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RESEARCH ARTICLE

ILLEGAL GOLD MINING IN THE RAPIDES GRAH CLASSIFIED FOREST, CÔTE D'IVOIRE: DETERMINING FACTORS AND ENVIRONMENTAL CONSEQUENCES

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ABSTRACT

Illegal gold mining is a growing threat for both forest and aquatic ecosystems in Côte d'Ivoire. This study aims to analyze the determinants of its development and its environmental impacts in the 'Rapides Grah Nord' Classified Forest. The methodology is based on a literature review, semi-structured interviews with institutional stakeholders, and spatial analysis using GIS and remote sensing tools. Physicochemical and metal analyses of water samples were also conducted. The results show that the abundance of forest and water resources, the presence of agricultural camps, and monitoring difficulties contribute to the persistence of illegal gold mining. Areas affected increased from 73 ha in 2013 to 343 ha in 2023. This activity causes forest cover degradation, soil erosion, and deterioration of water quality. The Hana River, in particular, shows high turbidity (249 NTU), a high concentration of suspended solids (154 mg/L), and cadmium and mercury levels exceeding the reference guideline values used in this study. These findings highlight the need to strengthen monitoring, restore degraded sites, and improve natural resources governance.

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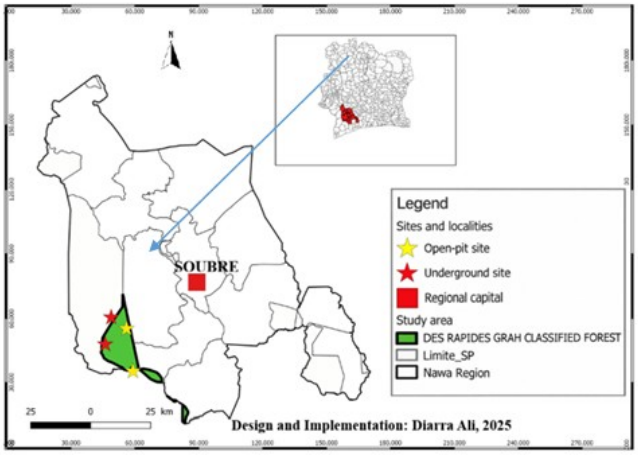
INTRODUCTION

In many sub-Saharan African countries' rural economy, artisanal and small-scale gold mining plays a significant role. While it provides a source of income and livelihood for many people, its expansion also brings about major changes to the landscape. In tropical regions, the opening and expansion of mining sites can lead to vegetation clearing, soil degradation, landscape alteration, and the disruption of water resources. When these activities take place in areas of high ecological value, their impact can also result in habitat loss and ecosystem fragmentation (Dossou Etui et al., 2024, p. 489). In West Africa, the growth of artisanal gold mining is part of a complex set of economic, social, and territorial dynamics. Factors such as the pursuit of income, the allure of gold, population mobility, territorial accessibility, and the conditions for accessing resources can all facilitate the establishment and spread of mining activities.This kind of mining can thus impede other forms of land use such as agriculture and natural resource conservation and contribute to the restructuring of rural areas (C. Soko, 2019, p. 70). Côte d'Ivoire is no exception to this trend. The expansion of artisanal gold mining across several regions of the country is followed by transformations in rural landscapes and natural resources. Documented impacts of gold mining activities include changes in land use, a reduction in vegetation cover, soil degradation, and the disruption of aquatic ecosystems (R. Mason et al., 2019, p. 1163). At the same time, the growth of unregulated activities has heightened the challenges surrounding land-use control and the sustainable management of natural resources. This situation has prompted Ivorian authorities to implement measures aimed at regulating and rationalizing artisanal gold mining. Notably, the adoption of the National Program for the Rationalization of Artisanal Gold Mining (PNRO) in 2013 reflects the State's commitment to gaining a better understanding of mining sites, organizing the sector, and combating illicit mining practices.Despite these measures, illegal gold mining persists in several areas and remains a concern for natural resource management and environmental protection (Ministry of Industry and Mines, 2014; Government of Côte d'Ivoire, 2022). The issue takes on particular significance when this activity develops within classified forests. Subject to specific conservation and management regulations, these areas serve as vital reservoirs of forest resources and ecological functions. The establishment of gold mining activities in these territories can bring about tension between conservation objectives and resource exploitation practices. The destruction of vegetation cover, soil alteration, the creation of tracks and pits, and the disruption of water resources can compromise the ecological functions of these areas at a local level (Ngom et al., 2022). The Rapides Grah classified forests exemplify this issue. Recent interventions by

