Environmental Impacts of Mining: Lessons from Ancient Rome and Contemporary Ghana

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ABSTRACT

Despite the adage that history repeats itself, humanity has often failed to learn from its past, particularly in resource exploitation. Mining, as a case study, reveals persistent patterns of economic ambition overshadowing sustainability and social equity. Mining has historically been a cornerstone of economic development across civilizations, from Ancient Rome to modern-day Ghana. In Ancient Rome, mining drove wealth and expansion, employing innovative techniques such as hydraulic mining but at great human and environmental cost. Similarly, mining is a critical industry in contemporary Ghana, contributing significantly to its GDP through the extraction of gold, bauxite, and other minerals. However, challenges such as environmental degradation, social displacement, and inequitable wealth distribution persist. Using the comparativist's approach, this research draws the similarities and dissimilarities between Roman mining practices and Ghana's modern mining industry. The study focuses on the period from the 1st to 3rd century A.D. for Roman mining and from 2000 to 2025 for contemporary Ghanaian mining. Thus, mining in ancient Rome originated in the early Republic (5th–4th century B.C) but evolved into a significant industry during the expansion of Roman influence, especially from the late Republic (2nd–1st century B.C) and reached its zenith during the Imperial period (1st–3rd century A.D). Similarly, mining in Ghana dates back over a thousand years, with evidence of gold extraction and trade as early as the 5th century CE. However, large-scale and organized mining began in the 15th century, when European traders, particularly the Portuguese, arrived and established trade routes along the Gold Coast. It is noteworthy that from 2000 to date, mining in Ghana has had severe environmental consequences, particularly due to large-scale industrial mining and illegal small-scale mining (galamsey). The findings highlight recurring patterns of exploitation, inefficiency, and unsustainable practices, emphasizing humanity's collective failure to learn from history. This study calls for urgent introspection, advocating for sustainable and equitable resource management to avoid repeating the mistakes of the past on a larger scale.

Keywords: Mining, Rome, Ghana, Impacts, Environment**.**

INTRODUCTION

Mining is the process of getting minerals and geological materials that are worth money from the Earth's surface or subsurface. This includes deposits found on land and under the seas. Minerals are typically characterized as naturally occurring inorganic entities with unique chemical compositions and physical attributes (Hustrutid & Clark, 2005; Balasubramanian, 2017). Mining has had a huge impact on the economy, politics, and social organization throughout history, and it has also had a huge impact on the environment and society.

Mining was a key part of imperial power in Ancient Rome. The mining of gold, silver, copper, and lead paid for the growth of the military, the running of the government, and big infrastructure projects. Roman mining methods, like hydraulic mining, deep-shaft excavation, and opencast extraction, were very advanced for their time. However, they relied heavily on slave and convict labor and caused a lot of damage to the environment, such as deforestation, soil erosion, and water pollution (Healy, 1978; Humphrey, Oleson, & Sherwood, 1998). These practices did help the economy in the short term, but they also caused long-term damage to the environment that lasted long after mining activities stopped.

Mining is still a big part of the economy in modern-day Ghana. Ghana, which used to be called the "Gold Coast," is one of the world's top gold producers. Mining is a big part of GDP growth, export revenues, and foreign exchange earnings (Hilson, 2002). Since the early 2000s, though, both legal and illegal small-scale mining (galamsey) have grown quickly, which has made the environment worse and caused social problems. Deforestation, water pollution, land degradation, and labor precarity have become prevalent, especially in rural communities reliant on mining (Akabzaa & Darimani, 2001). Even though there are new rules and better technology, many of the problems that come with mining in Ghana are the same as those that existed in ancient extractive economies. The ongoing nature of these patterns prompts essential enquiries regarding the extent to which modern societies have significantly assimilated lessons from historical instances of resource exploitation. Although the mining histories of Rome and Ghana have been thoroughly examined as distinct entities, comparative analyses that systematically investigate their common structural dynamics are still scarce. This gap is significant because comparing different times can show us things about extractive economies that are true no matter what time period they are in.

This research employs a comparativist historical approach to analyses mining practices in Ancient Rome during the Imperial period (1st–3rd centuries CE) and in Ghana from 2000 to 2025. Instead of showing two separate case studies, the analysis is organized around four main themes: (1) labor systems, (2) environmental effects, (3) governance and regulatory frameworks, and (4) economic extraction and distribution. Comparativism is implemented by examining how each society addressed analogous structural challenges stemming from mineral extraction, encompassing resource management, labor mobilization, environmental stewardship, and state oversight (Chang, 2016; Griffiths, 2007). The Roman case serves as a historical benchmark demonstrating the ramifications of state-driven extractivism, whereas the Ghanaian case exemplifies the complexities of mining within postcolonial governance and global capitalism. This comparison does not aim to imply historical equivalence; rather, it seeks to discern persistent patterns, divergences, and institutional responses over time. Utilizing primary ancient sources (including Pliny the Elder and Strabo), modern policy reports, environmental studies, and economic data, in conjunction with secondary scholarship, this methodology transcends descriptive history to achieve analytical comparison. By doing this, the study shows how extractive economies often put short-term economic gains ahead of social equity and environmental sustainability. It also gives insights based on history that are still useful in today's discussions about how to manage resources sustainably.

Historical Background of Mining as an Extractive System

Mining was a big part of the Roman Empire's growth and economic power. It gave them important materials like gold, silver, lead, copper, and iron. Roman mining operations were spread out over a large area and used advanced technology. Some of the methods they used were hydraulic mining (ruina montium), deep-shaft mining, and large-scale smelting. The industry was important for the economy, but it caused a lot of environmental damage and had bad working conditions. In the early Republic (5th to 3rd centuries BCE), mining was mostly done in small areas and focused on iron and copper, which were important for military equipment and infrastructure (Healy, 1978). Before the Romans took over, the Etruscans had already come up with advanced mining methods, especially in Etruria (now Tuscany), which is a place with a lot of iron ore. As the Romans gained more land, they used these methods and improved on them. Sardinia also became an early source of lead, silver, and zinc. The Etruscans were the first to take advantage of the island's mineral wealth, and the Romans made it even more valuable (Forbes, 1950).

Mining became much more important during the late Republic (2nd–1st centuries BCE) and peaked during the Imperial period (1st–3rd centuries CE). The empire's most important mining area was the Iberian Peninsula. Las Médulas in northwestern Spain is a well-known example of this. The Romans used hydraulic mining to take apart whole mountainsides in search of gold (Domergue, 1990). The Río Tinto area also had a lot of copper, silver, and lead. Asturia and Galicia were two other important gold-producing areas in Iberia that used large aqueduct and sluice systems to help with large-scale extraction (Wilson, 2002). Roman mining activities were widespread throughout Britannia. Dolaucothi in Wales is the only known Roman gold mine in Britain. It used hydraulic methods to get gold out of quartz veins (Burnham & Burnham, 2004). In England, the Mendip Hills became a major place for lead mining. The lead was used to make pipes, solder, and cosmetics. People all over the empire used lead from these mines for plumbing and building (Shepherd, 1993: 12). Another important

mining area was Gaul (now France), especially in Aquitaine and the Massif Central, where a lot of gold, silver, and iron were mined. Les Martys in southern France was an important place to get lead and silver (Shepherd, 1993: 12).

The gold mines at Roșia Montană (Alburnus Maior) in Dacia (now Romania) were some of the richest in the Roman Empire. They were important for paying for military campaigns and strengthening imperial control in the area (Hirt, 2010: 12–14). Roman mining also spread to North Africa, where areas like Mauritania and Numidia (now Algeria and Tunisia) provided iron and copper that helped the economy grow and the military build-up. Under Roman rule, Lydia (now Turkey) in Asia Minor continued its long history of mining gold and silver. Pannonia, which includes parts of modern-day Hungary and Serbia, was another important mining area. It provided iron and copper for Roman weapons and buildings (Parker, 1992: 23). Mining was not just a way to make money in Ancient Rome; it was also an important part of the empire's strategy. The Roman government systematically mined minerals to pay for wars, keep the infrastructure in good shape, and keep the money system stable. Not only were provinces rich in natural resources conquered, but they were also purposefully reorganized to make it easier to extract and move wealth around. In places like Hispania, Dacia, and North Africa, mining was part of the imperial government, which put long-term control and resource security ahead of environmental sustainability. This extractive logic made environmental damage, like deforestation, changes to the landscape, and water pollution, not just a side effect of imperial expansion but something that was expected (Andoh, 2025).

