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RESEARCH ARTICLE

Why is Ghana losing the war against illegal gold mining (*Galamsey*)? An artificial neural network-based investigations

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Abstract

Ghana, like most resource-rich countries, is saddled and inundated with resource curse challenges. Key among them is the problem of illegal small-scale gold mining activities (ISSGMAs), which is mercilessly robbing the nation of its ecological integrity, despite attempts by successive governments to remedy the situation. In the midst of this challenge, Ghana, year in and year out, performs abysmally on environmental governance score (EGC) variables. Against this framework, this study intends to uniquely establish the drivers behind Ghana's failure to overcome ISSGMAs. To achieve this, a total of 350 respondents were sampled through a structured questionnaire, with a mixed method approach from selected host communities, believed to be the epicenters of ISSGMAs in Ghana. The questionnaires were administered from March to August, 2023. AMOS Graphics and IBM SPSS vs 23 were used to analyze the data. In particular, the novel hybrid artificial neural network (ANN) and linear regression techniques were adopted to establish the relational linkages among the constructs of the study and their respective contribution to ISSGMAs in Ghana. The study displays intriguing results that explain why Ghana has failed to be victorious over ISSGMAs. In particular, the findings of the study demonstrate that the three key drivers of ISSGMAs in Ghana, in a sequential and consecutive order are as follows: bureaucratic licensing regime/weak legal framework, political/traditional leadership failures, and corrupt institutional officials. Moreover, socioeconomic factors and proliferation of foreign miners/mining equipment were also observed to contribute significantly to ISSGMAs. While the study contributes to the ongoing debate on ISSGMAs, it also proffers valuable and practical solutions to the menace as well as theoretical implications.

Keywords Ecological integrity · Pollution · Land degradation · Sustainability · Illegal small-scale gold mining

Introduction

According to the 2022, geological survey conducted by the USA, the estimated global reserve of gold is pegged at 54,000 t (USGS 2022). Out of this amount, Ghana is projected to have a total gold reserve of 10,000 t. Since the last two decades, the mining of mineral deposit in the country has been a cocktail of good and bad omen. Large-scale mining of Ghana's gold deposit has been satisfactorily managed and controlled with strict adherence to international best practices on green production protocols. In other words, the large-scale mining sector is able to go through procedural requirement in terms of prospecting, reconnaissance survey, and exploration of mineral resources. The sector is also able to embark on the needed reclamation activities that engender the restoration

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of ecological integrity of mined areas. In addition, the sector is noted for its corporate social responsibilities in line with livelihood empowerment programs in communities where they operate. The story is, however, different when it comes to the small-scale gold mining subsector which is characterized by illegal gold mining activities. Without mincing words, the spate of small-scale artisanal illegal gold mining in Ghana has assumed a terrific dimension in recent years with unprecedented dire environmental consequences on both arable land and freshwater resources had majestic rivers and streams. "Today, there is not much to celebrate about the Pra or the Birim, and there is not much to be excited about over our famed thick forests and the animals that inhabit them. Unacceptable mining and logging practices have laid them to waste" (Akufo-Addo 2021). This statement was made at the presidency of the Republic of Ghana on the back of several unsuccessful attempts by successive governments to fight Galamsey (i.e., illegal gold mining) To say the least, the trails of illegal small-scale gold mining activities (ISSGMAs) in Ghana on the ecological integrity of freshwater bodies and the general environment is posing as a national security threat, and a major public health concern. In the words of Donkor (2022), "The small-scale or artisanal mining sector has been the country's environmental headache. Highly unregulated, it is home to greed, politics, power play and policy dilemma." The ISSGM trade, typically, operates without recourse to regulatory agencies such as the host Municipal Assembly, Environmental Protection Agency, Forestry Commission, Ghana Mineral's Commission and Water Resources Commission. More so, the Ghana Water Resources Commission in 2017 claimed that 60% of the nation's aquatic ecosystem have been polluted (Owusu-Nimo et al. 2018). There are also disturbing reports that describe Ghana as a likely water distressed country. The wanting pollution of Ghana's freshwater bodies by ISSGMAs via carcinogenic substances and its underlying bioaccumulation have been empirically identified as the main causes of renal failure among communities that are doted along rivers with pronounced ISSGMA (Donkor 2022). Beyond the carcinogenic effect of heavy metals, research has also established their neurological effects, especially in children under 3 years. Moreover, Ghana's food security and export mix are threatened due to ISSGMAs. The nation has lost several hectors of its flora and fauna to ISSGMAs. As a result of climate change, the sustainability of cocoa production, which is a major component of the nation's export mix, is threatened. This is because freshwater bodies, which were used by cocoa farmers for farming and domestic activities, have been heavily polluted. The farmers are, therefore, unable to observe the necessary cultural practices that would enhance high yield. The residues from ISSGM sites are tunneled into surrounding cocoa farms, and thus, compromises with the quality of cocoa beans. As a result, there is an eminent ban on Ghana's cocoa beans on European Union markets. This comes on the heels of a new legislative instrument by the European Commission, ostensibly, to achieve sustainable cocoa production while restoring the ecological integrity of cocoa-growing areas. The trend of forest resources and freshwater bodies destruction in Ghana as a result of ISSGMAs will make the attainment of some key targets of the Sustainable Development Goals (SDGs) a mirage if care is not taken. These goals are as follows: Goal 3: "good health and wellbeing"; Goal 6: "clean water and sanitation"; Goal 13: "climate action"; Goal 14: "life below water"; and Goal 15: "life on land." Moreover, Ghana's Environmental Social Governance (ESG) score has been low in recent years.

The quest for finding solution to the Ghana's present environment predicaments to redeem its international image has been the holy grail for successive governments. During a consultative dialogue on small-scale mining in April 2021, the president of the republic remarked "Mining can create jobs, mining can improve livelihood, and mining can generate wealth. But cannot and must not do so at the expense of damaging the very environment that produces riches" (Akufo-Addo 2021). There are a number of failed attempts by successive government in Ghana to halt the operations of ISSGMAs for obvious reasons. For instance, the erstwhile president John Mahama's administration in 2013 commissioned a taskforce to clamp down on ISSGMAs. The problem, however, rear its ugly head, leading to a 6-month ban on all forms small-scale mining in 2017, by the president Affufo-Addo's government. So far, the cumulative effort by various inter-ministerial taskforces including "Operation Vanguard," "Operation Halt I and II," and "Galamstop" has not translated into the desired results (Eduful et al. 2020; Mantey et al. 2020). This trend begs the question of why Ghana is losing the war against small-scale illegal gold mining.

It must be acknowledged that the negative impact of ISSGMAs has led to the conduct of some studies. Most of these studies are, however, characterized by anecdotal details. Scholarly studies on ISSGMAs are dearth with a great deal of paucity despite its horrendous ecological impact. The dimension of prior studies on ISSGMA is also worthy of note. Arguably, the key features of these studies are, primarily, qualitative techniques with dominant applications of "traditional linear predictive models." Major areas covered on ISSGMAs in prior studies include inter alia, criminalization, environmental impact, spatial trend, gender choices, causes, turbidity, climate change, legal ramifications, land reclamation, formalization, enforcement, and social impact of ISSGMAs. Moreover, these studies were conducted without acknowledging the theoretical linkages and associated hypotheses that underpin the statistical relationships among the study constructs (Arthur-Holmes and Abrefa Busia 2022; Bansah et al. 2018; Espin and Perz 2021; Huggin et al. 2017).

To our knowledge, nontraditional quantitative studies on the key drivers of the ISSGM trade remains a gaping hole in literature. With this in mind, we intend to fill this knowledge gap by identifying the factors that contribute to Ghana's struggle to combat illegal gold mining. To achieve this, we plan to use a hybrid method that combines linear regression analysis and artificial neural networks (ANNs). By combining a linear regression with machine learning methods, this study seeks to provide a more comprehensive analysis of the complex factors that drive illegal mining in Ghana. This study is the first to use a hybrid approach to examine the problem of illegal mining in Ghana, and as such, it represents a significant contribution to the literature on this issue. It is envisaged that the implications of the study will counteract the havocs of ISSGMAs in Ghana as the country traverses through the post-corvid turbulence moments.

Review of related materials

In most countries in the world, the environmental problems of ISSGMAs have become an albatross around the neck of leadership (Ogunro and Owulasi 2022; Saim 2021). Accordingly, there have been some studies on ISSGMAs across the globe from diverse perspectives. For instance, Hasibuan et al. (2021) researched on the perception of those in small-scale mining activities with respect to the intervention of the government of Ghana to clamp down on ISSGMAs. The authors reported that the miners nurse the idea that the government should engage them directly in the attempt to ban ISSGMAs. The study, therefore, advocated an improved synergy between the miners and government officials.

Basu et al. (2015) studied on the integrated approach to find antidote to Ghana's ISSGMAs. The study revealed that the problem of artisanal mining is multi-faceted, and therefore, it can only be addressed through effective explanation of scientific results to all stakeholders. Moreover, Osei-Kojo et al. (2016) conducted a study on the challenges of artisanal mining law implementation in Ghana and established that inter alia, lack of government commitment, weak institutions, and corruption are the main anchors of ISSGMA in Ghana. Bansah et al. (2016) studied the dangerous nature of underground artisanal mining in Ghana. The findings of their study indicated that those who engage in underground artisanal mining do not use personal protective equipment (EPA), and their activities leads to land degradation. Owusu-Nimo et al. (2018) researched on the spatial trend of ISSGMA and concluded that a total of 7470 illegal artisanal sites are dotted across the 221 communities of Ghana's Western Region. Azumah et al. (2021) found in a study that school children who engage in Galamsey subsequently drop out of school.

Moreover, Hasibuan et al. (2021) conducted a study on Indonesia to establish possible remedies for ISSGMA and concluded on the following: law enforcement, information dissemination, education and training, alternative livelihood package, regulatory change, formalization and multi-sectorial collaboration. Arthur-Holmes and Abrefa Busia (2021) conducted a study involving women participation in artisanal mining in sub-Saharan Africa. The findings of the study problematized singular model of household decision-making, and accordingly, proffer a nuanced diagnosis of power sharing at rural mining settings. Furthermore, Ibrahim et al. (2020), conducted a study on the choices of gender in artisanal mining at Sierra Leone. The study concluded that gendered norms adversely affect women by curtailing their total participation in the mining sector. Benites (2022) jointly examined the criminalization of small-scale miming sector in Peru and Colombia and concluded that the current legal regimes for mining in the two countries need amendments.

