditions in mining. This study synthesizes available evidence to determine approaches to address exploitation in the mining sector and identify additional evidence needs to implement interventions that have the greatest probability of succeeding. Initiatives to address the complex drivers of exploitation in this sector will require definitions and theories of change that accurately represent the context in which mining-focused activities are implemented. Faulty assumptions about the target groups, underlying determinants, or incorrect definitions are likely to produce interventions that do not work, waste precious resources, and may even lead to unintended, harmful consequences for workers.

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.

Data availability

No data was used for the research described in the article.

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