Roman mining had a lot of economic benefits, but it also had a lot of bad effects on the environment and people. A lot of trees were cut down because a lot of wood was needed for smelting, fuel, and mine supports. Mercury and lead released during refining processes heavily polluted water sources, which caused long-term contamination of rivers and soils. There was a lot of labor exploitation, and mining depended a lot on slaves and prisoners who worked in very dangerous conditions and died a lot (Healy, 1978). Roman mining started to slow down in the fourth and fifth centuries CE. This was because mineral deposits that were easy to get to were running out, operating costs were going up, and the economy was becoming less stable. Invasions and political division made supply chains even more difficult, which led to lower productivity. Many of the mines that the Romans left behind became the basis for mediaeval European mining industries. This shows how Roman mining practices have had a lasting impact (Hirt, 2010).

Mining has also been a major part of Ghana’s economy for hundreds of years, long before Europeans came into contact with the country. Archaeological evidence shows that gold mining took place in places like Tarkwa, Obuasi, and Dunkwa long before Europeans came (Wilks, 1993). In the past, Ghanaians, especially the Akan kingdoms, mined gold from riverbeds and shallow pits to use for trade, decoration, and religious purposes (Boahen, 2000). People in trans-Saharan trade networks really wanted Ghanaian gold. They traded it for salt, textiles, and other goods from North Africa (Levtzion, 1973). The arrival of European traders in the 1400s greatly increased gold mining and trade. The Portuguese came to the Gold Coast in 1471 and set up a trading post at Elmina in 1482. This was the start of large-scale European involvement in gold mining (Daaku, 1970). As the Dutch and British expanded, they built forts and trading posts along the coast. During the colonial period, British authorities set up concessionary systems to make mining more official. This helped industrial mining grow. The founding of the Ashanti Goldfields Corporation in Obuasi in 1897 was a major turning point from small-scale mining by locals to large-scale industrial extraction (Dumett, 1998). During this time, other mining towns like Prestea, Tarkwa, and Bibiani were built. They are still important mining centers today.

After Ghana became independent in 1957, the government wanted to nationalize the mining industry. To do this, they set up the State Gold Mining Corporation (SGMC) in 1961 to oversee the biggest operations (Akabzaa & Darimani, 2001). But the economy got worse in the 1970s and early 1980s, which made state-run mines less productive. In the late 1980s, Ghana started Structural Adjustment Programs to get more foreign investment and privatize (Hilson, 2002). After that, multinational companies like AngloGold Ashanti and Newmont Ghana got major concessions, which boosted gold production and made Ghana one of the world’s top gold exporters. Ghana’s mining industry has grown quickly since the year 2000, but it has also caused serious problems for the environment and society. Illegal small-scale mining, or galamsey, has become very common in places like Dunkwa-on-Offin, Akwatia, and Kyebi. This has led to a lot of deforestation, water pollution, and land degradation (Aryee, Ntibery, & Atorkui, 2003). The unregulated use of mercury in gold mining has put both

human health and biodiversity at even greater risk (Hilson, 2017). Mining is still a major source of jobs and money, but people are still worried about its long-term effects on the environment.

Mining settlements and urban centers put more pressure on the environment in both Ancient Rome and modern Ghana. Roman mining areas drew in permanent settlements that handled administrative, commercial, and logistical tasks for the empire. This led to more demand for wood, water, and farmland, which sped up deforestation and soil degradation (Andoh, 2025). Similar patterns are observable in contemporary Ghana, where swiftly expanding mining towns like Obuasi and Tarkwa exert considerable pressure on local ecosystems. In both cases, urbanization linked to extractive economies made environmental damage worse by putting more people, businesses, and infrastructure close to mining areas. This historical parallel exemplifies a persistent trend: when economic priorities consistently eclipse environmental sustainability, extractive systems whether ancient or contemporary produce enduring ecological strain.

Mining Technologies and Environmental Consequences in Rome and Ghana

Mining has played an important role in economic development throughout history, from ancient Rome to modern Ghana. Roman mining techniques were advanced for their time, employing hydraulic mining, deep-shaft mining, and surface mining to extract precious metals like gold, silver, lead, copper, and iron. One of the most notable methods, ruina montium (mountain destruction), was used at sites such as Las Médulas in Hispania, where water diverted through channels was used to break down mountainsides, resulting in extensive gold extraction and significant environmental damage (Domergue & Herail, 2019). Similarly, deep-shaft mining was prevalent in Dacia (modern Romania), particularly at Roșia Montană, where shafts reached depths of 100 meters and were supported by wooden beams to prevent collapse (Hardwick, 2013). Roman mining thrived in Gaul and Britannia, with extensive operations in Dolaucothi, Wales, using both underground and hydraulic mining methods. Mining settlements were built to house workers, the majority of whom were enslaved people or condemned criminals working in harsh conditions (Jones & Bird, 2019).

Modern Ghana, a major gold producer, uses both large-scale and small-scale mining techniques. Multinational corporations conduct large-scale mining using advanced exploration and extraction technologies, such as open-pit mining in Tarkwa and Ahafo and underground mining in Obuasi (Hilson, 2013). Ore processing includes crushing and chemical treatment, often with cyanide, which raises environmental concerns about tailings disposal (Awudi, 2002). Small-scale, often informal, mining relies on manual labour and simple tools to extract alluvial gold from riverbeds, frequently using mercury for amalgamation, which poses significant health and environmental risks (Kuma & Ewusi, 2009). Both forms of mining have led to deforestation, water pollution, and land degradation, with small-scale operations often operating outside formal regulatory frameworks (Amponsah-Tawiah & Dartey-Baah, 2011). Despite these challenges, mining remains an important part of Ghana's economy, contributing significantly to GDP and export revenue (Aryee, Ntibery, & Atorkui, 2003). To mitigate environmental and social impacts, sustainable practices and stricter regulatory enforcement are required. The historical comparison of Roman and Ghanaian mining demonstrates the enduring nature of extractive economies, the reliance on labour-intensive techniques, and the long-term effects of mining on both human societies and nature.

Economic Benefits and Distributional Inequalities

Mining was a very important part of the Roman economy. It provided the materials needed for the empire to grow, the military to get stronger, infrastructure to be built, and the money to stay stable. Roman writers knew very well how important mineral extraction was to the economy. Pliny the Elder wrote in the first century CE that mining was one of the most profitable but also destructive things people did. He said that Rome “pierced the earth in search of wealth” (Natural History 33.1). Rome was able to stay in charge of the Mediterranean world and beyond because it systematically took gold, silver, lead, copper, and iron from provinces like Hispania, Dacia, Gaul, and Britannia.

The production of precious metals was especially important for the empire’s finances. The gold and silver mines in Hispania, especially the ones at Las Médulas, were some of the most productive in the Roman Empire. Pliny gives a detailed account of hydraulic mining (ruina montium), focusing on how effective and large it was. He

notes that whole mountains were brought down to get to gold-bearing deposits (Natural History 33.70–78). The bullion that was taken from these operations was very important for keeping the Roman currency system stable. The ability to make a lot of gold and silver coins made it easier to pay taxes, trade over long distances, and spend money on the state, as well as make sure that soldiers were paid on time. Roman military campaigns were very expensive, so mining profits were very important for keeping and growing the empire's power (McConnell et al., 2018: 24).

It was just as important to extract base metals as it was to extract precious metals. Lead mining, especially in Britannia and Gaul, gave people the materials they needed to build things, fix plumbing, and move water around. In De Architectura (8.6), Vitruvius talks about how lead pipes were used a lot in city water systems. This shows how mining products were used in everyday Roman life. Lead was later found to be toxic, but it was used to build aqueducts and distribution networks that helped cities grow and kept people healthy by Roman standards (Pipino, 2015: 21). Copper, which was mined in places like Cyprus, was very important for making bronze, which was used in Roman tools, military gear, and coins. These metals worked together to keep Rome's construction industry and huge public works projects going.