Ranjan (2018) researched on the contribution of the political-industry in the deforestation of mineral-rich region of Goa, India. The findings of the study, inter alia, point regulator impatience and political survival risk as the main drivers that propel ISSGMA. Danielsen and Hinton (2020) studied the social dimension of gender relative to small-scale mining in the Greats Lakes Regions of Africa. The authors found that discriminatory gender relations are legitimated and supported gender norms abound in the small-scale mining industry. Huggins et al. (2017) studied place-making pricing in Africa's artisanal mining industry and concluded that even though negative perceptions on artisanal mining are obvious, governmental agencies and NGOs are relentlessly engaging the miners to regularize their operations. Espin and Perz (2021) examined the environmental crimes linked to ISSGMA in Dios, Peru. The study indicated that lack of law enforcement bolsters ISSGMA.

Study area description

The small-scale gold mining sector in Ghana can be traced from the pre-colonial era. However, at that time, the sector was characterized by rudimentary equipment. Consequently, the sector did not, significantly, alter the country's ecological beauty and integrity. The sector, in recent times, has assumed a different dimension, partly due to the introduction of modern equipment including but not limited to excavators, Chanfan, and dozers. Moreover, those who engage in ISSGMAs in Ghana are well known for using harmful chemicals such as hydrocarbons and mercury. This new twist to small-scale mining is wreaking serious environmental havoc in mineralized communities of Ghana and beyond. Two regions of Ghana namely, Western North and Western Region, were selected for the study. Historically, these regions are arguably touted as the most resourceful regions in Ghana. The major economic activities undertaken in the two regions are

mining, manufacturing, fishing, cash and food crop farming. The exporting produce notable in the regions include oil, manganese, timber, cocoa, coffee, gold, copra, bauxite, and rubber.The regions can boost of a number of large-scale gold mining companies. Statistically, these two regions have10 out of a total of 14 registered large-scale mining companies in Ghana. Furthermore, out of a total of 1342 companies with permission to do small-scale gold mining, 396 of them (constituting 30%) are linked to these regions. On the other hand, these two regions are jointly described as the epicenter of ISSGMA in Ghana (Owusu-Nimo et al. 2018). The mineral wealth of Western North and Western Regions of Ghana has been a symbolic gesture for good and bad omen. More specifically, diverse degrees of fatalities and health challenges in these regions are linked to ISSGMAs. The trails of ISSGMAs in the two regions are seen in the form of abandoned wasteland, polluted water bodies, and destruction of farmland (rubber and cocoa plantation). Since the objective of the study is to identify the factors that fuel Ghana's struggle to combat ISSGMAs from the lens of a hybrid method that combines linear regression analysis and ANN, these two regions were selected due to their notoriety in illegal mining activities.

Theoretical framework and development of hypotheses

Social and economic factors

Market imperfections and governance challenges induce several macroeconomic setbacks. These distortions or setbacks have the propensity to trigger off a degenerated conditions if immediate measures are not taken. There are a myriad of empirical evidence which suggests that high levels of unemployment incentivize people to engage in legally-unacceptable ventures to earn a living. The motivations for people to engage in illegal activities are explained by social exclusion theories. According to Samuel (2018), there is "a recognition by the relational nature of social exclusion to be a preventing interaction, and institutional barrier to access a membership, or as a condition of insufficient social integration, cohesion, or solidarity." Social exclusion points theories point to the fact that demographic cohorts within a given population who feel left out or marginalized refuse to abide by the stipulated regulations that define and guide how socioeconomic activities should be conducted. The identifiable causes of social exclusion include inter alia, academic qualification, political and religious affiliations, corruption, gender, geographical location, old-boyism, age, recruitment process, and institutional policies Samuel (2018).

Ghana, with its developing democratic and emerging economic credentials, is saddled with her unique share of economic issues. Major rating agencies in the third quarter of 2022, described Ghana as a high-risk debt country. Currently, the country is facing a debt-to-GDP ratio of 90.74% and an external debt of $31.3 billion. This makes it the country with the highest indebtedness to the Breton Woods Institutions. Ghana's unemployment rate is frightening. Political policies, external pressure, lack of fiscal discipline, "resource-cursed challenge," and market oversaturation have jointly contributed significantly to high levels of unemployment. Currently, the unemployment rate in the country is estimated to be 13.9%. The future still looks bleak and despondent since an ongoing discussion with the International Monetary Fund (IMF) toward a bailout program has a public sector employment freeze component from the first quarter of 2023 (IMF 2022). This, therefore, presents dark images of social integration, economic resource utilization, social vices, and psycho-social dream attainment. Additional youth will further be pushed into illegal and menial jobs including ISSGMAs if these conditions prevail unabated.

Even though, the ISSGM landscape of Ghana has changed in terms of participation, the sector is largely described as poverty-driven. The wealthy individuals who engage in this illegal gold mining do so through proxies. Empirical records show that small-scale mining has existed in Ghana over centuries as an alternative livelihood channel in mineralized communities with inhabitants who do not have the know-how to fit into formal employment. However, there are opposing theses which suggest that due to the high rate of unemployment, a lot of graduates and professionals are drawn into ISSGMAs. Although people who indulge in ISSGMAs have appreciable knowledge on its horrendous effects on the environment, they justify their misconduct by the degree of marginalization imposed on them by the government and large large-scale mining companies. In other words, most illegal miners harbor the feeling of social exclusion because the government did not consider them while leasing out parcels of land to large-scale mining companies. With reference to the above sketch, we hypothesize that:

H_1: There is a positive relationship between socioeconomic factors and continuous ISSGMAs.

Political and traditional leadership failure

The global view of the mining industry paints a gloomy picture of a political-industry corruption. This unfortunate incident, escalate ISSGMAs. Some studies have, therefore, made attempt to examine the contribution of political incentives in deforestation and the unlawful extraction of mineral wealth via lax remediations. Specifically, Ghosh, 2012 reported that in India, the biodiversity region of Western Ghats is inundated with political-industry briberies and environmental degradation issues. Aulby and Ogge

(2017) validated that in excess of USD 2 billion was paid to Australian politicians in order to facilitate the mining of gas and coal. Essentially, the political decision to ignore environmental remediations is motivated by certain factors which may include safeguarding one's political career, the contribution of the mining industry to the economy. and the risk of conviction. Furthermore, environmental conservation measures, invariably, calls for the enactment and enforcement of eco-friendly laws. Oftentimes, these laws are at variance and loggerhead with the interest of the extractive industry. Hence, some politicians and the extractive industry engage in illegalities to advance their mutual benefits.

Meanwhile, there are alarming reports which indicate that the political economy and the traditional rulership of Ghana contribute to ISSGMAs. Similar to other resource-rich countries in the world, Ghana's mining industry is perceived to be steeped in political corruption. High-profile politicians have been constantly linked to illegal gold mining activities. These politicians, whose illegal gold mining operations are inextricably linked to the governing parties, are mostly known figures within the political arena. They are perceived to provide financial resources to their parties. Due to the centralized and partisan nature of appointments into high offices in Ghana, the judicial system and other auxiliary agencies are equally handicapped and incapable to handle cases involving politicians indiscriminately. With this background, politically-connected cases on ISSGMAs mostly reported in the media are handled poorly. Moreover, it has been observed that illegal miners invariably have field days during election years. This is because, to ensure electoral victory, politicians habitually relax all the remedial measures designed to clamp down on ISSGMAs (Agyekum et al. 2021).

The illegal gold mining ecosystem in Ghana is also believed to be exacerbated by the conduct of some irresponsible traditional leaders. Ghana's land tenure system has a subdivision on stool land. This component mandates chiefs as the custodians of lands within their jurisdiction. Reports, however, indicate that some chiefs at mineralized areas are overstepping their constitutional rights by engaging in the sale of lands to illegal miner.

Indeed, the contribution of leadership failure in the expansion of ISSGMAs cannot be underestimated. Major mining places in the world are saddled with cases involving the political economy's failure to engage miner to remediate mining-induced ecological damages. The political class oftentimes are involved in rent-seeking behaviors and this very act undermine environmental sustainability measures. Mining companies constantly lobby the ruling class to enact laws that will be beneficial to their operations. Because of the symbiotic relationship between politicians and miners, some laws are passed without acknowledging their detrimental effects on the environment (Bansah et al. 2018; Ranjan, 2018; Tschakert 2009). We, therefore, hypothesize that:

H_2: There is a positive relationship between political/traditional leadership failure and continuous ISSGMAs.

Bureaucratic licensing regime and weak legal framework

Bureaucracy is a well-crafted formal structure or organizational establishment with the singular aim to actualize a pre-determined set of social goals. It is perceived by many as a dominant force in modern administrative governance. Following this claim, bureaucracy can therefore, be defined as the possession of control or oversight (through authority, knowledge or power) over something or individuals. Specifically, bureaucratic management theories hinge on two main pillars. The first involves the establishment of proper definition for methods, regulatory frameworks and procedures for executing a desired operation. And the second is on the need to design an organizational hierarchical structure (Ross 1973; Groenendjk 1997).

Bureaucracy carries different connotations to people at the workplace. To some people, bureaucracy involves exasperating experience that undermines adhocracy to projects red tapism. Bureaucracy is seen as a mechanism that does not incentivize people to be creative or innovative. It involves power exploitation, promote one-way communication, inflexible methods, and time wastage. It is mostly deemed as a mechanism that undermines the freedom of choice. It engenders corrupt practices as spelt out by the principal-agent theory (Ross 1973; Groenendijk 1997). On the contrary, there is other schools of thought which posit that bureaucracy helps enterprises to function properly by defining the operative boundaries. It helps to minimize a chaotic working environment by injecting order into operational systems.

Similar to other developing democracies, Ghana's public sector governance is deep-seated in bureaucratic structures (Adu-Baffour et al. 2021; Brierley 2020; Gerth and Mills 2008; Gyamerah et al. 2022). As demonstrated in many studies, bureaucrats capitalize on regulatory provision to unfairly apply their legal-rational authorities on individuals who may need license to venture into economic activity. Some do so by extracting public rent from applicants for their personal interest. In essence, most applicants who are issued with their business licenses on time are those who are perceived to bribe the authorities or were given preferential treatment. Such illegalities have a cascading effect on the activities of those who are given license to operate. Specifically, most of them, refuse to follow the lay down principles enshrined in the scheme of operation. Studies indicate that bureaucrats tend to facilitate the applications of politically-connected applicants. This is because bureaucrats, in most cases, are politically exposed individuals and are appointed to do the biddings of the governing party (Adu-Baffour et al. 2021; Brierley 2020; Lehman and Morton 2017; Oslen 2008; Sudibyo and Jianfu 2015).