Ivorian forest management authorities in this sector confirm the persistence of illegal gold mining and the need for monitoring and enforcement actions (Ministry of Water and Forests, 2026). However, the mere existence of enforcement operations does not reveal how gold mining activities are spatially distributed, how their footprint evolves over time, or which territorial characteristics facilitate their establishment. The scientific challenge thus lies in the gap between the persistence of illegal gold mining in a protected forest area and the need to comprehensively assess its environmental consequences. This issue gives rise to the following question: What factors are associated with the establishment of illegal gold mining in the Rapides Grah Nord Classified Forest, and what are its main environmental consequences? The overall objective of this study is therefore to identify the factors associated with the establishment of illegal gold mining in the 'Rapides Grah Nord' Classified Forest and to assess its main environmental consequences. Thus, the study is structured around two complementary dimensions: identifying the associated geographical and socioeconomic factors, and assessing the environmental consequences.

METHODOLOGY

Study area location : The Rapides-Grah Nord Classified Forest is located in southwestern Côte d'Ivoire, in the San-Pedro area, and constitutes the northern section of the Rapides-Grah forest complex/network. It is managed by a SODEFOR Forest Management Unit (UGF) known as Rapides-Grah Nord.



Source : Bnetd, 2021

Figure 1. Study area

The Rapides-Grah Nord Classified Forest is located in southwestern Côte d'Ivoire, within the Soubré administrative zone and the vast Rapides-Grah forest massif. It forms part of the State's permanent forest estate and lies in a region characterized by dense, humid, evergreen forest. The Rapides-Grah massif extends across prefectures of San-Pedro and Soubré, as well as Méagui and Grand-Béréby sub-prefectures. Its northern boundary adjoins Taï National Park, while other boundaries are demarcated by forest tracks, watercourses, and conventional boundary lines.

Data collection: Initially, a literature review was conducted for the study to be situated within its theoretical and conceptual framework. This process involved examining scientific publications, institutional reports, and administrative and regulatory documents concerning artisanal and illegal gold mining, its drivers, and its environmental impacts. Analyzing this literature made it possible to identify the study's key concepts and existing knowledge on the issue, as well as to highlight the main factors likely explaining the rise of illegal gold mining. This stage also served as a basis for formulating research hypotheses and defining the methodological approach guiding fieldwork. Subsequently, a qualitative approach was adopted to gain an in-depth understanding of the rationales driving the various stakeholders involved, as well as the institutional, territorial, and socio-political factors fostering illegal gold mining in the Rapides Grah Nord Classified Forest. Empirical data collection relied primarily on semi-structured interviews. Tailored interview guides were developed based on the respondents' profiles and responsibilities, ensuring that the topics discussed were adapted to the specific characteristics of each stakeholder group. Interviews were conducted with representatives from the Regional Directorate of Mines, local administrative authorities, and officials from the Soubré Forest Management Unit which was responsible for managing the Rapides Grah Nord Classified Forest at the time. These exchanges made it possible to gather contextualized information on the ways in which illegal gold mining establishes and spreads, the mechanisms of regulation and control, the interactions between the various actors, and the institutional constraints associated with the management and protection of this forest area.

