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Comparative Analysis of Economic and Profitability of Artisanal Gold Mining in Part of Niger and Osun States, Nigeria

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ABSTRACT: *Comparative analysis of economic and profitability of artisanal gold mining in part of Niger and Osun states was carried out to assess the cost of production, assess the production rate of alluvial and elluvial gold deposits in the study areas, determine the concentrates of alluvial and elluvial gold deposits in the study areas, compare the concentrates of alluvial and elluvial gold deposits in the study areas and determine the level of profitability in the study areas. The concentration of alluvial gold deposits was carried out using FAS – 121 Au Fire Assay, 50 g Fusion, AAS Trace Level analytical method while that of the elluvial gold deposits was carried out using FAS – 425 Au Fire Assay, 50 g Fusion, Gravimetric analytical method. The cost of production for alluvial gold deposits in Osun state were computed to be ₦30,000.00, ₦38,000.00 and ₦27,000.00 at Isereyun, Samuaye and Okere Oloja Villages respectively while that of elluvial gold deposits in Niger state were computed to be ₦125,000.00, ₦98,000.00 and ₦95,000 at Tutugo, Paiko and Bosso Villages respectively. The comparison of gold concentration in the two states shows that the elluvial gold deposits in Niger state has higher concentrates than the alluvial gold deposits in Osun state which could be due to the fact that elluvial deposits are mostly host rock for gold deposits. The level of profitability in alluvial gold deposits in Osun state ranges from 300% and 400% after the cost of production while that of elluvial gold deposits in Niger state ranges 300%, 400% and 500% after the cost of production. With the level of profitability of the alluvial and elluvial deposits, it can be observed that the profitability for all locations were close but there were differences in the cost of production.*

KEYWORDS: Nigeria, gold, mining, profitability, artisanal, fire assay, profitability

INTRODUCTION

The African continent contain about 30% of the world's mineral resources, and possesses the largest known reserves of strategically minerals, including gold (Bradshaw and Sodhi, 2010; Darimani *et al.*, 2013; Edwards *et al.*, 2014; Ericesson, 1991; Mutemeri and Petersen, 2002; Taylor *et al.*, 2009). Nigeria is one of the countries in the sub-Saharan Africa where mining formed huge source of export prior oil boom period in 1970s (Ericsson, 1991). Mining refers

to the process of extraction of mineral deposits from the Earth or form beneath the surface. Mining can only take place where minerals are present and economically viable. The general important of the mining sector has been document to include foreign exchange, employment and economic development (obaje and Abba, 1996, Obaje *et al.*, 2005, Nwajiuba, 2000). Nigeria has an average of 21.37 tons of gold deposit from 2000 to 2018, and reaching an all-time high of 21.40 tonnes in the first quarter of 2018. Despites having this huge gold deposit, Nigeria is yet to benefit from the natural resource due to lack of big investors and illegal mining activities in the solid minerals sector. Gold deposits are found in Northern Nigeria, most prominently near Maru, Anka, Malele, Tsohon Birnin Gwari-Kwaga, Gurmana, Bin Yauri, Okolom-Dogondaji, and Iperindo in Osun- State.

Currently, the extraction of industrial minerals such as granite and precious minerals like gold is primarily conducted by artisanal miners in select regions of the country. These miners may lack awareness regarding the geological history, mining techniques, gold grades, as well as the environmental, economic, and health implications associated with their activities. The presence of such mining activities has been identified in the northwest and southwest regions of the country. However, the Federal Government has not made significant efforts to convert these activities into sources of income and revenue generation (Betancur-Corredor et al., 2018; Taiwo et al., 2023; Melodi et al., 2022; Mata et al., 2022).