Indeed, the ongoing narrative suggest that the nonaligned and those who are unable to pay their way through for certification process are oftentimes denied or unduly delayed in their license acquisition procedures. Eventually, the category of people who fit into this description are forced to start their operation without certification as exemplified in the small-scale mining sector of Ghana. Moreover, there is a segment of illegal small-scale (mostly less educated and subsistence) miners who refuse to start the application process because they claim to have no hope in sight. These individuals might have been briefed by their predecessors about the power play dynamism and the bureaucratic nature of the procedure and have accordingly resolved to operate without license.

Another window that is perceived to contributes significantly to ISSGMAs in Ghana is gross latitude of regulatory framework on mining throughout the value chain process. There is open sale and ready market for mining product regardless of the origin. Even though, the Precious Minerals Marketing Company (PMMC) is the sole authorized agency legally mandated to "grade, assay, value, process, buy and sell precious minerals and to license agents in Ghana," illegal gold miners are able to sell their produce seamlessly to licensed middlemen, due to the absence of effective regulatory framework. In other words, such condition has the propensity to balloon ISSGMAs in Ghana. On the other hand, extant literature has raised a genuine concern on the lack of proper enforcement of existing law on small-scale mining in Ghana. There is apparent reason to believe that this trend is fueling ISSGMAs in Ghana (Adu-Baffour et al. 2021; Bansah et al. 2016; Brierley 2020; Oslen 2008; Ranjan 2018). Following the above claims, we hypothesize that:

H_3: The is a positive relationship between bureaucratic licensing regime/weak legal framework and continuous ISSGMA.

Corrupt institutional officials

Corruption is defined as the abuse of entrusted power for personal gains. It is deemed as a major global problem. Consequently, its minimization is considered as a fount for socio-economic growth and an omen for good governance. Myriad of studies validate that nations engulfed in high incidence of corrupt practices are steeped in developmental retrogression Theoretically, corruption is perceived as multifaceted and complex in nature. As a result, a single theory cannot be used to deconstruct the drivers of corruption within the public sector. However, scholars posit that it is through the prism of the principal-agent, collective action, institutional and game theories that corruption can be perfectly understood (Eduful et al. 2020; Groenendjk 1997; Ross, 1973; Sudibyo and Jianfu 2015).

According to the principal-agent theory, the urge for private gains is mostly deemed as the root cause of corrupt practices. The principal-agent theory assumes the dualism of a principal and an agent dichotomy in the discharge of public service. Under this theory, the principals (mostly referred to as supervisors) hire public official (i.e., agents) for a protected interest. However, because of the problem of information asymmetry and conflict of interest, agents are mostly incentivized to engage in corrupt practices. In other words, the agency problem is encountered when hired public officials (agents) decide to act corruptly in pursuance of their private gains or in a manner that contravenes the principals' defined interest.

The collective action theory on corruption is touted as the best way to explain systemic corruption. According to Groenendijk (1997), "systemic corruption as a collective problem, because people rationalize their own behavior based on the perceptions of what others will do in the same situation." Whenever a given society is reduced to the level where corruption is culturally perceived as a social norm, the inevitable is that people consider it as a conduit for business transactions. People are aware of the consequences of corruption; however, they are incentivized to engage in it because it is deemed as an absurdity to be the sole honest person in a corruption-stricken society.

The game theory is actually a variant of the collective action theory. According to the game theory, individuals are locked up in a loop of "prisoner's dilemma." In a manner which demonstrates a conflict-of-interest scenario between group and individual rational decision-making. Essentially, the individual nurses the thought of being worse off if s(he) frowns of corruption, while others engage in it, given similar circumstances. Consequently, each individual receives some element of benefit. However, their individual cumulative benefit will never be equal to what they would have gained collectively if they had refrained from corrupt deeds (Brierley 2020; Gronenendjk 1997; Ross 1973).

The institutional theory on corruption (institutionalism) attributes the occurrence of corruption to the pertinent features of the laws that establish state institutions. These laws are but not limited to those that are enacted for implementation, enforcement, or to fight corruption. Institutionalism examines how policies, routines, and structures emerge as authoritative framework to shape societal behavior. Institutionalism espouses that corrupt practices are motivated by the conduct of the political environment. It, however, argues that the association between institutions, corruption, gender, and the political environment is multi-layered (Groenendijk 1997; Ranjan 2018; Brierley 2020).

A lot of studies assert the reciprocal effects of corrupt practices on the extraction industry. In other words, studies have established a positive relationship between institutional corruption and loss of ecological integrity. For instance, Akhbari and Nejati (2019) found that corrupt practices heighten the emission of carbon in developing countries; Sinha et al. (2019) identified that corruption

engender ecological damagers by reducing the positive effect of green energy on environmental equality; Wang et al. (2018) found that corruption leads to resources misallocation; and Chang et al. (2022e) studied that corrupt behaviors promote loss of biodiversity. Scores of studies indicate that Ghana's young democracy is engulfed in corrupt practices. The Transparency International, for instance, scored Ghana 43, on a scale of 100, corruption perception index (Transparency International 2022; Teschner 2012; Wireko-Gyebi et al. 2020). Based on the above illustrations, we hypothesize that:

H_4: There is a positive relationship between corrupt institutional officials and continuous ISSGMAs.

Proliferation of foreign miners and mining equipment

Historically, before independence, Ghana was called Gold Coast by the Portuguese (Basu et al. 2015). This presupposes that small-scale mining started way before the arrival of the Europeans. As already acknowledged, the landscape of the small-scale mining sector at the early stage was entirely different. The sector has grown in leaps and bounds due to its current composition. Specifically, during the early stages, the sector, was considered as the preserved of the poor, itinerant Ghanaians who had received little or no formal education and thus, faced the obvious challenge of alternative employment avenues. Consequently, these people plied their trade by applying simple craft and tools including chisel, head pans, picks and sluices, and left no significant impact on the environment (Owusu-Nimo et al. 2018; Wireko-Gyebi et al. 2020; Worlanyo et al. 2022).

In recent times, however, the small-scale miming sector in Ghana has witnessed the participation of foreigners and the introduction of heavy duties equipment. Indeed, Ghana's enviable outstanding democratic credentials, relative peace and sound investment climate have attracted a lot of foreigners who engage in various form of economic activities. Due to the presence of weak institutions, a good number of these foreigners engage in ISSGMAs (The Guardian 2013; Myjoyonline 2017). These illegal foreign small-scale miners have significantly changed the face of small-scale mining in Ghana. Arguably, they are partly responsible for the huge investment in the form of heavy-duty equipment such as caterpillars, bulldozer, and Chanfan in the small-scale mining sector. Collectively, the participation of foreigners in the ISSGM trade in Ghana and the resultant proliferation of mining equipment have scaled up the sector.

Due to the huge return on investment in the industry, coupled with lack of regulatory enforcement, illegal small-scale miners find it prudent to invest in the sector. Some studies suggest that the expansion of ISSGMAs in Ghana is partly blamed on foreigners (The Guardian 2013; Myjoyonline 2017; Wireko-Gyebi et al. 2020; Adu-Baffour et al. 2021). The Ghanaian media landscape is awash with reportages on irresponsible mining by foreigners (Donkor 2022). Characteristically, they operate with utter disregard to buffer zone restrictions and no land reclamation or conservation intention. We, therefore, hypothesize that:

H_5: There is a positive relationship between proliferation of foreign miners/equipment and continuous ISSGMAs.

The proposed relationships among socioeconomic factors; political and traditional leadership failure; bureaucratic licensing regime and weak legal framework; corrupt institutional officials; proliferation of foreign miners/equipment; and continuous illegal small-scale gold mining activities in Ghana are summarized in Fig. 1.

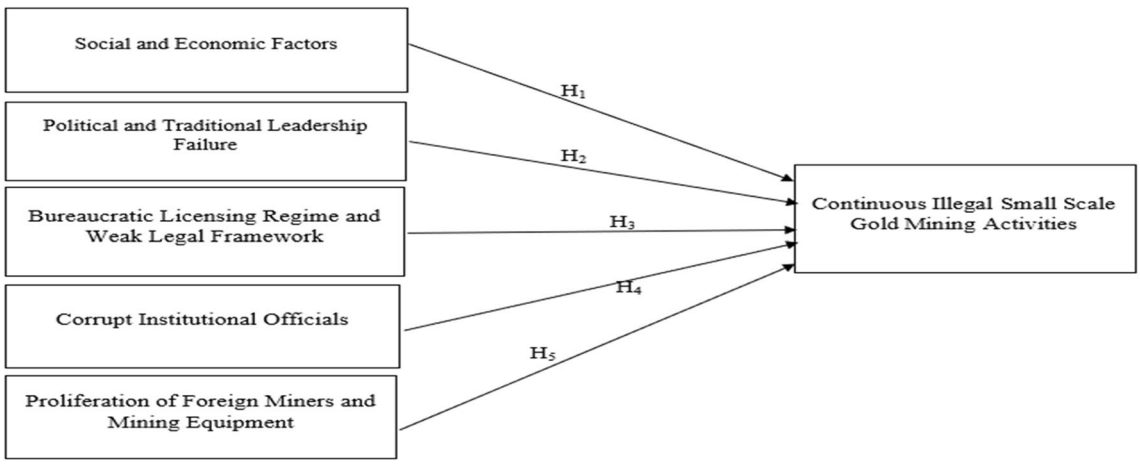

Fig. 1 Proposed conceptual framework of the study

Materials and methods

Survey instrument design

There are two stages that were used in the data collection procedure of the study. The first is the planning stage, and the second is the data collection stage. These were done to enhance the reliability, validity, and the efficacy of the survey instrument. Drawing upon Wireko-Gyebi et al. (2020), the study was designed by applying triangulation techniques to enhance the generalization of the results. Each of the two stages, however, involved a thorough review of ISSGMAs related materials. The highlights of reviewed literature, specifically, were on small-scale mining activities, its socioeconomic impact, ecological impact, associated policy dilemma and legal ramification, trend, and causes. These were used as the keywords to search databases including Web of Science, Scopus, and ScienceDirect for relevant documents. Subsequent to the development of the survey instrument, i.e., questionnaire, there were a series of interviews with the relevant agencies and individual purposely, to assist in the designing of the items of the study and to serve as potential respondents.

Following Owusu-Nimo et al. (2018), the main stakeholders and agencies that were involved in the designing of the study instrument were security personnel (including the Ghana Police Service, the Ghana Immigration Service, the Ghana Armed Forces), Academics, the Ghana Chamber of Mines, Minerals Commission and the Ministry of Environment, Science, Technology and Innovation. The others are traditional authorities, Water Resources Commission, Ghana Environmental Protection Agency, registered small-scale mining companies, Forestry Commission, Ghana Water Company Limited, large-scale mining companies, the media, and the host Municipal Assembly. Moreover, inhabitants from the host communities were also engaged at this stage. The study also engaged a number of pro-environmental non-governmental agencies (NGOs). The list includes Ecological Restorations, Center for Energy, Environment and Sustainable Development.