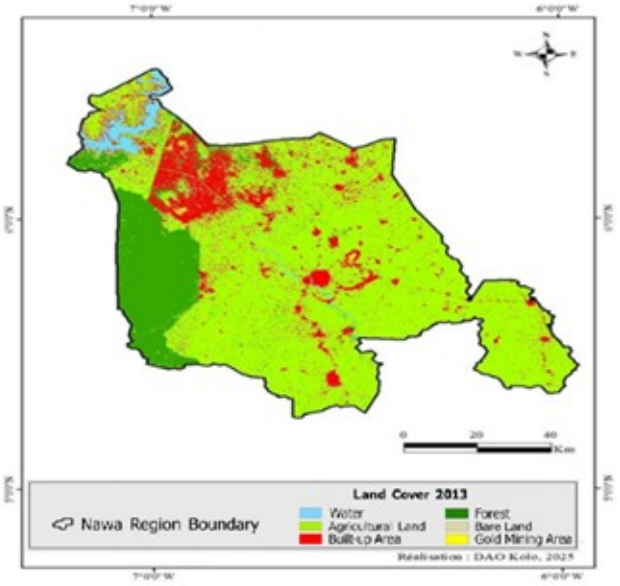
Data analysis and processing: Data derived from the literature review and field investigations were processed and analyzed using several software tools. Excel was used for data entry, organization, and processing of quantitative data, as well as for creating tables and graphs to summarize the study's key findings. Furthermore, the combined use of R, Excel, and QGIS 3.16 software along with QuickBird software for processing remote sensing data enabled the production of maps and thematic charts essential for analyzing the spatial distribution of illegal gold mining activities and the environmental changes observed in the study area. To assess the impact of gold mining on aquatic environments, analyses regarding the presence of specific metallic elements were also conducted. Heavy metals specifically mercury (Hg), lead (Pb), cadmium (Cd), and arsenic (As) were identified and quantified using atomic absorption spectrometry (AAS). This analytical method allows for the precise determination of trace-level concentrations of metallic elements within the environmental matrices being analyzed. Additionally, physicochemical water analyses were performed to evaluate water quality and characterize any changes associated with gold mining activities. The selected physicochemical parameters provided a baseline assessment of watercourse quality in the study area and helped evaluate the pressures exerted on water resources by human activities, particularly gold mining.

RESULTS

Abundant forest and water resources: an environment conducive to the development of illegal artisanal gold mining in the Rapides Grah Nord Classified Forest

Importance of forest resources and their influence on the establishment of illegal artisanal gold mining

The Rapides Grah Nord Classified Forest, covering an area of approximately 131,950 hectares, is located in the Nawa region (Figure 2) and is characterized by significant floral diversity. This rich vegetation is a key ecological feature of the forest area and shapes the activities that take place there. Tree species found in the area include *Gmelina* (*Gmelina arborea*), *Dégébena* (*Nesogordonia papaverifera*), *Fraké* (*Terminalia superba*), *Malemba* (*Pycnanthus angolensis*), and *Moriendi* (*Holarrhena floribunda*); some of these possess characteristics highly valued for artisanal gold mining operations. In particular, miners use the wood to construct the support structures needed to secure mining galleries and excavations. This practice represents a form of direct extraction of forest resources to support gold mining activities.

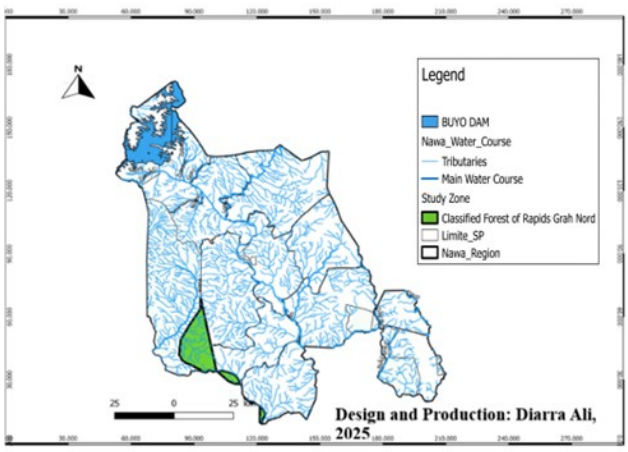


Source: Bnetd, 2023

Figure 2. Vegetation cover of the Nawa region

Furthermore, the density of the vegetation cover is a key characteristic of the environment where clandestine gold mining activities take place. Forest vegetation can help conceal mining sites, particularly when they are located in areas that are difficult to access. Forested areas with relatively dense vegetation including zones already disturbed by human activity can thus provide favorable conditions for the persistence of certain illegal mining operations. Vegetation cover limits direct visibility of the sites from transport routes and complicates ground-based surveillance operations. It can also reduce the detectability of certain installations when the resolution of available satellite data or observation conditions do not allow for a clear distinction of disturbances to the forest canopy.