Mining also helped the empire's infrastructure and government work together. Roads, aqueducts, fortifications, and monumental architecture required a lot of mined materials, and having them available made it easier for provinces that were far apart to work together economically. In his Geographica (3.2.9; 4.6.7), Strabo talks about how rich in minerals places like Iberia and Gaul are. He also talks about how Rome reorganized conquered lands to get the most resources out of them and move them around. The Roman road system, which was built with mined materials, made it easy to move goods, troops, and money around. This connected the empire into a single economic system.

State organization and military oversight made Roman mining even more effective. Mining was a strategically run business that had its own towns, government oversight, and security measures. Pliny makes it clear that mining areas were often protected and strictly controlled because they were so important to the economy (Natural History 33.97). In provinces like Dacia and Hispania, advanced extraction methods like hydraulic mining and deep-shaft excavation were used, which made it possible to keep large-scale production going (Núñez & Sánchez-Palencia, 2015: 11). Roman garrisons were set up near important mining areas and transportation routes to protect operations and make sure that raw materials could get to cities and ports without any problems. Roman writers, on the other hand, also talked about the environmental costs of this system of extracting resources. Pliny famously complained about the damage mining did, saying that the search for mineral wealth caused "wounds upon the earth" (Natural History 33.2). The high demand for wood for smelting, mine supports, and infrastructure sped up deforestation, and hydraulic mining changed river systems and permanently changed landscapes. So, the same state-backed security and logistical efficiency that kept Roman mining going for hundreds of years also made environmental damage worse. Roman mining shows that centralized power and extractive efficiency can lead to both economic growth and long-term damage to the environment (Andoh, 2025). Mining helped Rome pay for wars, stabilize its currency, build huge infrastructure, and bring provincial economies into an imperial system. But as both archaeological evidence and ancient writers show, these successes came with big changes to the environment and social costs. The Roman experience exemplifies early historical tensions within extractive economies, which persist in modern mining contexts like Ghana.

Ghana is the second-largest gold producer in Africa and one of the top ten in the world. Mining is a major part of the country's economy. The sector made big contributions to GDP growth, export earnings, jobs, and foreign exchange inflows between 2022 and 2024 (Minerals Commission, 2024). Mining's share of GDP went up from 4.5% in 2021 to about 7.6% in 2022, making it the second-largest economic activity in the country after retail trade. By the second quarter of 2023, the mining and quarrying subsector added an estimated GHS 5.8 billion to GDP. This was due to continued growth in the sector, which was mostly due to gold production (Minerals Commission, 2024). Ghana s biggest export sector is still mining. In 2022, mineral exports made up about 36% of all exports, and gold made up almost 90% of the money made from mineral exports. Mining companies put back more than $4.2 billion into the economy in 2023. This helped the economy stay stable even though the government was under a lot of pressure and the value of the dollar was changing (GCM, 2023; World Bank, 2023). Royalties, corporate taxes, and other fees show how important the sector is to the economy. For example,

gold royalties brought in about $860 million for the government in 2022, which paid for public spending on education, health, and infrastructure (GCM, 2023).

Creating jobs is another important economic benefit. Large mining companies hire thousands of skilled and semi-skilled workers. Small-scale and artisanal mining, on the other hand, provides jobs for many people in rural areas, even though it is not very formal. Mining also creates indirect jobs through services like transportation, equipment supply, catering, and construction. This makes the multiplier effects of mining even stronger in areas that depend on it (Minerals Commission, 2024). The fact that most jobs in the small-scale sector are not formal raises concerns about job security, safety at work, and labor laws. This shows a major conflict between creating jobs and providing decent work. Investment in mining has also helped build infrastructure at the subnational level. Mining companies have helped build roads, schools, health facilities, and water systems, especially in the Western, Western North, Central, and Ashanti regions. They have done this through corporate social responsibility programs and community development agreements. These investments have made it easier for people to get basic services and have helped the local economy, but their long-term effects and fairness are still up for debate because the benefits are often not evenly shared and aren't enough to make up for the losses in the environment and people's livelihoods (Hilson & Nyame, 2006; Yankson, 2010). Foreign direct investment (FDI) is another way that mining helps Ghana's economy. Multinational companies like AngloGold Ashanti and Newmont have brought money, cutting-edge technology, and technical know-how to the table, which has made production more efficient and made it easier for some local workers to learn new skills (GCM, 2024). These technological improvements have only had a small effect on other fields, such as engineering and manufacturing. Even so, Ghana's economy is vulnerable to changes in global commodity prices because it relies so heavily on foreign-owned extractive capital. This makes it harder for the country to capture value.

Recent policy changes try to fix these structural weaknesses. The Ghanaian government wants to build the country's first large-scale gold refinery to add value, cut down on exports of raw minerals, and strengthen ties with local businesses. At the same time, Ghana is becoming part of new global supply chains by branching out into minerals like bauxite, manganese, and lithium, which are important for renewable energy and battery technologies (GCM, 2024). These strategies show that industrialization is moving towards using resources more efficiently. However, they will only work if there are good rules, protections for the environment, and clear ways to manage revenue. Mining was a key part of Ghana’s economy from 2022 to 2024, supporting growth, exports, jobs, and public revenue. At the same time, ongoing problems like environmental damage, informality, uneven wealth distribution, and gaps in regulatory enforcement show how limited extractive-led development can be. The long-term economic benefits of mining in Ghana will depend on more than just continuing to mine and finding new uses for minerals. They will also depend on using sustainable methods and governance systems that can turn mineral wealth into development that benefits everyone and lasts.

From the above, we will realize that mining played a multifaceted role in sustaining the Roman and Ghanaian economy. The extraction of gold, silver, lead, and copper not only contributed to the wealth and power but also facilitated the development of critical infrastructure, trade, and industry. The organizational and logistical capabilities of the Romans and Ghanaians in managing mining operations helped them maintain control over a vast and diverse resources, making mining a key driver of their economic prosperity.

Environmental Impacts of Mining in Rome and Ghana

Several regions in Ancient Rome suffered significant environmental consequences due to mining activities, particularly areas rich in mineral resources that became vital to the empire's economic expansion. In Hispania (modern Spain), for instance, the large-scale hydraulic mining operations at Las Médulas, a prominent gold mining site, led to extensive deforestation, soil erosion, and the silting of rivers. The environmental scars of these activities are still visible in the region today, illustrating the long-term impact of Roman mining practices (Domergue, 1990: 231). Similarly, the Balkans, including regions like Rosia Montana in modern Romania, experienced widespread landscape destruction from gold mining, with tailings polluting local water sources. In Britannia (modern United Kingdom), gold mining at Dolaucothi in Wales caused similar ecological damage. Hydraulic techniques and deforestation for fuel contributed to land degradation and left open pits and disturbed landscapes that remain to this day. Gaul (modern France) faced similar challenges in regions like the Massif Central, where the extraction of lead and silver led to deforestation and air pollution caused by smelting

operations. Sardinia and Corsica, exploited for lead, silver, and copper, suffered environmental degradation and social displacement as local communities were forced to relocate or work in harsh conditions (Saez, Donaire & Moreno, 2001: 23).

Roman mining techniques, such as hydraulic mining (ruina montium), had lasting effects on river ecosystems, contaminating water sources with sediments and toxic heavy metals. The Romans employed large-scale hydraulic mining, especially in regions like Hispania (modern Spain) and Dacia (modern Romania). They used aqueducts and reservoirs to direct high-pressure water streams onto gold-bearing deposits, washing away overburden and exposing gold veins. Pliny the Elder, in Natural History (33. 21), describes this method as highly effective but devastating to the environment. This process released significant amounts of sediment and heavy metals into nearby rivers, drastically affecting water quality (Pliny the Elder, Natural History).