As part our structured interview, at most, five officials from the aforesaid state agencies, academics, and NGOs with expert knowledge were contacted. The selection of these stakeholders was exclusively based on their willingness and interest to participate in the study. As part of the data triangulation scheme, the authors designed a mixed technique for data collection from both registered and unregistered (hereafter referred to as illegal) small-scale mining operators from the host communities. Specify, this was done via structured interviews and focus group discussion. The focus group discussions were done during town hall meetings with miners and other stakeholders at host communities on diverse themes ranging from the causes to the environmental impact of illegal gold mining. The proceedings of the focus group discussions were recorded and eventually transcribed. This was, however, done upon permission from the participants. Audio speeches that were recorded in the local language (Twi) were accordingly translated to English language. Various data collection methods including systematic sampling, snowball sampling and convenient sampling were used. These methods were adopted at various stages of the study based on the availability of sampling frame (e.g., registered miners list); difficulties in getting respondents due to the sensitive nature of the issue (e.g., illegal miners); and convenience. It must be reiterated that the respondents who were used in the study were interviewed after acknowledging all ethical consent protocols.

A total of six constructs were used in the study. These constructs or latent variables were coded for easy reference and seamless development of related items. They are social and economic factors (SEF_s), political and traditional leadership failure (PFLF), bureaucratic licensing regime and weak legal framework (BLRWLT), corrupt institution officials (CIO), proliferation of foreigner miners and mining equipment (PFMME), and continuous illegal small-scale mining activities. The associated items of these constructs were operationalized based on reviewed literature. In particular, the items on SEFs were adapted from Bansah et al. (2018), Samuel (2018); and Wireko-Gyebi et al. (2020). PFLF items were operationalized from Ranjan (2018) and Donkor (2022). Moreover, the items on BLRWLT were operationalized from Williams and Horodnic (2017), Brierley (2020), and Espin and Perz (2021). The items on CIO were adapted from Lehman and Morton (2017); Dincer and Fredriksson (2018), and Ganda (2020). Lastly, the items on PFMME were operationalized from The Guardian (2013), Myjoyonline (2017), and Donkor (2022) (see Appendix). Following Ampaw et al. (2019), a five-point Likert scale (1 = strongly disagreed through to 5 = strongly agreed) was used. After the pilot survey, the final deployment of the questionnaires was done between March and August 2021. The idea behind the pilot survey was to evaluate the research instrument with respect to distribution channels, questions, and survey structure. The distribution of the questionnaires was done among the leadership of governmental agencies, NGOs, miners, and the inhabitants of the mining communities through research assistants. AMOS Graphics and IBM SPSS version 23 were used to analyze the data.

ANNs

Artificial neural networks (ANNs) is a mathematical model designed to handle data classification and predictions. It was designed to handle nonlinear cases seamlessly. In a typical

regression model, the estimation of linear association is done by multiplying the explanatory variables (hereafter referred as independent variables) by "optimal beta (β) coefficient (weights) and mapping the sum of the results onto output values (dependent variables) that match, as closely as possible the true output" (Aryadoust and Baghaei 2016). In essence, a linear multiple regression model tries to minimize the level of error between the actual and the estimated values. The application of linear regression models is faced with some challenges. These include conforming to a set of assumptions (such as homoscedasticity, multivariate normality, no autocorrelation, linear relationships, and no multicollinearity). These assumptions are somewhat deemed as a mechanism for the loss of certain pertinent component of the dataset (Cook 2020; Albahri et al. 2022).

The inherent limitations of linear multiple regression including its inability to handle nonlinearity is, however, addressed by ANN. In other words, ANN is equipped with the robustness and the dexterity for "the nonlinear aggregation of weighted data" (Aryadoust and Baghaei 2016). Typically, the hidden layer of ANN models is crafted to "aggregate the weighted inputs and passes them to the nonlinear mathematical function to estimate a value that maps to the output nodes" (Aryadoust and Baghaei 2016). ANN determines the exact betas (β s) or weights by random selection of weights. The accompanying error is measured afterwards (i.e., the difference between the actual and the estimated. The ANN mechanism is such that the underlying error is backwardly propagated in the network loop. At this stage, the weights are adjusted via feedback algorithms which is based on iterations, ostensibly, to smoothen the size of the error term. ANN has some robustness advantages over traditional predictive models such as linear multiple regression and structural equation models. Specifically, ANN, by nature, is highly adaptive and scalable, and thus, it does not succumb to linearity constraint.

The estimation process of ANN architecture

ANN is a "nature inspired" machine learning tool (Mehedinta 2022). ANN traces knowledge from a set of data and afterwards stores the acquired knowledge in a form of weights. The weights denote the gravity of the strength between the dependent and the independent variables in a similar manner to regression weights (coefficients). Basically, ANN applications can be done in two ways. These are "multilayer perceptron" and "radial basis function networks." Intuitively, each method estimates weights differently (i.e., learning patterns from raw data) by utilizing activation functions. We adopted the multilayer method in this study.

The multilayer perceptron (MLP) method of ANN does pattern recognition or traces knowledge from data via backpropagation. The algorithm of backpropagation is programmed in a manner that weights are automatically updated whenever the dataset is processed. Another difference between ANN weights and regression coefficient (β) is seen in their estimation features relative to local and global effects. More specifically, both statistics—ANN weights and regression coefficients (β)—are capable of establishing the relationship between the dependent and the independent variables. Structurally, the weights of ANN are designed to estimate local effect. On the other hand, regression coefficients (β) are meant to "estimate global effects of independent variables on dependent variables across all observations, ANN weights measure local effect" (Aryadoust and Baghaei 2016). Given this illustration, the weights of ANN's independent variable can assume positive values on specific nodes and negative values on other nodes.

The architecture of MLP has tripod layers. These are the input layer which consist of the independent variables; the hidden layer which is sandwiched between the input and the output layers; and the outer layer which consist of the model's dependent variable. ANN is mostly referred to as a "black box model" simply because no one has an idea about what really transpires within the model. Moreover, hidden layers are "so called because we don't really know the math that inspire the connectivity between the input and the output variables" (Aryadoust and Baghaei 2016). Figure 2 is a typical multilayer perceptron ANN which has 3 input layers namely X_1, X_2, X_3; 2 hidden layers denoted as H (1:1) and H (1:2); with 2 outer layers, namely, Y_1 and Y_2). Essentially, MLP ANN models attempt to find estimate for the weights (i.e., W_1–W_{14}) that link the input layer to the output layer. By default, the weights indicate the "importance" or the contribution of the input variables to the hidden layer (or the black box). Figure 2, also has additional component which is referred to as "bias." The bias component of ANN is essentially, the equivalent of intercepts in linear regression models (Aryadoust and Baghaei 2016).

In ANN model, the relative effect of the input variables on the output variable is calculated by updating the weights constantly. The regular weights update is proceeded by the application of mathematical functions mostly with "S-shaped" sigmoid function or hyperbolic tangent function to examine the corresponding results. A sigmoid function is considered as a unique form of logistic function (Aryadoust and Baghaei 2016).

MLP ANN utilizes the sum of square error statistics to update the weighs. Moreover, the precision of the weights is constantly tested by adjusting them and in the process the underlying algorithm modifies the gradient of the function. Through this process, the best estimation relative to the output is obtained (Aryadoust and Baghaei 2016; Albahri et al. 2022). ANN models are designed to define the causal relationships between the independent variables classified within the input layer and the classified dependent variables in the output layer during the training stage. The training stage of ANN is proceeded a validation phase by using

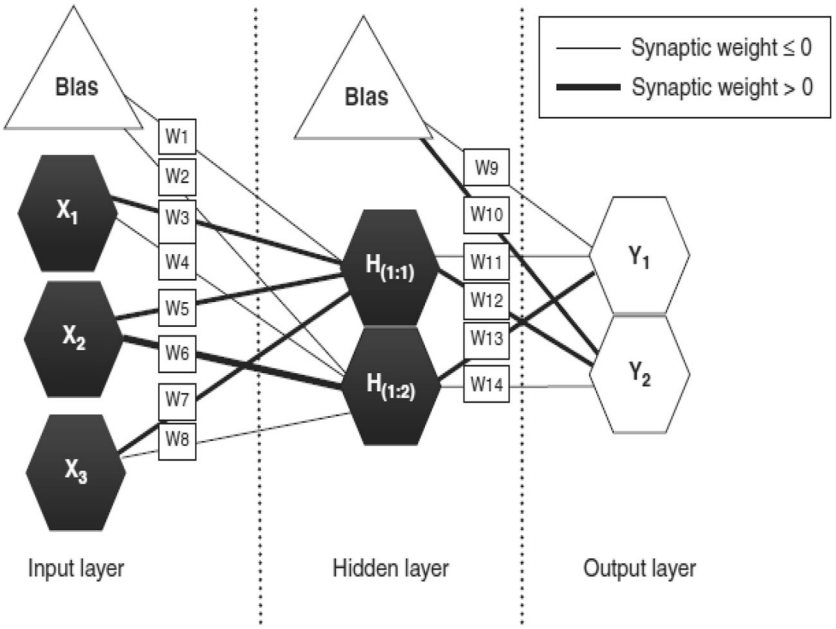

Fig. 2 A three-layer MLP ANN architecture

testing data. Arguably, ANN models have predictive (classification) accuracy, albeit they have not been leveraged much in behavioral sciences to enhance the optimality of results (Aryadoust and Baghaei 2016; Albahri et al. 2022). Hence, its application in our study (Fig. 2).