Rapides Grah Classified Forest, a river network conducive to illegal gold mining: The Rapides Grah Nord Classified Forest is characterized by a relatively dense and diverse river network (Figure 3), consisting of several watercourses and tributaries that shape its ecological functioning. Notably, it is traversed by several tributaries of the Hana River a major watercourse in this part of southwestern Côte d'Ivoire whose drainage basin is linked to surrounding areas, including Taï National Park. This hydrological configuration gives the classified forest particular importance regarding ecosystemfunctioning and the socioeconomic activities that take place there. The year-round or seasonal availability of water resources is also a favorable factor for artisanal and semi-mechanized gold mining.

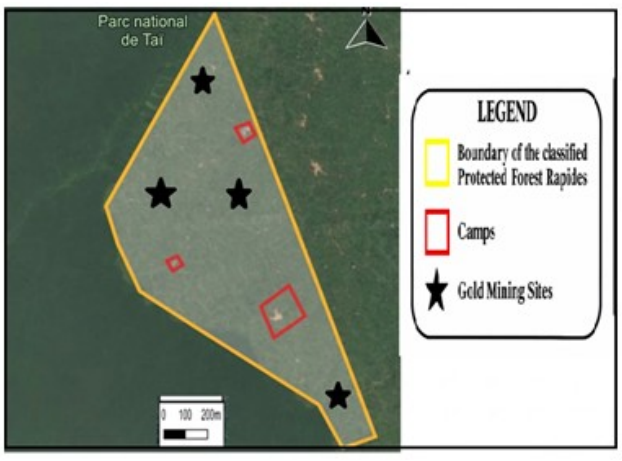


Source: Bnetd, 2023

Figure 3: Hydrographic network of the Nawa region and the Grah Rapids classified forest

Water plays a key role in various stages of the gold ore processing workflow, particularly in the washing and separation of excavated materials. Proximity to watercourses ensures that operators have an easily accessible resource for the technical requirements of processing gold-bearing materials. This factor helps explain why certain mining sites are concentrated in areas with abundant water supplies. Beyond its direct role in mining operations, water also shapes the spatial organization of gold mining activities. The presence of watercourses, low-lying wetlands, and water points influences where illegal gold miners set up their camps. These locations provide a source of water for daily domestic needs, such as cooking, drinking, and hygiene. Access to water thus makes certain forest areas more suitable for the long-term or temporary settlement of populations involved in gold mining.

From agricultural camps to areas of refuge: a spatial configurationcomplicating the fight against illegal gold mining: The presence of agricultural camps within or near the Rapides Grah Nord Classified Forest is a key feature of how this area is occupied. Originally established to support agricultural activities, these camps (Figure 4) constitute relatively permanent settlements, linked to networks of tracks, water sources, and rudimentary infrastructure. Their existence thus helps shape human settlement in areas that are sometimes difficult to access and increases the human footprint within the classified forest.



Source: google eatrh, 2025

Figure 4. Presence of camps in the classified forest

These camps are also occupied or used as staging points by individuals involved in illegal gold mining. The presence of dwellings and agricultural activities creates a human environment where clandestine operations can be harder to distinguish from ordinary activities. The proximity of agricultural areas to gold mining sites also facilitates movement and interaction among the various forest users. This situation poses a particular challenge for monitoring and enforcement efforts targeting illegal gold mining in the Rapides Grah Nord Classified Forest. According to information gathered from SODEFOR officials, eviction and enforcement operations often encounter preemptive and evasive strategies devised by illegal miners. Information regarding planned interventions is reportedly sometimes leaked to the miners by individuals acting as intermediaries or "guardians" within the camps.