Several river sites bore the brunt of Roman gold mining activities. The Sil River in Spain, particularly near Las Médulas, one of the largest Roman gold mining sites, suffered from heavy sedimentation due to mining operations. Recent geological studies indicate elevated levels of mercury and lead contamination in the river sediments, likely remnants of Roman-era mining. Similarly, in Dacia, Alburnus Maior (modern Roșia Montană) was a critical gold mining site under Roman control. The Olt River, a tributary of the Danube, experienced contamination from mining debris and toxic by-products such as cinnabar (mercury sulphide), which was used in gold extraction. Mercury poisoning from such activities would have affected aquatic life and human populations relying on river water. The Tagus River, which flows through modern-day Portugal and Spain, was another major water body affected by Roman gold mining. Mining operations in Lusitania led to extensive siltation and the release of arsenic, which has been detected in sedimentary layers dating back to Roman activity (Nunez & Sanchez-Palancia, 2015: 13).

The environmental impact of Roman gold mining persists today. Studies of ancient mining regions show elevated levels of heavy metals in soil and riverbeds, indicating that pollution from Roman times had long-lasting ecological effects. The extensive deforestation and alteration of river courses further exacerbated soil erosion and biodiversity loss. The disruption of these ecosystems demonstrates how deeply human activities in antiquity could shape the environment for centuries. Gold mining in Ancient Rome, particularly through hydraulic mining and mercury amalgamation, had devastating consequences for both aquatic life and drinking water sources. The contamination of rivers with heavy metals, sediments, and toxic substances significantly altered ecosystems, affecting fish populations and endangering human settlements that relied on these water sources. Roman gold mining operations released large amounts of mercury, lead, and arsenic into rivers, which had a direct toxic impact on aquatic organisms. Mercury, commonly used in gold extraction, bio accumulates in fish, affecting their nervous systems and reproductive health. The Sil River near Las Médulas experienced heavy sedimentation and mercury contamination, reducing fish populations. Modern studies have found traces of mercury and lead in sediments from Roman times, indicating long-term pollution. Similarly, the Tagus River saw arsenic and lead contamination from Roman mining in Lusitania, leading to fish mortality and ecosystem imbalances. In Romania's Olt River, gold mining led to significant mercury and arsenic pollution, affecting local fish species and invertebrates dependent on clean water. Beyond heavy metal poisoning, Roman hydraulic mining caused massive soil erosion, leading to increased turbidity in rivers. High sediment loads reduced oxygen levels in the water, making it difficult for fish and aquatic plants to survive. Some species, particularly those requiring clear water for spawning, faced population decline or extinction in affected rivers. The combination of heavy metal pollution and habitat destruction drastically altered aquatic ecosystems (Nunez & Sanchez-Palancia, 2015: 11).

The impact of Roman mining extended beyond aquatic life to human settlements that depended on rivers for drinking water. Many Roman communities suffered from contaminated water supplies, which carried mercury, arsenic, and lead. Chronic exposure to such toxins could have caused neurological disorders, kidney damage, and developmental issues. In Las Médulas, Roman workers and nearby settlements likely consumed water contaminated with mine runoff, which may have contributed to long-term health problems. Similarly, at Roșia Montană, arsenic released from mining operations polluted the Olt River, affecting nearby communities. Archaeological evidence suggests that arsenic from Roman mining also polluted local drinking water supplies near the Tagus River, making it hazardous for consumption (Fernández-Lozano et al., 2016: 11-23).

Even after mining ceased, toxic heavy metals remained in river sediments for centuries, continuously leaching into water supplies. Modern environmental studies have detected traces of Roman-era pollution in river basins once used for mining. This enduring contamination underscores the profound environmental consequences of Roman mining practices. Roman gold mining had a profound environmental impact, severely affecting aquatic life and drinking water quality. Heavy metal pollution from ancient mining operations persisted in river systems for centuries, disrupting ecosystems and endangering human health. Rivers such as the Sil, Tagus, and Olt continue to show traces of contamination, highlighting the long-lasting effects of Roman mining practices. The environmental degradation caused by Roman mining serves as an early example of the unintended consequences of industrial-scale resource extraction, reminding us of the delicate balance between economic progress and environmental sustainability (Fernández-Lozano et al., 2016: 11-23).

In addition, one of the most severe consequences of Roman gold mining was widespread deforestation. The extraction of gold required large quantities of timber for building mine supports, smelting, and fuel for water diversion systems. In regions such as Las Médulas in Hispania, vast forests were cleared to construct wooden aqueducts and reservoirs needed for hydraulic mining (Domergue, 1990: 234). The removal of vegetation led to increased soil erosion, as exposed land became vulnerable to heavy rains and wind. Studies of Las Médulas have shown significant loss of fertile topsoil, making the land unsuitable for agriculture even centuries after mining ceased (Fernández-Lozano et al., 2016: 11-23). Similarly, in Dacia, the Roman mining site at Alburnus Maior (modern Roșia Montană) experienced extensive deforestation due to gold extraction. The hills and valleys surrounding the Olt River were stripped of trees, causing severe erosion and sediment buildup in nearby water sources (Davies, 2019:23). This sedimentation not only degraded the land but also affected agricultural productivity in surrounding regions.

Roman mining techniques, particularly ruina montium, had a lasting impact on the landscape. This method, which involved using high-pressure water to collapse mountains and expose gold deposits, drastically altered the topography of mining regions. Las Médulas is one of the most well-documented examples of such landscape transformation. The large artificial cliffs and deep ravines seen today are a direct result of Roman mining activities (Domergue, 1990: 123). Modern geological surveys indicate that these man-made formations have remained largely unchanged for nearly two millennia, highlighting the permanence of land degradation caused by Roman mining (Fernández-Lozano et al., 2016:12). In Lusitania, the Romans mined gold along the Tagus River, leading to extensive landscape modification. The removal of large amounts of earth and rock left behind pits and waste heaps, which made the land uninhabitable and infertile (Pereira et al., 2017:16). Even today, traces of these abandoned mining sites can be observed in sedimentary records, indicating prolonged environmental damage.

The expansion of Roman gold mining led to the loss of fertile agricultural land. In Hispania, the fertile plains surrounding mining regions were transformed into barren wastelands due to soil erosion and contamination from mining waste (Nriagu, 1996:11). Mercury and arsenic, which were used in the extraction process, further polluted the soil, making it toxic for plant growth (Higueras et al., 2012:13). Farmers living near mining regions faced challenges in cultivating crops, as the depleted and contaminated soil could no longer support traditional agriculture. Biodiversity was also severely affected. The destruction of forests and alteration of river courses disrupted ecosystems, leading to the decline of various plant and animal species. In Roșia Montană, deforestation and toxic waste deposits led to a significant reduction in local wildlife, some of which never recovered (Davies, 2019:18).

Thus, Roman gold mining, while essential for economic prosperity, resulted in severe land degradation that had long-lasting environmental consequences. The deforestation, soil erosion, and landscape modifications in regions such as Las Médulas, Roșia Montană, and Lusitania highlight the destructive impact of Roman mining practices. Modern geological and environmental studies confirm that the effects of Roman-era mining persist, demonstrating how ancient industrial activities shaped and, in many cases, permanently damaged the natural environment.

Moreover, mining in Ghana has profound social and environmental impacts, particularly in regions such as the Central, Western, Western North, Ahafo, Bono, and Ashanti regions, where mining activities are most prominent. While the industry is a cornerstone of the national economy, driving revenue and creating

employment opportunities, it has also led to significant challenges for local communities (Ministry of Land and Natural Resources, 2022: 14). For instance, in areas such as Tarkwa in the Western Region and Upper Denkyra East of the Central Region and Wasa Akropong of the Waa Amanfi East of the Western Region farmland have been taken over by mining operations, forcing farmers to relocate and find alternative sources of income (Ofosu-Mensah, 2011: 10). This displacement disrupts social structures and economic stability in affected communities. However, the mining sector faces significant challenges, including environmental concerns such as land degradation, water pollution, and deforestation. There are also issues of land disputes between small-scale miners and large-scale operators. Addressing these challenges is crucial to ensuring that mining's economic benefits are sustainable and that the sector's long-term growth is balanced with environmental protection and social equity (MoLNR, 2022: 23).