Figure 3 shows a hyperbolic tangent function of sigmoid function form. Mathematically, sigmoid and logistic functions are expressed respectively as:

$$f(x) = \frac{1}{1+e^{-t}}, and$$
$$f(x) = \frac{R}{1+e^{-R(x-x_0)}}$$

where

e = a constant natural log of 2.718

R = the curve's maximum value.

k = the curve's shape, and

x_0 = the initial value assumed by the function

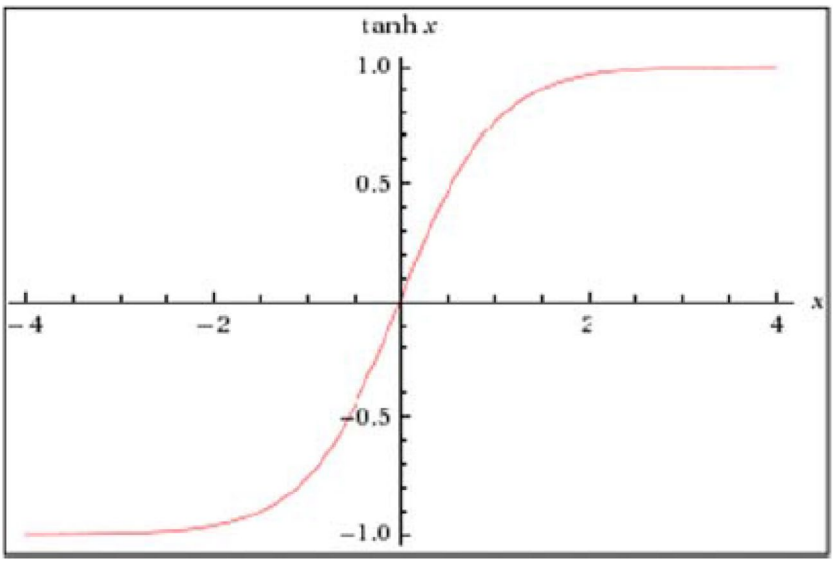

Fig. 3 A hyperbolic tangent function of sigmoid function form

Table 1 Kaiser–Meyer–Olkin (KMO): sampling adequacy and Bartlett's test of sphericity metrics

Measure/test	Value
KMO	0.894
Bartlett's test	
Chi-square	5358.008
df	253
Sig	0.000

Results and discussion

Preliminary analyses based on psychometric measurement

The usable questionnaires for the study were 350. This number constitutes the accumulated questionnaires obtained from the miners, governmental agencies, NGOs, and the host communities. To reduce the incident of data dimensionality, some key pertinent features of the dataset were explored. This was done through exploratory data analysis (EDA). This procedure was augmented by confirmatory factor analysis (CFA), in order to obtain a deep insight on the structure of the constructs of the study. Some specific tests were conducted for both EFA and CFA. Among them are model adequacy, reliability, and convergent (construct) validity. The preliminary analysis of the study indicated that the *P* value relative to the chi-square metric based on the Bartlett's test (Table 1) was significant ($P < 0.05$). This indicates the presence of a relationship among the constructs of the study.

Further checks were done to establish possible causality within the study constructs by using the Promax rotation method under maximum likelihood estimation (MLE) to cluster the study constructs under unrelated blocks. This makes it possible to assess the psychometric properties of the measurement scale. Accordingly,the results of the factor analysis (FA) component had a KMO of 0.894 (see Table 1). This value exceeded the recommended threshold of ≥ 0.7, in literature for model adequacy. Model adequacy can also be done by observing the values of the communalities (see Table 2). It can be observed that each of the factor loadings in the pattern matrix exceeded the recommended threshold. Essentially, "model adequacy measures how well a hypothesized model 'fit' describes the sample data" (Ampaw et al. 2020).

Reliability is used as an indication of internal consistency of the survey instrument. Following Koning and Franses (2003), the Cronbach's α value (0.887) was used as the metric for reliability in the study. The value obtained was within the recommended threshold (> 0.7). Moreover, the validity of our measurement scale was assessed by using the cross loadings of the "factor correlation matrix" (Table 3). As a

Table 2 Factor loading pattern matrix

Constructs	1	2	3	4	5	6
CIO_1		0.786				
CIO_2		0.840				
CIO_3		0.925				
CIO_4		0.844				
PTLF_1						0.874
PTLF_2						0.917
PTLF_4						0.645
BLRWLF_1					0.774	
BLRWLF_2					0.753	
BLRWLF_4					0.814	
BLRWLF_5					0.612	
SEFs_1			0.706			
SEFs_2			0.923			
SEFs_3			0.879			
SEFs_5			0.740			
PFMME_1				0.716		
PFMME_2				0.966		
PFMME_3				0.636		
PFMME_4				0.698		
CISSGMA_2	0.777					
CISSGMA_3	0.944					
CISSGMA_4	0.953					
CISSGMA_5	0.807					

Table 3 Correlation matrix

Constructs	CIO	PTLF	BLRWLF	SEFs	PFMME	CISSGMA
CIO	1.000					
PTLF	0.252	1.000				
BLRWLF	0.486	0.253	1.000			
SEFs	0.332	0.381	0.511	1.000		
PFMME	0.545	0.225	0.501	0.362	1.000	
CISSGMA	0.475	0.53	0.321	0.239	0.613	1.000

demonstration of validity, none of the off-diagonal values was found to be above the acceptable level (> 0.7) (Koning and Franses 2003). Figure 4 was used to check the normality of our dataset.

Structural model: hypotheses testing

The analysis of the dataset indicates a positive relationship between the independent and the dependent variables (Tables 4 and 6). Specifically, the study found a positive relationship between SEFs and CISSGMA ($\beta = 0.427$; $p < 0.001$). This implies that the prevailing socioeconomic situation in Ghana is a key contributor to ISSGMAs. A sizeable number of the population within the economically active bracket oftentimes engage in illegal mining as a means for sustenance and livelihood as indicated as found by Bansah et al. (2018) and Wireko-Gyebi et al. (2020). Also, the study found a positive relationship between BLRWLF and CISSGMS ($\beta = 0.231$; $p < 0.001$). In other words, ISSGMAs are fuelled by bureaucratic licensing regimes and weak legal framework. Most of the small-scale mining applicants abandon their procedural journey for acquiring operational license due to embedded bureaucratic bottlenecks. In effect, those who have made a series of attempt but to no avail engage in mining activities without authorization. Moreover, the current legal framework on mining in Ghana appears to be weak and limited. Some miners, therefore, hide behind the loopholes in the existing mining laws to engage in illegalities. This finding confirms previous studies (Espin and Perz 2021).

The study further found that political and traditional leadership failure contributes to ISSGMAs.That is, PTLF and CISSGMA are positively related ($\beta = 0.276$; $P < 0.001$). This finding validates studies conducted by The Chronicle (2016) and Ranjan (2018), who found that one major contributor to ISSGMA is lack of political will. Other studies also point to the fact that some traditional rulers in the host communities play diverse roles in contributing to ISSGMAs. The study established a positive association between CIO and CISSGMA ($\beta = 0.303$; $P < 0.001$). In other words, another driver of ISSGMAs in Ghana is corrupt institutional officials. The findings of the study collaborate prior studies which assert that the inter-ministerial taskforces commissioned to combat ISSGMAs have not been successful because reliable sources indicate that their activities were embroiled in corruption and unpatriotic tendencies. Government officials, instead of doing the needful, are rather being unpatriotic and encouraging illegality by taking brides and conniving with illegal miners.

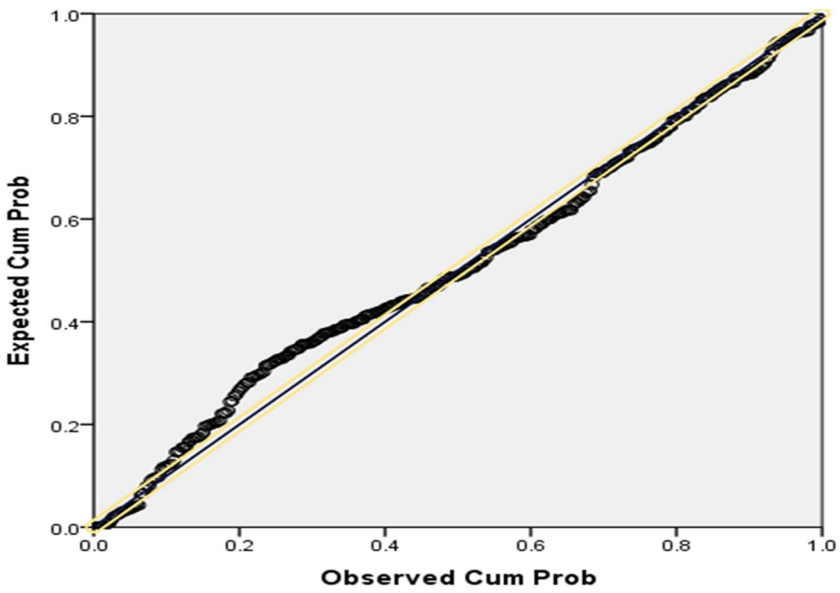

Fig. 4 Normal P-P plot of standardized residuals

Table 4 Hypothesized relationships, standardized coefficient path estimates (effects size)

Hypotheses	Path	Estimates	*P* value	Remarks
H_1	Mean_SEFs → Mean_CISSGMA	0.427	0.000*	Accepted
H_2	Mean_PTLF → Mean_CISSGMA	0.276	0.000*	Accepted
H_3	Mean_BLRWLF → Mean_CISSGMA	0.251	0.000*	Accepted
H_4	Mean_CIO → Mean_CISSGMA	0.303	0.000*	Accepted
H_5	Mean_PFMME → Mean_CISSGMA	0.352	0.000*	Accepted

All the hypotheses were supported at a significance level of $p < 0.001$. Thus, $p^* < 0.001$

According to the findings of the study, there is an indication of a positive association between PFMME and CISSGMA ($\beta = 0.352$; $P < 0.001$) as evident in prior studies (Guardian 2013; Joyonline 2017; Donkor 2022). More specifically, the proliferation of foreign miners and mining equipment in Ghana poses as enabler to ISSGMAs. The vast mineral resources in Ghana have attracted a lot of foreigners. Some of these foreigners partner with unscrupulous Ghanaians to engage in ISSGMA. The problem of illegal gold mining in Ghana is exacerbated by the unrestricted flow of heavy-duty mining equipment. On the bases of the aforementioned findings, all the five hypotheses namely, H_1, H_2, H_3, H_4, and H_5, were supported.

Artificial neural network modelling

Drawing upon (Aryadoust and Baghaei 2016), we chose a training sample of 70% and 30% as our testing data to execute the ANN model. This splitting scheme was, therefore, used as the rules on the number of hidden layers and iterations to be executed. We chose the multilayer perceptron (MLP) functions approach of ANN due to its ease of usage. The key activation function of MLP is the hyperbolic tangent function. One unique thing about MLP model is that it can be applied even if the outcome variable is continuous or categorical (non-metric). In an event that the outcome variable is a categorical data, the ANN software has an inbuilt mechanism which automatically generate forecasted values for every data point. On the other hand, the ANN "generates a predicted value for each case" if the outcome variable is continuous (Wilson and Bettis-outland 2020).