This advance notice allows them to temporarily abandon the sites before enforcement teams arrive, thereby diminishing the immediate effectiveness of eviction operations. Furthermore, the agents interviewed note that some illegal miners adjust their working hours to minimize their exposure to surveillance operations. Working at night serves as a strategy to continue mining activities outside the times when enforcement teams are typically present. This practice is facilitated by the absence of a permanent SODEFOR operational base within the classified forest. The distance between monitoring teams and the various operational sites, combined with the vastness of the forest area, consequently limits the capacity for rapid response to illicit activities. These factors highlight the significance of the spatial, logistical, and informational constraints affecting the surveillance system. They also demonstrate that the persistence of illegal gold mining depends not only on access to natural resources but also on the operators' ability to develop adaptive strategies in response to control mechanisms. According to the institutional stakeholders interviewed, the lack of a permanent operational presence thus appears to be a factor that complicates continuous monitoring of the classified forest.

Environmental consequences of illegal gold mining: forest cover degradation, soil disturbance, and alteration of water resources

The expansion of gold mining in the Rapides Grah Nord classified forest: growing pressure on a forest continuum near Taï National Park: The Rapides Grah Nord classified forest is a major source of timber used in illegal gold mining operations. Wood harvested from the forest cover is primarily used to shore up extraction shafts and tunnels, as there are no technical systems available to secure the excavations. Miners fell trees near the mining sites to construct rudimentary structures designed to support tunnel walls and reduce the risk of collapse. As mining activity expands, the demand for shoring timber rises, leading to increased forest harvesting (figure). The proliferation of excavations and infrastructure associated with gold mining can thus gradually transform the forest landscape. Areas initially characterized by relatively dense vegetation cover may give way to fragmented, sparse, or severely degraded landscapes. This dynamic therefore stems not only from the initial clearing required to establish mining sites, but also from the ongoing exploitation of woody resources essential to gold mining operations.

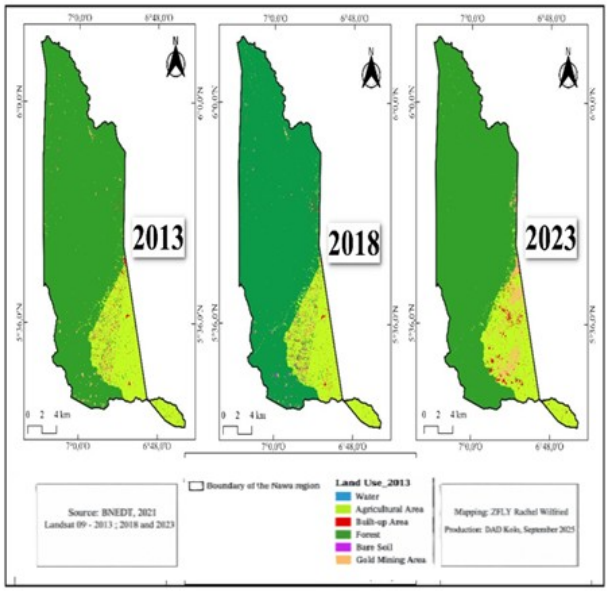


Figure 5. Deforestation trends within both Taï National Park and the classified forest

A diachronic analysis of land cover between 2013 and 2023 reveals contrasting trends regarding forest areas and zones affected by artisanal gold mining in the study area. During this period, the total forest area comprising Taï National Park and the surrounding woodlands decreased from 661,450 ha to 660,450 ha a reduction of approximately 1,000 ha (-0.2%). Although this change appears relatively minor in proportional terms, it is particularly significant given the protected status of these areas and the nature of the forest ecosystems involved, which can be exceptionally slow to recover following major disturbance. Conversely, the area identified as affected by artisanal gold mining saw a much more pronounced increase, rising from 73 ha in 2013 to 343 ha in 2023 a nearly fivefold increase (factor of 4.7) over the decade. This trend reflects a significant spatial expansion of gold mining activities and highlights the intensifying human pressure on forest environments. The establishment of mining sites involves the clearing of forest openings, the creation of access tracks, the setting up of camps, and a proliferation of excavations—transformations that can increase habitat fragmentation. While this study focuses specifically on the Rapides Grah Nord classified forest, the analysis cannot be separated from the broader ecological context in which the forest is situated. The proximity of Taï National Park a vast protected forest complex gives this area particular importance regarding ecological connectivity and habitat conservation.