Health issues are another major concern. Mining generates dust, noise, and the release of toxic substances such as mercury and cyanide, which expose residents to respiratory illnesses, skin conditions, and waterborne diseases. Communities near mining towns like Obuasi and Prestea have reported widespread health problems due to environmental contamination. Social tensions and conflicts are also prevalent, often arising between mining companies and local residents over issues such as land use, environmental degradation, and inequitable revenue distribution (Obiri, Dodoo, Essumang & Armah, 2010: 23). Illegal mining, commonly known as galamsey, exacerbates these tensions, leading to rivalries, lawlessness, and even violent confrontations in towns like Wassa Akropong in the Western Region. Another social issue is the exploitation of vulnerable populations, including children. In many galamsey operations, children are employed under hazardous conditions, depriving them of education and exposing them to exploitation and danger (Teschner, 2012: 14). Environmentally, mining has left an indelible mark on the landscape and ecosystems of Ghana. One of the most visible impacts is deforestation, as large-scale and artisanal mining operations clear vast areas of forest. This destruction is particularly evident in regions such as Ashanti and Western North, Western, Ahafo and Central where forest reserves like the Atiwa, Achimota and Kakum Forests have been significantly affected. Land degradation is another pressing issue, as mining leaves behind large pits, degraded soils, and unproductive lands. This makes agriculture, the primary livelihood for many residents in mining communities, nearly impossible (Hilson & Nyame, 2006: 11-16). Towns like Dunkwa-on-Offin, Diaso, Ayanfuri, Kyekyewere in the Central Region have experienced severe land degradation, with large areas rendered barren and unsafe. Water pollution is perhaps the most severe environmental consequence of mining. Rivers and water bodies, such as the Pra, Offin and Ankobra rivers in the Western, Ashanti and Central regions, are heavily contaminated with mercury, cyanide, and sediments from mining activities (EITI, 2021, GWCL, 2024: 23)). This pollution not only affects aquatic life but also makes water unsafe for drinking and farming irrigation. Illegal mining has been a significant contributor to this contamination, worsening the already precarious situation for communities that depend on these rivers for their daily needs. Air pollution is another concern, with dust from blasting and machinery operations leading to respiratory problems for residents. Additionally, the destruction of habitats due to mining has resulted in a decline in biodiversity, with many species losing their homes. The cumulative environmental effects also contribute to climate change, as mining activities release greenhouse gases and lead to deforestation (Thommen, 2012: 9, Hilson 2001: 4 and Hilson, 2002: 45).

Specific communities in these regions illustrate the depth of these impacts. In Obuasi, a major mining hub in the Ashanti Region, the operations of AngloGold Ashanti have provided employment and infrastructure but also resulted in extensive water and air pollution. Cyanide spills in the area have contaminated water sources, harming both humans and livestock. Similarly, in Tarkwa in the Western Region, mining has caused widespread deforestation, land degradation, and severe pollution of the Pra River (Aryee, 2001: 11). In Wassa Amenfi in the Western North Region, illegal mining dominates, leading to environmental degradation and social instability. Dunkwa-On-Offin in the Central Region faces similar challenges, with water pollution and land degradation severely affecting the local population's health and livelihoods. Addressing these issues requires concerted efforts from all stakeholders (Wilson, 2002: 11, Yankson, 2010: 13).

Moreover, major rivers in the area, such as the Ankobra and Asesree, which once served as the primary sources of water for domestic use in the surrounding townships, have been heavily polluted due to mining activities, particularly illegal small-scale mining, commonly known as galamsey (Bloch & Owusu, 2012: 34-37). Mining, especially surface mining, has resulted in severe environmental degradation, significantly impacting water

bodies in Ghana through the release of harmful effluents such as mercury, arsenic, and solid suspensions. Studies have revealed that between 1994 and 2001, five major cyanide spillages and leakages occurred, contaminating several major rivers in Ghana (Hinde, 2010: 11). These spills, caused by mining companies such as Goldfields Ltd and Ashanti Goldfields Company Ltd (now AngloGold Ashanti), polluted key water bodies, including the Anikoko, Teberebie, Bodwire, and Assaman rivers, all located in the western region of Ghana. This contamination led to a significant loss of aquatic life, the displacement of local communities, and the depletion of drinking water sources, thereby affecting livelihoods (Yankson, 2010: 26-29).

Furthermore, illegal small-scale mining operations are conducted in open-air environments without appropriate safeguards or adherence to environmental standards. As a result, contaminated water is discharged into the surrounding environment, polluting nearby rivers, soils, and vegetation. This finding aligns with previous studies, which estimate that approximately five tons of mercury emissions are released annually into various water bodies by small-scale mining activities (Bastidas, 2004: 14-16). This leads to siltation, water discoloration, de-oxygenation, and the destruction of aquatic habitats, ultimately reducing aquatic populations. Mercury is extensively used in the gold mining process, where it is added to refined concentrates to form a gold amalgam, which is then heated to extract gold. Research conducted in the Dumasi Township, located in the western region of Ghana, confirmed high levels of mercury contamination, with significant concentrations found in groundwater, river sediments, and fish. This widespread pollution poses a severe threat to both human health and the environment (Domfe, 2003: 23). Interviews with residents in Prestea according to Serfer-Armah et-al, during the field survey revealed that they are spending significant amounts of money to access and treat groundwater for domestic use, including drinking, cooking, washing, and bathing. Due to the severe pollution of surface water sources, the government has initiated the drilling of boreholes in some communities to provide safer water. As a result, many residents in Prestea have resorted to using groundwater (Serfer-Armah et-al., 2006: 4-11)

In a study conducted my Mensah et-al (2015) on environmental impacts of mining, one respondent stated that they have to drill as deep as 80 meters underground to reach uncontaminated water. He further explained that the total cost of drilling, laying pipes to extract the groundwater, and installing a Tanks for water storage and distribution can amount to as much as 12,000 Ghana Cedis (approximately 3,500 USD). The heavy pollution of rivers and other surface water bodies due to mining activities has made this costly alternative a necessity rather than a choice. Similar findings were reported in a study conducted in Obuasi, in the Ashanti region of Ghana, where high levels of arsenic contamination were found in drinking water sourced from streams, shallow wells, and boreholes, with concentrations ranging from 2 to 175 µg/L. This contamination was attributed to two primary factors: pollution from mining activities and the natural oxidation of sulphide minerals, particularly arsenopyrite (FeS_2) (Mensah et-al, 2015: 81-94). The study further revealed that a significant proportion of land in mining areas has been rendered barren due to extensive mining activities. Large tracts of land in areas such as Nankaba, Asoampa, Ashtown, Bondaye, Ankobra, and Anfegya have suffered severe deforestation, biodiversity loss, soil erosion, and the destruction of cultural sites and water bodies. Small-scale gold mining has been a major contributor to the removal of vast quantities of surface vegetation, leading to mass deforestation in Ghana (Mensah et-al, 2015: 81-94).

Additionally, mining activities generate large amounts of waste materials, commonly referred to as mine spoil or overburden, which are characteristic of most gold-mined lands in Ghana. The method of surface mining, frequently used by both registered large-scale mining companies and unregistered small-scale miners, often leads to excessive land destruction, deforestation, and deep trenching. Productive arable lands are left bare without any protective measures, increasing surface runoff and water turbidity (Babut et-al, 2003: 14-18). The environmental consequences of mineral resource exploitation include extensive soil degradation caused by the destruction of vegetation and alteration of microbial communities, which ultimately lowers soil fertility and productivity. According to the Food and Agriculture Organization (FAO), between 1990 and 2005, gold mining activities in Ghana contributed significantly to land degradation and the loss of cultivable land. During this period, mining activities led to a massive decline in forest cover (26%) and a reduction in arable lands (15–20%) in key mining areas such as Tarkwa, Ayanfuri, Dunkwa, Esaase, and Bogoso (Mensah et-al, 2015: 81-94 and GSS, 2014: 4).

Mining, regardless of its scale or method of operation, causes significant environmental damage when appropriate regulations are not strictly enforced. In Ghana, extensive areas of land and vegetation have been cleared to accommodate surface mining activities, leading to severe environmental degradation. This study observed that gold mining operations have disproportionately damaged landscapes in many affected areas. In small-scale mining, underground operations are often haphazardly constructed, excavated to unsafe depths, and supported by flimsy wooden logs and branches. These underground pits, commonly referred to as "ghettos," serve as entry points for miners searching for gold (Assessment-GFR, 2005: 11-14). Additionally, vast patches of forest have been cleared in some areas to establish makeshift resting grounds for miners, further contributing to deforestation and altering local hydrological patterns in Prestea (Mensah, 2015: 11).