The execution of ANN involves an estimation of weights (Table 5). The weight estimation (analogous to regression β_s) is done within the hidden layer. These weights are considered as the local or unique contribution of each input variable relative to the outcome variable in the model. In this study, we adopted the scale conjecture gradient approach to compute the weight estimates. This method involves two parameters with varied boundaries namely, sigma (from 0.00 to 0.0001, inclusive) and lambda (from 0.00 to 0.000001, inclusive) which must be specified in the study (2018). Following Aryadoust and Baghaei (2016), 0.00005 was chosen as the sigma parameter, and 0.0000005 was chosen as the parameter for lambda. Moreover, the study employed the hyperbolic tangent function to normalize the training dataset. The ANN diagram of the study (Fig. 5) has two bias terms (depicting the intercepts), five input layers (as the dependent variables), nine hidden layers (as the estimated weights), and twelve outer layers (as the outcome variable).

Specifically, the input layer are the means of the responses of the items of the study which were coded in no particular order as Mean_CIO, Mean_PTLF, Mean_BLRWLF, Mean_SEFs, and Mean_PFMME. The details of the estimated weights in the 9 hidden layers are demonstrated in Table 5. Contrary to the regression coefficients (β_s), the estimated weights of ANN have intra-factor differences. For instance, the weights of Mean_CIO across five neurons within a hidden layer (denoted as H (1:5)) is given as − 0.255, − 0.197, 0. 044, − 0.375, and 0.017. The intra-factor difference is explained by the nonlinear nature of the dataset. ANN bias term (coefficient) equips the network with the mechanism to learn the pattern that governs it. In the present study, − 0.562, − 0.645, 0.237, − 0.390, − 0.252, − 0.052, 0.241, 0.306, and − 0.396 were found as the coefficients of the bias term (Table 5). As a demonstration of nonlinearity, the bias coefficients have some element of variation.

Table 5 ANN weight indices for independent and dependent variables

Predictors	Hidden layers								
	H(1,1)	H(1,2)	H(1,3)	H(1,4)	H(1,5)	H(1,6)	H(1,7)	H(1,8)	H(1,9)
Bias	− 0.562	− 0.645	0.237	− 0.390	− 0.252	− 0.052	0.241	0.306	− 0.398
Mean_CIO	− 0.255	− 0.197	0.044	− 0.375	− 0.017	− 0.080	0.241	0.306	− 0.398
Mean_PTLF	− 0.580	0.06	− 0.038	− 0.500	0.329	− 0.164	0.026	0.75	0.119
Mean_BLRWLF	− 0.186	0.27	0.259	− 0.113	0.114	− 0.075	− 0.141	− 0.030	0.72
Mean_SEFs	− 0.136	− 0.019	− 0.003	0.018	0.166	0.105	− 0.107	− 0.128	0.029
Mean_PFMME	− 0.009	0.114	− 0.049	− 0.091	0.024	0.108	0.136	0.095	0.014

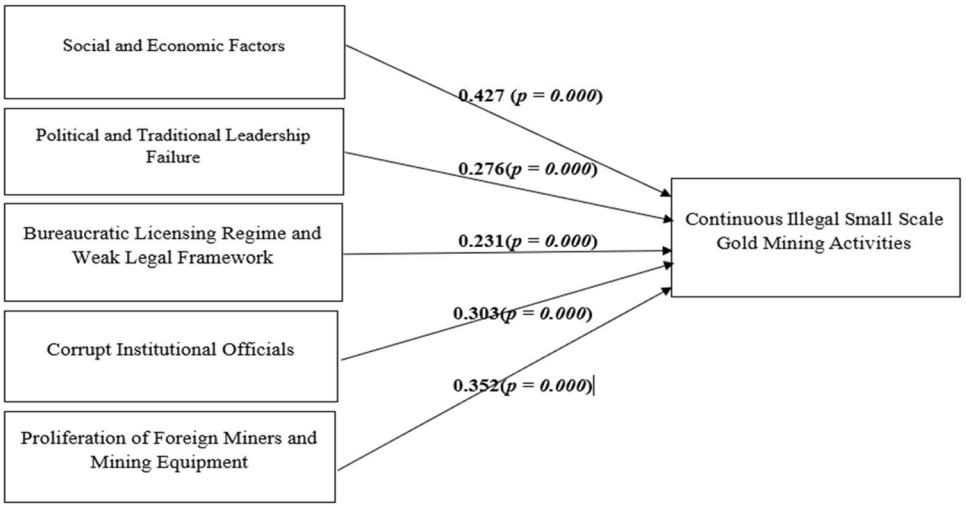

Fig. 5 Structural model results. Source: AMOS Graphics output

In order to determine the contribution of each input variable in the behavior of the output variable, we conducted an independence variable importance analysis. The findings indicated that among the five input variables (BLRWLF, PTLF, CIO, SEFs, and PFMME), BLRWLF, with a normalized importance of 100%, contributes the most to the output variable (CISSGMA). PTLF was identified as the second major contributor to CISSGMA. It had a normalized importance of 64.3%.

Moreover, CIO with a normalized importance of 55.5% was found as the third major contributor to CISSGMA. SEFs (with a normalized importance of 40.7%) and PFMMF (with a normalized importance of 23.7%) were found to be the fourth and fifth contributors to CISSGMA, respectively (see Table 6). It can be observed that the relative contributions of the input variables to the outcome variable under ANN is different from what was observed under the hypotheses testing stage when the regression coefficients were used to establish the relationship between the input and output variables. The reason is that the application of linear regression analysis warrants that the input (independents) variables and the output (dependent) variables should be linearly related. This implies that, linear regression analysis cannot handle a dataset with inherent nonlinear characteristics unless the necessary transformations are made with strict adherence to the underlying assumptions. On the contrary, the ANN model has the knack for the automatic handling of nonlinear dataset without data transformation (Aryadoust and Baghaei 2016; Wilson and Bettis-outland 2020) (Fig. 6).

Discussion

The authors used a mixed method of linear regression analysis and ANN models to address the objective of the study. These methods were used as a complement to each other. In practice, linear regression models are strictly used to examine linear relationships in cases such as theoretical-based hypotheses testing and determination of causal relationship. For this reason, it may have the weakness of oversimplification during multicriterial decision-making. To overcome the challenges of nonlinear and complex linear associations in scientific studies, ANN are used. Arguably, ANN models are considered to have a high degree of predictive precision than traditional regression methods. This is due to ANN models' inherent capability to handle nonlinear and complex linear associations for topnotch forecasting precision. Notwithstanding this, ANN models are not considered as the ideal choice when handling cases involving hypotheses testing and causal relationships. This is as a result of the black box mechanism that is involved in the implementation of ANN. Traditional linear regression methods are therefore, used when conducting analyses on hypotheses testing and causal relationships (Elareshi et al. 2022).

Following Mehedintu and Soava (2022), the discussion of the results pertaining to theoretical hypotheses testing and causal relationship between the input variables and the dependent variable in this study was done by using computed regression coefficients from the structural model. On the other hand, the discussion on the contribution of each input variable to the output variable was done based on ANN results.

Essentially, based on the hypotheses of the study, there are five key findings which are worthy of note. Fist, the study established a positive link between SEFs and CISSGMA.

Table 6 ANN independence variables importance

Factors	Importance	Normalized importance
Mean_CIO	0.195	55.5%
Mean_PTLF	0.226	64.3%
Mean_BLRWLF	0.352	100.0%
Mean_SEFs	0.143	40.7
Mean_PFMME	0.083	23.7%

Fig. 6 ANN model based on the independent and dependent variables

This implies that the prevailing nature of pervasive ISSGMAs is heavily fueled by the socioeconomic challenges the country is facing. According to the Ghana Statistical Service (GSS) report, the unemployment rate as of the second quarter of 2022, stood at 13.9%. In December 2022, the GSS published the inflation rate of Ghana as 50.4%. In fact, the upsurge in the rate of these critical macroeconomic variables have translated into socioeconomic hardship in the country. As a result of these macroeconomic indicators, and the resultant socioeconomic problems such as high cost of living and high dependency ratio, a lot of the youth are drifting into ISSGMAs as the only means of survival. This finding validates prior studies (Bansah et al. 2018). A group member at the focus group discussion profusely lamented:

After completing school, we are not getting work do to. The government has not given us any work to do. Our

parents are out of work and they are not taking care of us anymore. They expect us to provide for them, and for ourselves We can't go and steal. Galamsey is what we can do to survive.According to the findings of the study, if swift measures are not put in place by the government machinery to fix the current socioeconomic hardship in the country, the desire to find a remedy to the prevailing situation of ISSGMAs will be mirage. This implies that the wanton destruction of the ecological integrity of Ghana will go on unabated. Beyond the environmental destruction, and public health concern as a result of ISSGMAs, there are also social problems including teenage pregnancy, drug peddling, and usage that are common at the host communities.

Second, the study found that there is a positive relationship between political/traditional leadership failure and ISSGMAs (i.e., PTLF and CISSGMA). In other words, the political and traditional leadership structures in Ghana, collectively, contribute to ISSGMAs. This finding validates previous anecdotal and empirical publications which claim that both the political and traditional leadership space are involved in illegal gold mining (Ranjan 2018; Rj et al. 2003; The Chronicle 2016; Donkor 2022). Moreover, the findings of the study collaborate with a leaked report authored by Ghana's former Minister of Environment, Science, Technology, and Innovation which implicates government officials in the Galamsey menace. In particular, the report suggests that some key politicians are linked to some Galamsey sites, and that their influence thwart efforts made to clamp down on the menace (Ghanaweb 2023). On the other hand, the Ghanaian land tenure system has a component of stool land by which traditional rulers are recognized as the custodians of the lands. Within this framework, there is deep-seated perception that some traditional rulers at the host communities, without a recourse to due process, engage in the sale of mineralize plots of lands to illegal gold miners. A respondent had this to say during the community level engagement:

> We are not able to go to some of the places we were mining again. The chief of the town has sold the land to some foreigners who are using big machines to destroy the land. The chief says the land is for him. We are now suffering. They will call the police if you go there.

As rightly established in the study, the political class in Ghana has overarching role to play in the continuity of ISSGMAs. There are reliable sources which posit that some of the ISSGMs sites are owned by influential and well-placed politicians. These politicians are able to purchase heavy-duty mining equipment which ordinary Ghanaians are not able to buy and contract people as proxies. The political hand in the ISSGMAs is negatively affecting the success of the war against the menace. Specially, this unfortunate situation has weakened the inter-ministerial apparatus commissioned sometimes ago to fight ISSGMAs in the country by successive governments. The law enforcement agencies are not able to duly prosecute those who are found culpable for flouting mining regulations due to their affinity to political parties. There are reported instances where some foreign illegal gold miners have been left off the hook due to the failure of the State to do the needful. A miner and a focus group participant remarked:

Look, we are not able to buy Chanfan, bulldozers, caterpillars and large concession. The politicians, because they have money are able to do. I can take you to a Galamsey site which is for a politician we all know. They have people who work for them. Third, the findings of the study indicates that bureaucratic licensing regime and weak legal framework on mining correlate positively with continuous illegal gold mining activities in Ghana (BLRWLT and CISSGMA). Even though, it is evinced in literature that mining started in Ghana prior to the arrival of the European in 1400 s, not much has been done in terms of comprehensive laws and regulations that govern mining activities. Moreover, the enforcement of existing regulations due to weak institutions and resource constraint has been identified as a major problem that promotes illegality on the mining industry. It must be admitted that there are governmental agencies such Minerals Commission which is "responsible for the regulation and management of the utilization of the mineral resources of Ghana and the co-ordination and implementation of policies related to mining," according to the 1993 Act 450 of the Minerals Commission, the mining industry is inundated with a lot of illegal mining operations. Aside their resource constraint, their mandate and purview for efficient operation is woefully inadequate. The problem is compounded by the deep-seated bureaucratic bottleneck for acquiring legal mining license.