Illegal gold mining: a persistent threat to water resources : Illegal gold mining in the beds and along the banks of the Hana River's tributaries has led to a significant increase in water turbidity. This phenomenon is caused by the suspension of fine particles (silt, clay, organic debris), which disrupts water clarity and reduces sunlight penetration. Physicochemical analyses of the Hana River's waters reveal significant alterations in several quality parameters. Turbidity levels are particularly high, registering at 249 NTU exceeding the 150 NTU reference value adopted for this study. This high turbidity is linked to a high concentration of suspended solids (SS), estimated at 154 mg/L, which is more than five times the maximum threshold of 30 mg/L. These elevated levels indicate a heavy particulate load in the water, likely resulting from sediment mobilization and transport within the watershed.



Credit photo: A. Diarra, 2025

Photo 1. A tributary of the Hana River affected by gold mining

Added to this are discharges of chemical substances notably mercury which exacerbate both the physical and chemical pollution of the watercourse. Indeed, analysis of heavy metals in the waters of the Hana River reveals varying levels depending on the specific element. The arsenic (As) concentration, at 9.070 µg/L, remains slightly below the WHO (2006) guideline value of 10 µg/L. In contrast, the cadmium (Cd) level of 3.092 µg/L slightly exceeds the guideline value of 3 µg/L. The lead (Pb) concentration, estimated at 8.970 µg/L, remains below the guideline value of 10 µg/L. However, the mercury (Hg) concentration stands at 1.559 µg/L, exceeding the guideline value of 1 µg/L. These results thus highlight a concerning level of contamination, particularly regarding cadmium and mercury, as their concentrations exceed the reference values.

Soil disturbance and structural degradation related to artisanal gold mining activities: Undoubtedly, one of the primary and most visible consequences of illegal artisanal gold mining on the soil environment within the classified forest is accelerated soil erosion. This degradation stems from the drastic removal of vegetation cover during the site setup phase, when trees, shrubs, and herbaceous plants are systematically cleared to gain access to the gold-bearing subsoil (Photo 2). Yet, vegetation plays a crucial role in soil stabilization: root systems ensure soil cohesion, while the cover protects the surface from the direct impact of runoff water.



Credit photo: A. Diarra, 2025

Photo 2. Soil erosion in the classified forest

Since natural cover is failing, particularly heavy rainfall in this forest zone causes intense leaching and exposes the topsoil horizons, which are rich in organic matter. These layers, essential for soil fertility and water regulation, are washed away sometimes within a few weeks leading to an irreversible loss of the land's agricultural potential.

DISCUSSION

The establishment of illegal artisanal gold mining in certain state-owned lands stems from a combination of factors, as highlighted by the results of this study. Among these, the availability of natural resources specifically water resources and vegetation cover emerges as a particularly decisive factor. These findings align with the observations of B.W. Zely et al. (2025, p. 247), who emphasize the role of natural resources in the dynamics of artisanal gold mining establishment. Notably, these authors highlight that the extensive river network in the Dapeoua sub-prefecture acts as a favorable factor for the development of this activity. Similarly, E. Sawadogo (2021, p. 53) underscores the importance of water resources and vegetation cover in the expansion of artisanal gold mining in Burkina Faso. The availability of these resources thus appears to be a condition that favors not only the arrival of miners but also the maintenance and long-term viability of gold mining activities in forest areas.

CONCLUSION

This study demonstrates that illegal gold mining is prevalent in the Rapides Grah Nord classified forest. Its expansion is facilitated by the availability of water and timber resources. The presence of agricultural settlements also makes it easier for gold miners to establish themselves in certain areas. Surveillance challenges further contribute to the persistence of this activity within the forest. The spread of gold mining leads to the gradual degradation of forest cover. It also results in the creation of numerous excavations and causes soil erosion. Water resources are particularly vulnerable to the impacts of this activity. Analyses reveal high turbidity and significant levels of suspended solids in the Hana River. The presence of cadmium and mercury is also a cause for concern regarding water quality. These various forms of degradation can have long-lasting effects on the classified forest's ecosystems. Combating illegal gold mining therefore requires enhanced surveillance of the forest area. Monitoring of mining sites must also be improved. Restoring degraded areas must be part of the measures implemented. Closer collaboration between relevant authorities and local communities is also essential. These actions can help better protect the Rapides Grah Nord classified forest and its natural resources.

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