Research indicates that surface mining concessions have taken over approximately 70% of the total land area in Tarkwa, a major mining community in Ghana's Western Region. It is estimated that by the end of a mining operation, about 40–60% of the concession space will have been utilized for infrastructure such as mines, heap leach facilities, tailings dumps, open pits, mine camps, roads, and resettlement sites for displaced communities (Aryee, Ntibery and Artorkui, 2003: 11-16). This extensive land use severely impacts local vegetation and agricultural activities, which serve as the primary livelihoods for many residents. One study reported that the tailings dam of a single mine occupied 6.3 hectares of land. Given an estimated cassava yield of 108,000 bags per hectare annually, this means that the tailings dam alone has deprived local farmers of at least 275,351 bags of cassava per year. Furthermore, the tailings dam, plant site, and feed stockpile of Ghana Australia Goldfields Ltd. are projected to affect approximately 315 farmers who currently cultivate land in the area, significantly reducing their income and threatening food security (Sheoran et-al., 2011: 11-16).

The small-scale surface mining method often involves the removal of large quantities of topsoil, rendering the land barren and highly susceptible to erosion. Once the topsoil is stripped, the land becomes practically unfit for crop farming. A World Bank report on Ghana estimated that by the end of 1995, small-scale mining activities had destroyed approximately 150,000 hectares of land. Other significant environmental consequences include acid mine drainage (on a micro scale), cyanide contamination (in certain districts), siltation, river dredging and alteration, and widespread erosion (Armah et-al., 2011: 13). Moreover, abandoned mining pits left by both large- and small-scale miners without proper reclamation further degrade the landscape. These unfilled pits make the land unsuitable for future use and often turn into stagnant water bodies, creating ideal breeding grounds for malaria-infected mosquitoes that pose serious health risks to both humans and animals (Okoh & Hilson, 2011: 9).

Obuasi, one of Ghana's major mining towns, is often described as a hanging town due to the prevalence of underground mining in addition to surface mining. The underground method requires the use of heavy explosives to break down rocks, leading to severe landscape destruction and exposing the environment to pollutants such as dust, chemicals, and toxic fumes (Amponsah-Tewiah & Dartey-Baah, 2011: 11-15). These activities significantly contribute to air and water pollution, further exacerbating the negative environmental and health effects associated with mining. Mining has a severe impact on soil quality in Ghana, particularly in areas where surface mining is prevalent. Numerous studies indicate that mining activities significantly degrade soil health. The use of heavy machinery and blasting during mineral extraction destroys essential soil organisms, disrupts stable soil aggregates, and depletes the soil of organic matter. As a result, mined soils or newly formed substrates often become inhospitable to vegetation due to a combination of physical, chemical, and microbiological factors. One of the most critical issues affecting mined soils is the depletion of essential macro-nutrients, particularly nitrogen (N), phosphorus (P), and potassium (K). Research suggests that regardless of the type of overburden used, plant-available nitrogen and phosphorus remain low on mined soils, which negatively affects tree growth. The process of stripping, stockpiling, and reinstating topsoil during mining operations results in significant nitrogen transformations and losses, ultimately reducing soil fertility and productivity (Scheuler, 2011:15-25).

Additionally, low pH levels pose a persistent challenge, especially in waste materials containing iron pyrites. When exposed to weathering, iron pyrites generate sulfuric acid, which can lower pH values to below 2.0 in the absence of acid-neutralizing minerals. This extreme acidity leads to toxicity issues, particularly with metals such as aluminium and zinc, which can severely hinder plant growth. Studies have reported that soil pH levels in Prestea and Bogoso, two major mining communities in Ghana's Western Region, are as low as 3.96, a common

characteristic of gold-mined substrates in the country. The removal of vegetation due to mining activities inevitably leads to the depletion of soil nutrients (Amankwah & Anim-Sackey, 2001: 15-17). Research conducted in the Golden Star Resources Prestea/Bogoso mining area found that the soil organic carbon (SOC) content was only 0.14%, significantly lower than the acceptable threshold for soil fertility. Generally, organic matter content is classified as low if it falls below 4%, moderate between 4% and 8%, and high if above 8%. The disruption of the ecosystem, removal of vegetation, and loss of the litter layer during mining operations contribute to a significant decline in soil nitrogen and phosphorus levels compared to undisturbed natural forests (Macdonald, Lund, Blanchette and Mauleugh, 2011: 23-26).

Furthermore, the mining process involves the scraping of topsoil, which is typically only about 20 cm deep and contains most of the essential plant nutrients. The use of bulldozers and other heavy machinery strips away this nutrient-rich layer, exposing subsoil that is largely unsuitable for crop production (Amegbey, 2011: 11). This not only reduces soil fertility but also compromises the long-term sustainability of agriculture in mining-affected areas. Another major concern is the stockpiling of mined soil, a common practice during mineral extraction. Stockpiling negatively impacts the biological, chemical, and physical properties of the soil, reducing its overall quality. Studies indicate that stockpiled soil becomes anaerobic over time, leading to the death of plant propagules and a significant decline in populations of beneficial soil microorganisms (Armah & Gyeabour, 2013: 44). Additionally, stockpiling generates heat, which can kill beneficial soil organisms that cannot withstand high temperatures. The process further exacerbates soil degradation by disrupting microbial activity, which is essential for maintaining soil health and fertility (Kumah, 2006: 12).

Thus, the adverse effects of mining on soil in Ghana are far-reaching, resulting in severe degradation, loss of fertility, and disruption of ecosystems. The removal of topsoil, exposure to acid-generating materials, and the stockpiling of mined soil contribute to long-term environmental damage. Without proper reclamation efforts and soil conservation strategies, the affected areas may struggle to recover, posing significant challenges for agriculture, biodiversity, and local livelihoods.

Mining in Ancient Rome and Ghana: A Juxtaposition

There are many structural similarities between the environmental effects of Roman gold mining and modern mining in Ghana, especially when it comes to deforestation, water pollution, and land degradation. In both cases, mining was a key part of economic growth, but it also had huge social and environmental costs. This comparative viewpoint shows that extractive economies, no matter what time period they are in, usually put short-term economic gains ahead of long-term environmental sustainability.

In Ancient Rome, mining was a government-run business that helped the empire grow, paid for the military, and gave the rich what they wanted. During this time, advanced methods like hydraulic mining (ruina montium), opencast extraction, and underground excavation made it possible to mine minerals on a large scale in places like Hispania, Dacia, Gaul, and Britannia. These activities brought in a lot of money for the empire and helped build up its infrastructure, but they also caused a lot of damage to the environment. Mining is also very important for the economy of modern-day Ghana. The sector made up about 7.6% of GDP and about 36% of all exports in 2022. Gold was the most important mineral to produce. Mining has brought in a lot of money, just like it did in Roman times, but not everyone has gotten their fair share.

Even though they were important to the economy, both the Roman and Ghanaian mining systems had a big impact on the environment. Roman hydraulic mining cut down a lot of trees to get wood for mine supports, smelting, and water-management systems. Rivers like the Sil, Tagus, and Olt were full of silt and toxic metals, which left scars on the environment that can still be seen today. Ghana shows similar patterns, especially through illegal small-scale mining (galamsey), which has caused a lot of deforestation, pollution of water, and damage to land. Mercury, cyanide, and sediment have polluted major rivers like the Pra, Offin, and Ankobra so badly that the water is no longer safe to drink or use for farming. In both societies, the breakdown of water systems made food less safe, harmed public health, and hurt biodiversity.

Land degradation is another big area of agreement. Roman mining changed the way the land looked by making artificial cliffs, deep ravines, and abandoned pits. This was especially true at places like Las Médulas in Spain.

Long after mining stopped, these changed landscapes were no longer good for farming or living in. In the same way, surface mining in Ghana has made a lot of land unusable, especially in places like Dunkwa-On-Offin, Ayanfuri, and Kyekyewere, where open pits and poor soils have made farming impossible. Mining fundamentally changed the landscapes in both cases, making it harder for the economy and the environment to recover in the future.