The findings of the study is consistent with previous studies which espouse that the procedure for acquiring a valid mining permit in Ghana is very cumbersome (Hilson 2001). The process deters prospective miners to do the needful. Miners, who have for a long time made effort to acquire valid mining permit but to no avail, eventually, engage in mining activities without certification from the relevant governmental agencies. In effect, because most people are not successful in getting their license, where possible on time, there is a section of Ghanaians who have decided not to make any attempt to acquire a valid mining permit due to the sheer fact that they will be either delayed or turned down. Arguably, the existing laws on mining in Ghana does not involve the collective decision from other governmental agencies such as EPA, Ghana Forestry Commission, Water Resources Commission, and Ghana Water Company Limited. Lack of collective decision-making and broader consultations have led to the issuance of mining license to certain small-scale miners whose operations eventually contribute significantly

to the destruction of freshwater bodies, forest reserves and the failure to conform to buffer zone regulations. During consultative dialogue and community engagement on how to streamline small-scale gold mining operations in Ghana, one theme that mostly come up for discussion was the need to review the existing laws in the country. The following is the remark of a participant at a consultative dialogue meeting:

> People engage in Galamsey because they find laxity in the mining laws. Without new laws on mining, Galamsey will still go on.

Four, the finding of the study indicates that there is a positive association between corrupt institutional officials and continuous illegal small-scale gold mining activities in Ghana (i.e., CIO and CISSGMA). Once again, this finding is a confirmation of earlier studies (Eduful et al. 2020; Wireko-Gyebi et al. 2020). Arguably, Ghana's economic woes is partly blamed on corruption and weak institutions. Corrupt practices are perceived to have permeated in every sphere of the country's institutional hierarchy. It is believed that the failure of successive governments to win the war against ISSGMAs is because state officials who have been mandated, resourced and commissioned to clamp down on ISSGMAs are rather pursuing counterproductive schemes that inure to their selfish gains. Specifically, the establishment of inter-ministerial taskforces (e.g., Operation Vanguard and Operation Halt I and II) to clamp down on ISSGMAs in Ghana to restore the country's ecological glory did not see the light of day due to the inherent and instrinsic selective justice, corruption tendencies and conflict of interest embroidered in their operations. Moreover, the Ghanaian media space is awash with reported cases where military personnel who have been detailed to forest protect river bodies, and some heavily-destroyed illegal mining communities to ward off illegal gold miners end up to provide cover for these miners after taken bribe for them. These allegations were unanimously collaborated by participants during a focus group discussion comprising of miners and residents at the host communities:

> We are aware that the soldiers the government has brought are not doing the right thing. They are allowing the people to mine in areas where they are not supposed to mine. If you can pay some amount of money to them, they will allow you to do your Galamsey. The police are also part. They take bribe and make sure that do your work. They only worry those who are not able to pay what they ask for.

Moreover, a section of a leaked report by an ex-chair of the 'Inter-Ministerial Committee on Illegal Mining' opines that a soldier, posthumously named Major Maxwell Mahama, who was mistaken for an armed robber and gruesomely murdered in cold blood during the heat of the Galamsey saga in 2017, was actually providing security for a notorious Galamsey site in Denkyira Oduase co-owned by C&J Aleska, through a special arrangement from the Ghana Army (Ghanaweb 2023). Five, the findings of the study demonstrates that there is a significant positive relationship between proliferation of foreigners/mining equipment and continuous illegal small-scale gold mining activities in Ghana (i.e., PFMMF and CISSGMA). Historically, the small-scale mining landscape in Ghana has evolved significantly to assume the current national security threat status. Prior to the last two decades, simple techniques involving tools such as pan, pickaxe, shovel and washing of gold-laden soil were mostly used by small-scale miners. The sector, in recent times, has scaled up and grown in leaps and bounds, partly because of the influx of advanced mining equipment and other technologies. The ease of access to this equipment (such as bulldozers and caterpillars) has contributed significantly to ISSGMAs and its resultant effects in Ghana. The wanton destruction of river bodies, farmlands, and forest reserves as a result of ISSGMAs are done through the usage of these machines. Studies indicate that because most small-scale miners have limited know-how, they are unable to efficiently conduct reliable scientific assessment at mineralize areas before they embark on their operations. Consequently, vast tracts of land are destroyed without obtaining any meaningful amount of gold.

On the other hand, there has been an increasing trend of participation of expatriates in ISSGMAs in Ghana. These people came to Ghana due to the country's much celebrated mineral wealth, its serene investment climate, stable democratic governance (credentials), and the general hospitable nature of Ghanaians. Unfortunately, some of these expatriates end up joining the ISSGM trade after forming business partnership with Ghanaians. Community engagement reports point to the fact that most of the well-resourced illegal miming sites are owned and operated by foreigners either wholly or on partnership basis. These people are emboldened and operate with impunity and latitude due to the weakness of some state institutions.

As already acknowledged, due to the superior advantage of ANN models in terms of forecasting precision, the importance of the independence variables to the dependent variable were determined by using the normalized importance of the ANN results. Basically, the normalized importance of ANN output explains in percentage terms, the importance of each independent variable in the behavior of the dependent variable. Given this background, the findings of the study indicates that the first major driver of ISSGMAs in Ghana is bureaucratic licensing regime/weak legal framework. It had a normalized importance score of 100%. This implies that the weakness, latitude, limitations of mining laws, coupled with thecomplex hierarchy for small-scale mining license acquisition are cumulatively

fueling ISSGMAs in the country. People who are bent on mining hide behind these unfortunate prevailing conditions to carry out their nefarious activities. This, therefore, calls for the urgent review of the existing mining laws in the country to make it comprehensive to achieve effective results. The second most important driver of ISSGMA in Ghana per the findings of the study is political and traditional leadership failure. It had a normalized importance score of 64.3%. Indeed, this confirms the widespread perception on the participation of influential politicians and traditional leaders in ISSGMAs (Wireko-Gyebi et al. 2020). People who have been placed in trusted positions as custodians of national treasure and heritage, policy makers and law enforcers, out of unpatriotic behaviors are engaging in unacceptable behaviors for their parochial interest which feed the menace of ISSGMAs.

With a normalized score of 55.5%, the findings of the study scored corrupt institutional officials as the third major driver of ISSGMA in Ghana. This presuppose that one major canker which needs to be tackled before attaining a meaningful result in the fight against ISSGMAs is corruption. There are perceptions of high-level corruption within Ghanaian institutions. Without a concerted effort to stamp out corruption in Ghana, ISSGMAs will keep on to rear its ugly head despite its horrendous ecological impact. Socioeconomic factor was scored as the fourth most important determinant of ISSGMAs (with a normalized score of 40.7%). This is in a stark contradiction and counterintuitive to the coefficient of the socioeconomic produced by the linear regression output. More specifically, the regression results rated the socioeconomic factor as the factor with the highest positive correlation with ISSGMAs in Ghana. The obvious explanation is the differential computational methodology employed by the two methods. An inference can also be made from the nonlinear nature of the dataset of our study. While ANN perfectly works with a nonlinear and complex dataset, linear regression analysis is solely applicable to linear dataset. The scoring of the socioeconomic factor by ANN also provides a convincing explanation that the country's socioeconomic challenges are impacting negatively on the fight against ISSGMAs. The situation, therefore, calls for a realistic socioeconomic intervention programs that will absorb the teeming youth into meaningful employment schemes. As researched by Arthur et al. (2016), the youth are trapped into ISSGMAs due to the high rate of unemployment in Ghana.

Lastly, according to the findings of the study, proliferation of foreign miners and mining equipment had a normalized importance of 23.7%. With this, it was scored as the fifth major contributor to ISSGMAs in Ghana. Indeed, the form and dimension of ISSGMAs are different from the early days of the trade.

Conclusion

Ghana is perfectly described as a West African tropical country with a unique climate which used to provide support for nature-based agricultural activities. The country is also endowed with an eye-watering stretch of mineral resources such as gold, diamond, bauxite, oil, manganese and natural gas. However, the illegal extraction of some of these mineral wealth, especially gold, is significantly causing the destruction of arable land and important river bodies, with dire public health hazards. In fact, ISSGMAs in Ghana has evolved as a major national security issue, and accordingly, has garnered lots of discussion and debates on how to halt the menace in order to sustain human and ecological health. Successive governments have marshaled diverse mechanisms to bring the issue under control but have recorded close to no success. It is an admissible fact that the horrendous impact of ISSGMAs has attracted a lot of attention in academia. Arguably, publications made so far on the subject matter are considerably skewed toward qualitative methodologies, without much theoretical underpinning and related hypotheses testing components to better reflect scientific procedures. In particular, a myriad of these studies covered themes such as regulations and laws on mining, effects and plausible solutions of illegal mining, gender distribution in artisanal mining, perceptions on the ban on small-scale mining. With this in mind, the objective of this study is to theoretically examine the key drivers of the ISSGM sector in Ghana quantitatively.

The achieve the objective of the study, a through literature search was first conducted to identify the likely constructs that push people into ISSGMAs. These constructs were operationalized to suit the context of the study. Moreover, through a focus group discussion in the host communities, other themes were deduced as critical and instrumental to the causes of ISSGMAs in Ghana. In all, five constructs (themes) were found to be the likely drivers of continuous CISSGMA in Ghana. These constructs are social and economic factors (SEFs), political and traditional leadership failure (PTLF), bureaucratic licensing regime and weak legal framework (BLRWL), corrupt institutional officials (CIO), and proliferation of foreign miners and mining equipment (PFMMF). Accordingly, a survey instrument was designed from these constructs, and subsequently administered in some selected mining communities in Western North Region and Western Region of Ghana.

The findings of the study indicated interesting revelations that are indispensable for policy direction and managerial advice. Specifically, the ANN results demonstrated the contributions of each construct to ISSGMAs in Ghana. According to the ANN findings, the factor that contributes the most to ISSGMA in Ghana is bureaucratic

licensing regime/weak legal frame. This explains the fact that most people hide behind the limitations in the current legal framework on mining to engage in ISSGMA. This particular finding validates prior research which posit that the lacuna in the existing laws and regulations in Ghana empowers illegal miners to soldier on in their activities There is, therefore, a loud public outcry on the need to revisit the existing laws and regulations on mining to inculcate the necessary clauses that will make ISSGMA impossible and unattractive trade to venture into. The study also indicates that there is a lack of proper enforcement of the existing laws on mining in Ghana. In other words, authorities with the statutory powers to enforce existing laws are not doing so due to their parochial interest. Moreover, the length of time it takes to acquire a legal permit to mine was also considered as a key component that cause people to engage in ISSGMAs.

The ANN findings of the study established that political/traditional leadership failure is the second most important driver ISSGMA. This confirms the long-standing belief that political actors and traditional leaders are in one way or the other involved in ISSGMAs. It also explains the resultant failure by successive governments to deal with the menace despite the loss of ecological integrity, international appeal for carbon credit and possible ban on Ghana's cocoa beans on the European Union market. There are incessant allegations of political machineries being financed by some illegal small-scale miners. Hence, the failure to deal with them decisively when they are caught. On the other hand, traditional leaders, without recourse to statutory agencies are perceived to sell off their mineralized lands to illegal gold miners.

The ANN results rated corrupt institutional officials (CIO) as the third major contributor to ISSGMAs. This finding is a testament to the deep-seated perception of corruption in Ghanaian institutions. The study indicates that statutory officials who have been mandated to ensure compliance with various strategies designed by successive governments to clamp down on ISSGMAs are rather joining forces with the illegal miners to perpetuate their despicable activities. There are even reported cases where inter-ministerial taskforces which have been deployed to selected host communities to combat ISSGMAs were caught on camara taken brides and shielding illegal gold miners. Moreover, the ANN findings of the study indicates that the fourth contributor to ISSGMAs in Ghana is socioeconomic factors. Indeed, it must be admitted that the current economic hardship and its corresponding worsen socioeconomic conditions have deepen the unemployment problems in the country. Youth unemployment is, arguably, at its all-time high. In the midst of this, job insecurity is a major problem now. Consequently, some people, especially the youth, are driven into ISSGMAs as the sole means earn their livelihood.

Proliferation of foreign miners/mining equipment (PFMME) was identified as the least contributor to ISSGMA in Ghana. Regardless of how PFMME was ranked, this aspect of the findings of the study is consistent with prior studies which admit that the landscape of ISSGMAs in Ghana has significantly changed. This is due to the introduction of modern equipment and the influx of foreigners. Before the introduction of modern miming technologies in Ghana, the existing know-how for small-scale mining was the applications simple tools.

In terms of the linear regression analyses, the finding of the study indicates a positive relationship between each of the independent variables and the dependent variable of the study. Comparatively, the linear regression output is not the same as the ANN output. The singular reason which accounts for the differential output in these methods is that the architecture of ANN models has a superior advantage to handle non-linear dataset.

Policy and theoretical implications

The findings of the study will serve as reference mine for managerial advice. Specifically, the study indicates that ISSGMA cannot be curtailed or stamped out without finding a remedy to the acute unemployment problem in the country. In view of this, the government of Ghana as a matter of urgency must make concerted effort to establish alternative employment schemes to absorb the teeming unemployed youth population. It is believed that such alternative employment schemes will serve as effective exit route with the proclivity to draw those entrapped in ISSGMA to a more decent and legally permissible enterprises. Second, the study observed that influential politician and traditional rulers are involved in ISSGMA. Policy intervention in the form of "name and shame" should be employed to publicly exposed these influential, unpatriotic, and unscrupulous individuals in society. The concept of name and shame interventions can be equally applied on corrupt State officials who are found to engage in bribery and corrupt practices. Whistleblowers whose effort translate into meaningful outcomes relative to name and shame interventions should be duly rewarded by the appropriate governmental agencies, among others.

The nature of the present legal framework on mining in Ghana, as established in the study, in diverse ways promote ISSGMA. The laws on mining in Ghana, therefore, need to be reviewed to make it more stringent. This will avoid any potential lapses for illegal miners to operate. The revised laws on mining should stipulate the joint involvement of all relevant agencies such the Minerals Commission, Forestry Commission, Resources Commission, and the Ghana Water Company Ltd., in the issuance of mining permit, its enforcement, monitoring, and evaluation. These agencies should be better resourced to discharge their duties efficiently. Again,

they should be empowered to have the necessary legal backings to coopt other governmental agencies where necessary to execute actions such as routine patrol in host communities to ensure closer of illegal mining sites, compliance, and enforcement of buffer zone restriction. Moreover, the revised laws on mining should pronounce a more punitive actions against those who engage in illegal mining. A more stringent and harsher punishment will deter people from engaging in the act. A policy intervention on decentralization (i.e., adhocracy measures) of the process of acquiring mining permit is also deemed as indispensable in the fight against ISSGMA. The application of ANN in the present study has a number of theoretical implications. This is because, to our knowledge, this happens to be a novel study which applies ANN to the debate on illegal gold mining. First, ANN allows for a more sophisticated analysis of the dataset. This is due to the fact that ANN has the wherewithal to identify complex relationships between the various factors that may not be captured by traditional regression analysis. This is particularly relevant in the case of ISSGMAs, where there may be multiple interacting factors that contribute to the menace. Second, the use of ANN also enables the creation of complex predictive models that can be used to anticipate robust future trends in ISSGMAs. Against this framework, corresponding practical and realistic remedies can be marshalled ahead of time. This has significant policy implications, as it can help policymakers to better understand the causes of ISSGMAs and develop targeted interventions to remedy the menace. Third, the combination of linear regression analysis and ANN in this study provides an opportunity to compare the results of both techniques and assess their relative strengths and weaknesses. This has important methodological implications for future research, as it highlights the potential benefits of using a hybrid approach to analyze complex data. All in all, the study represents an important contribution to the literature on illegal mining, as it utilizes a hybrid approach of linear regression analysis and ANN to identify the predominant factors that promote illegal gold mining (or explain why the fight against illegal gold mining is being lost in Ghana). The theoretical implications of the study highlight the potential benefits of using ANN in combination with traditional regression analysis to analyze complex data and develop predictive models for policy interventions.

Limitations of the study

The study is confronted with two main limitations. First, the outcome of the study is based on cross sectional survey. A longitudinal study is, therefore, recommended to be carried out to validate the findings of the study. Second, in determining the drivers of ISSGMA, a five-factor model, comprising of SEFs, PTLF, BLRWLT, CIO, and PFMMF, were used. We, therefore, recommend that future studies should explore other factors that might also contribute to ISSGMA. Third,the present study employed ANN as a machine learning (ML) technique.Future research, could therefore, adopt other MA techniques such asrandom forest, support vector machine (SVM), clustering, associationrule learning, k-nearest neighbor (KNN), and naïve Bayes to explorediffer-ent factors that may influence ISSGMAs.

Appendix

Constructs and items of the study (Questionnaire)

Social and economic factors (SEFS):

Most people engage in small-scale illegal gold mining due to lack of alternative employment opportunities (SEF1)

The current economic hardship in the country is forcing many people into small-scale illegal gold mining (SEF2)

People engage in small-scale illegal gold mining due to the problem of job insecurity (SEF3)

Most of the youth are in small-scale illegal gold mining as a result of peer pressure

(SEF4)

People engage in small-scale illegal gold mining because they are disappointed in the prevailing social structures (SEF5)

Political and traditional leadership failure (PTLF):

There is obvious lack of political will in the fight against small-scale illegal gold mining

(PTLF1)

The political system supports small-scale illegal gold mining (PTLF2)

There is involvement of traditional leaders in small-scale illegal gold mining (PTLF3)

Influential politicians are involved in small-scale illegal gold mining directly (PTLF4)

The political system provides only kneel jerk solutions to small-scale illegal gold mining problem (PTLF5)

Bureaucratic licensing regime and weak legal framework (BLRWLT):

The licensing procedure for operating small-scale gold mining is too cumbersome

(BLRWLT1)

The centralized nature of licensing acquisition deters people from doing the right thing

(BLRWLT2)

Unfair denial of license force people to engage in illegal small-scale gold mining

(BLRWLT3)

The legal framework on small-scale gold mining in Ghana is limited

(BLRWLT4)

There is weak enforcement of regulatory framework on small-scale mining

(BLRWLT5)

Document requirements before issuing with a gold mining license is a major challenge

(BLRWLT6)

Illegal gold miners hide behind the weakness of mining regulation to engage in small-scale illegal mining (BLRWLT7)

Corrupt institutional officials (CIO):

The inter-ministerial taskforce commissioned to tackle small-scale illegal mining are compromising (CIO1)

The nation has weak institutions to fight small-scale illegal gold miming (CIO2)

Government officials tasked to fight small-scale illegal gold mining are not patriotic and responsible (CIO3).

Government official responsible for fighting small-scale illegal gold mining end up pursuing their selfish interest (CIO4)

Government officials are refusing to process small-scale illegal gold mining culprits for court due to perceived bribery and corruption incidence (CIO5)

Proliferation of foreign miners and mining equipment (PFMME)

Some foreigners in Ghana are providing logistic support to Ghanaians who are into small-scale illegal gold mining (PFMME1)

Modern mining equipment and technology have significantly contributed to small-scale illegal gold mining in Ghana (PFMME2)

Some foreigners are using capital intensive methods to engage in small-scale illegal gold mining directly (PFMME3)

The influx of foreign miners has significantly improved the sale of mineral resources

(PFMME4)

The open sale of mining equipment has exacerbated small-scale illegal mining activities

(PFMME5)

Continuous illegal small-scale gold mining activities (CISSGMA):

There is no hope in sight in the fight against small-scale illegal gold mining (CISSGMA1)

I am convinced that we have lose the fight against small-scale illegal gold mining (CISSGMA2)

The probability of eradicating small-scale illegal gold mining is zero (CISSGMA3)

I am convinced that attempt to clamp down on small-scale illegal gold mining is an exercise in futility (CISSGMA4)

I doubt in our success to win the fight against small-scale illegal gold mining (CISSGMA5)

Auhor contribution Enock Mintah Ampaw, Junwu Chai, Yuguo Jiang, provided conceptualization, methodology and writing of the draft; Enock Mintah Ampaw and Junwu Chai did the reviewing and editing. Koffi Dumor and Edem Koffi Amouzou conducted data curation and visualization. Enock Mintah Ampaw, Junwu Chai, and Yuguo Jiang supervised the study.

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Declarations

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