Exploitation of workers is also an important part of the comparison. Roman mining depended a lot on slaves and prisoners who worked in very dangerous conditions, which led to high death rates. Even though modern Ghana does not use forced labor on the same scale as before, mining especially illegal artisanal operations has created new kinds of precarity, like unsafe working conditions, child labor, and informal jobs without any legal protections. Even though these labor regimes are different from each other in the past, they all show a pattern in which extractive economies put social costs on weak groups of people.

There are, however, some important differences between the two contexts. Roman mining was limited by the fact that it relied on manual labor and simple hydraulic systems. In contrast, modern mining in Ghana uses heavy machinery, explosives, and chemical processing on an industrial scale. This increase in technology has made extraction faster and more extensive, which has made the damage to the environment worse. Roman mining was mostly controlled by the emperor, but Ghana's mining industry is more decentralized, with state regulation coexisting with multinational corporations and informal artisanal miners. This lack of consistency in regulations has made it especially hard to enforce environmental laws in Ghana.

The comparison shows that even though mining technologies, political systems, and social structures have changed, the basic conflicts between making money, protecting the environment, and treating everyone fairly are still there. The Roman experience exemplifies the enduring repercussions of unregulated extraction, whereas Ghana's current mining sector underscores the resurgence of analogous patterns in contemporary contexts. These cases show that we need better rules, responsible mining practices, and governments that can balance economic growth with the health of the environment and people.

CONCLUSION

Mining has acted as a double-edged sword in both Ancient Rome and modern Ghana, fostering economic growth while concurrently causing significant environmental degradation and social inequality. This study's comparative analysis shows that both societies have long-lasting structural patterns of extractive resource exploitation, even though their histories, technologies, and systems of government are very different. These encompass the prioritization of immediate economic benefits over ecological sustainability, the marginalization of labor, and the inadequacy of regulatory frameworks to avert enduring environmental damage. Utilizing a comparativist framework, this study transcends mere parallel historical narration to elucidate how extractive economies consistently perpetuate inefficiency, exploitation, and ecological degradation over time. The Roman experience shows how state-led over-extraction and ignoring environmental limits caused damage to the landscape that could not be fixed and lasted long after mining stopped. Ghana's modern mining industry, which is shaped by global capitalism, industrial technologies, and informal artisanal practices, has similar effects, especially on land degradation, water pollution, and social displacement. These similarities show how hard it is for people to turn technological progress and historical knowledge into responsible resource management.

The results show that we need to learn from history right away. First, sustainability needs to be at the heart of mining policy. This means strictly enforcing environmental laws and using technologies that not only boost productivity but also lessen environmental damage. To avoid the permanent damage seen in Roman mining landscapes, Ghana can use modern technologies like using renewable energy in mining operations and systematic land rehabilitation. Second, the way Roman miners exploited workers shows how important it is to have strong labor protections in today's world. To stop the social inequalities that have always come with extractive industries, it is important to make sure that workers are paid fairly, work in safe conditions, and have a say in how things are done. Equally important is the enforcement of environmental laws, such as the Minerals and Mining Act, as well as responsible waste management, land reclamation, and water protection. To lessen the social and economic disruption caused by mining, communities that are affected must be helped with fair compensation, new job opportunities, and programs to help people learn new skills. To stop illegal mining, we

need more than just police. We also need to teach people and give them other ways to make money. To clean up polluted areas and protect public health, it is important to invest in water treatment and ecosystem restoration.

Lastly, the ongoing disparities in wealth distribution seen in both Ancient Rome and modern Ghana necessitate governance frameworks that guarantee mining revenues benefit local communities, as well as states and corporations. To turn mineral wealth into broad-based social progress, we need revenue-sharing systems and targeted community development programs, especially in health care, education, and infrastructure. This study illustrates the significance of historical analysis in modern policymaking. Integrating historical perspectives into governance and public education can assist decision-makers in foreseeing the long-term ramifications of unsustainable practices and cultivate a culture of environmental stewardship and social responsibility. Until such measures are intentionally and consistently enforced, extractive economies will perpetuate cycles of degradation and inequality. However, by critically analyzing historical experiences and applying their lessons to contemporary challenges, mining can be converted from a source of persistent harm into a sustainable catalyst for equitable development.

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Figures

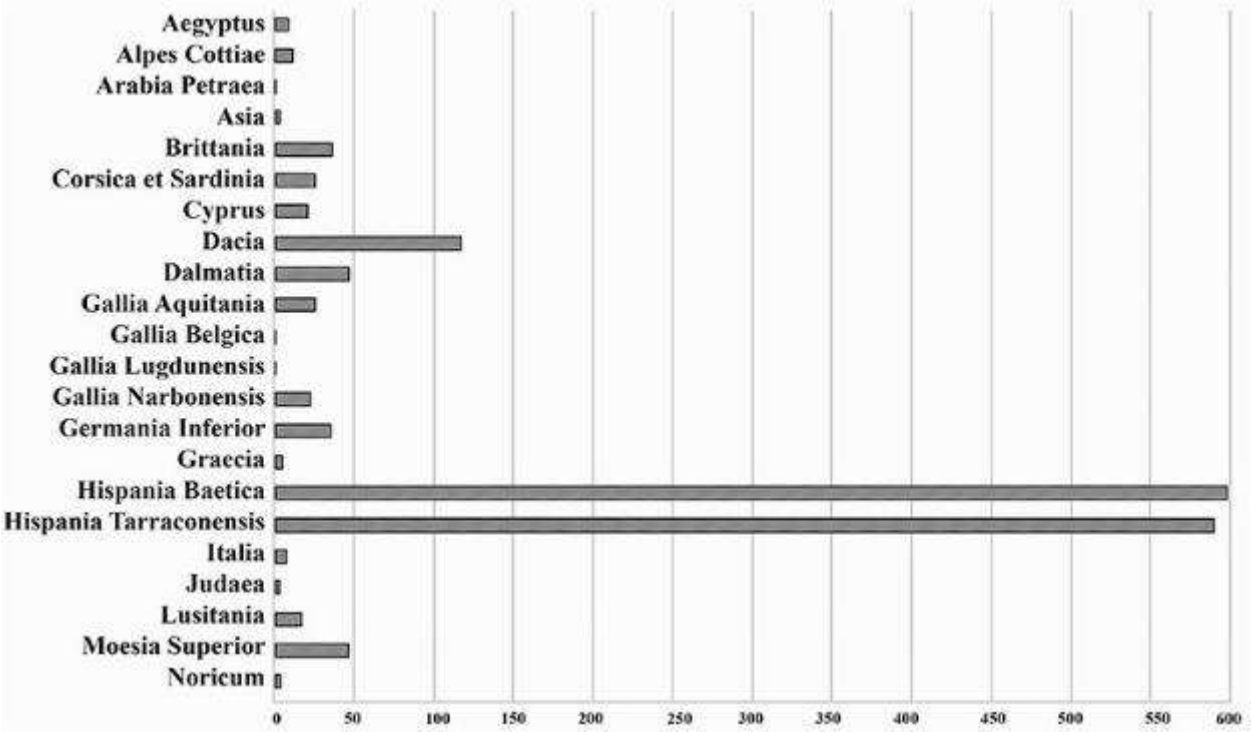

Figure 1. The number of Roman mines in each province as recorded by the Oxford Roman Economy Project. Source: Adopted from Linda Gosner (2024) Mines and Mining, Roman. Oxford University Press

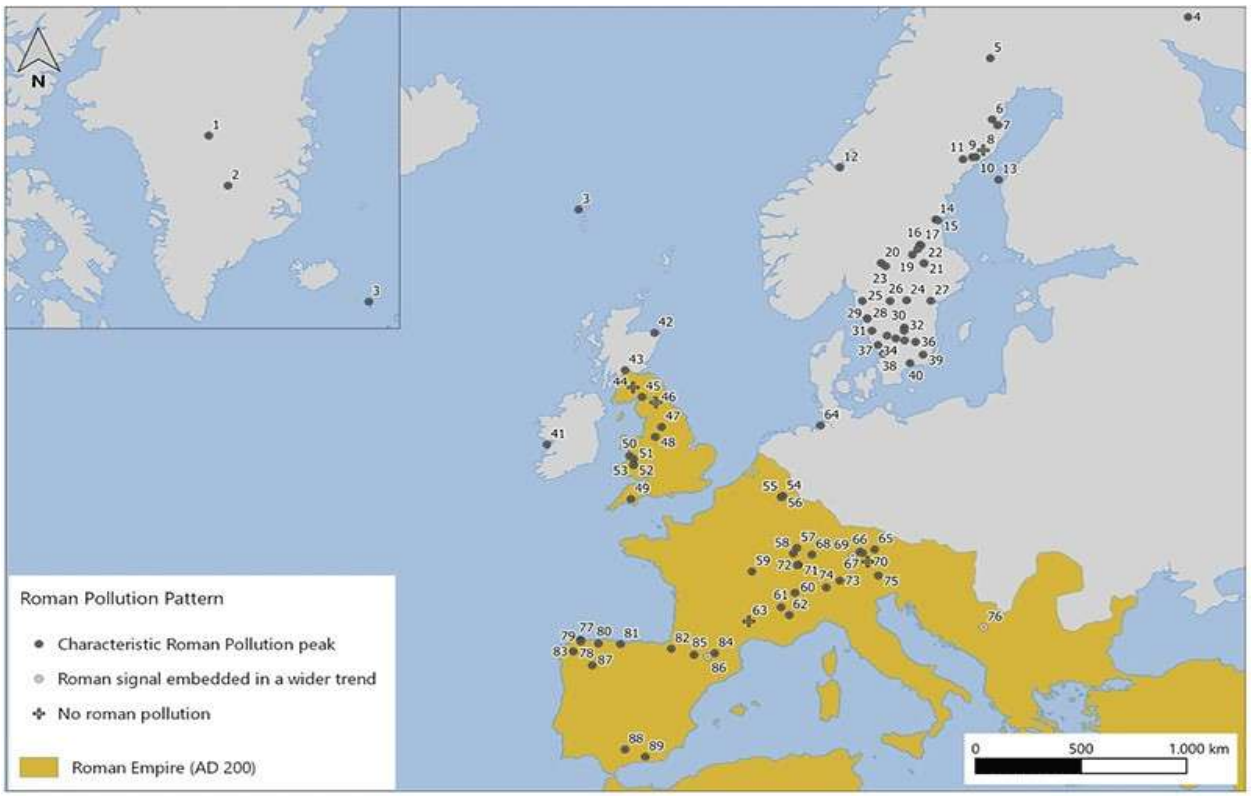

Figure 2. Map of locations of palaeo-environmental studies of peatlands, lakes, and ice cores indicating places where a peak in pollution during the Roman period was detected.

Source: Noemí Silva-Sánchez and Xose-Lois Armada, "Environmental Impact of Roman Mining and Metallurgy and its Correlation with the Archaeological Evidence: A European Perspective Environmental Archaeology.

Figure 3. Opencast gold mining pit at Três Minas, Portugal. Source: Gosner (2024).

Placer mining was a common way to get alluvial gold and tin that was spread out in sand or gravel in streambeds (secondary deposits) or glacial deposits called placers or shoals. The methods used could be as easy as panning for ore along the banks of rivers. To get more water, aqueducts were used to move water into tanks, and then it was released at high speeds to loosen the ground. This process is called hushing. In the second stage, big rocks were taken out and water was sent through fake sluices to separate the ore from the waste. People then took out the nuggets by hand. Even though evidence of panning doesn't last long, there are still signs of large-scale placer mining along the Tagus River in Portugal. These signs include big piles of rocks along the sides of channels and the remains of hydraulic infrastructure. Pliny (1) the Elder (Plin. HN 33.74–76) called the process of getting deep alluvial deposits in north-west Spain ruina montium. To make the earth collapse, underground channels were cut and then filled with water. Las Médulas in north-west Spain has amazing remains of this method that are still there.

Figure 4. Remains of the ruina montium technique at Las Médulas, Spain. Source: Gosner, (2024)

Copper, gold, and argentiferous galena (from which lead and silver were made) were all mined underground. This method used vertical shafts that went down from the surface and connected them to horizontal galleries and adits, which are passages cut into slopes for access, drainage, and/or ventilation. To keep them from falling

down, passages were often supported by wooden or stone scaffolding. People used wooden ladders and pulleys to get from one level to another underground. Oil lamps were placed in niches in the walls of galleries to light the way. People dug these kinds of mines by hand with iron picks, hammers, and gads. Then, baskets were used to collect the ore and bring it to the surface, sometimes with pulleys. In southeast Spain, there are well-preserved shaft-and-gallery mines from the Republican period. In the Iberian Pyrite Belt (Portugal and Spain), there are mines from the imperial period.

Figure 5. Roman gallery with stairway in Cărnic Massif, Roșia Montană, Romania. Source: Gosener (2024)

Some underground mines also show signs of fire-setting, where people use fire to heat the rock face and then spray it with water or vinegar to make it weaker or crack it before breaking it down with iron tools. It was hard to deal with flooding in underground mines that went below the water table. You could either manually bail out the water (Plin. HN 33.97) or let it flow through drainage adits. In some situations, people also used bucket chains, Archimedean screws, and/or water wheels to move and drain water. People have found water wheels in Riotinto and other mines in southwest Iberia, as well as in Dolaucothi and Alburnus Maior (fig. 6). Other tools that were used were baskets, rope, and safety gear like sandals, helmets, and knee pads. Examples made from esparto grass come from southern Iberia.

Figure 6. Source: Author (2025)

This picture shows a mining site in Wasa Akropong, which is in Ghana's Western Region. This region is known for both small-scale and large-scale mining. The picture shows a damaged landscape with exposed sand, mining equipment, and water bodies that look like they were affected by mining. This site shows how mining can hurt the environment, like cutting down trees, polluting water, and ruining land. In Ghana, "galamsey" is the term used to describe both legal and illegal mining operations that cause these effects. The water in the background looks dirty, which could be because of the chemicals and sediment that come in during the extraction process. Most of the plants around the area have been cut down, leaving the land bare and easy to erode.

Figure 7. Source: Author, (2025)

The picture shows a landscape that has been badly damaged, with big holes filled with dirty water, bare soil, and uneven ground from digging. The presence of mining hoses and equipment shows that mining is still going on or has just finished. The lack of plants in the area shows that a lot of land has been cleared. This site shows the environmental and ecological problems that mining can cause, such as land degradation, water pollution, and habitat loss. The reddish-brown colour of the water could mean that sediment and pollutants, like heavy metals or chemicals, are leaking into the area around it.

Figure 8. Source: Author, (2025).

The picture shows a big mining quarry in Wasa Akropong, which is in Ghana's Western Region. It shows a lot of land degradation, with steep, eroded cliffs and a surface that is bare and rocky. There are heavy mining machines, like excavators, at the bottom of the quarry, which means that mining is going on. The big difference between the natural landscape and the mined area shows how big mining operations can hurt the environment. You can see human settlements in the background, which makes people worry about how close these kinds of operations are to local communities and the health and safety risks that dust, noise, and chemical contamination

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could pose. The site looks rough and has no plants, which shows that there have been no efforts to restore or reclaim it. These efforts are important for reducing the environmental impact of mining.

Figure 9. Source: Author, (2025).

This picture shows a part of the Offin River in Dunkwa-On-Offin, Ghana's Central Region, that is dirty. The river looks very dirty, with murky, reddish-brown water that suggests sedimentation and pollution. This is probably because of illegal mining activities, which are often called "galamsey." The area around the house shows signs of serious environmental damage, such as soil that has been disturbed and bare earth that has no plants.

Figure 10. Source: Ministry of Lands and Natural Resources (2021).

The figure illustrates the severe environmental degradation of River Pra due to illegal mining (galamsey) activities. The polluted, reddish-brown water reflects sedimentation and contamination, disrupting the river's natural flow and ecosystem. The surrounding landscape shows stripped vegetation, disturbed soil, and extensive erosion, which collectively highlight the destructive impact of unsustainable mining practices. This situation underscores the urgent need for intervention and restoration efforts to mitigate environmental harm, protect water resources, and promote sustainable resource management.