The drop in national interest in mining has been observed during the period of the oil boom. This decline has led to an increase in sporadic, informal, uncoordinated, and unmonitored management of both current and potential mines. Consequently, there has been a notable rise in artisanal mining activities inside the country (Edwards et al., 2014). Artisanal mining is a livelihood strategy predominantly embraced in rural regions (Veiga, 2003). Gold is extracted through artisanal mining, a process in which individuals employ basic tools and equipment for extraction purposes (Bradshaw et al., 1997). According to Azubike (2011), this particular industry operates beyond the confines of established legal and regulatory structures. Northern Nigeria is known to possess substantial gold reserves in many locations such as Anka, Maru, Malele, Tsohon, Osun, Birnin, Gwari-Kwaga, Bin Yauri, Gurmana, and Iperindo. The commencement of production may be traced back to the year 1913, with its zenith occurring in the 1930s, followed by a subsequent decline during the period of war. The abandonment of mines, similar to the coal industry, resulted in the lack of recovery within the gold mining sector. While Nigeria currently lacks large-scale gold mining activities, there exists a presence of small-scale gold mining conducted by artisans. This activity is characterized by a non-formal, unstructured, unplanned, and unmanaged approach. Artisanal mining methods are prevalent in Africa, and numerous studies have examined their characteristics. Hilson (2001) presents a comprehensive analysis of the operational dynamics within Ghana's small-scale mining sector. The author asserts that recent efforts have been made to establish a regulatory framework and formalize the industry's operations. These initiatives aim to mitigate the adverse environmental consequences and resolve conflicts arising from land use. With the exception of the recent initiatives undertaken by the Ministry of Mine and Steel Development, the gold mining sector in Nigeria remains mostly unregulated, with a significant proportion of operators lacking proper licensing (Oramah et al., 2015). Research has demonstrated that mine sites are often located in close proximity to agricultural lands, resulting in the potential accumulation of

chemicals in the fruits and leaves of crops. Furthermore, soil contamination in these mine sites can lead to significant levels of heavy metal contamination in water sources, posing a risk of poisoning to both humans and animals if consumed (Bartremet et al., 2014; Lo et al., 2012; Oramah et al., 2015; Plumlee et al., 2013). Despite the significant economic and environmental risks associated with this practice, the proliferation of artisanal gold mining operations persists due to an increased demand for gold and the lack of appealing alternative livelihood options. Insufficient equipment and technology necessary for the mining operations. The region of Minna in Nigeria, along with its surrounding areas, is significantly impacted by the activities of artisanal miners, particularly in the villages of Tutugo, Paiko, and the local government authorities of Bosso and Paikoro in Niger State. The majority of Nigeria's gold production, approximately 90%, is generated from alluvial deposits that originate from primary gold mineralization found in the foundation rocks.

The predominant occurrence of primary gold mineralization in the schist belt is typically observed along quartz veins that traverse various lithological units. The production sites primarily exist in the western region of the basement, where the schist belts are most extensively formed. There is a notable correlation between these production locations and certain schist belts, however gold quartz veins may also be found in gneisses such as Malele, Diko, and Iperindo. According to Woakes and Bafor (1983), there are four distinct gold fields that may be delineated, namely Ilesha – Egbe, Minna – BiminGwari, Sokoto, and Yelwa. Each of these gold fields spans a considerable expanse of several thousand square kilometers.

Among the top 30 gold producing countries, over 60% are low or lower-middle income countries with substantial socio-economic development needs (Arthur-Holmes *et al.*, 2022). Artisanal and small-scale mining of solid mineral resources is one important livelihood activity that can help to reduce poverty and achieve rural economic renewal through the development of non-farm income generating opportunities. The vast economic potentials of mining sector in Nigeria where government holds all mineral rights has been widely reported (Merem *et al.*, 2017). Mining of mineral resources is under the exclusive list of the Federal Government of Nigeria and no State or Local council has right to explore, prospect or exploit mineral resources found in their territory without license from the Federal Government. Many African countries are dependent on the exploration and the exploitation and their mineral resources such as gold among other many other minerals. Gold mining have been identified to provide means of livelihood to individuals and local communities. In spite of the profitable employment generation to her teaming unemployed youth, the larger portion of the country's gold mining is still under-developed. In spite of the relevance of artisanal gold mining of the economy very few published studies have been carried out to assess the profitability of the artisanal gold mining to and identify the constrains faced by the miners.

Study Area

Niger and Osun State were the two locations considered for this research work. Niger state is a state in Central Nigeria and the largest state in the country. The state capital is Minna, and other major cities are Bida, Kontangora and Suleja. It was formed in 1976 when the then North-Western state was bifurcated into Niger State and Sokoto State. It has twenty-seven (27) Local Government Areas. The location of Niger State in Nigeria is coordinates 10° 00′ N 6° 00′ E.

covers total area of 16,363km^2. The state is named after the River Niger. Two of Nigeria's major hydroelectric power station, the Kainji Dam and the Shirroro Dam are located in Niger State. The famous Gurara falls in Niger State in Gurara Local Government Area. Also situated there is Kainji National Park, the largest National Park in Nigeria, which contains Kainji Lake, the Borgu Game Reserve and Zugurma Game reserves.The study areas are located in Paikoro and Bosso Local Government Areas in the Northern part of Niger State (Figure 2) and three Artisanal Gold Mining sites will be selected at different communities within the Local Government Areas.

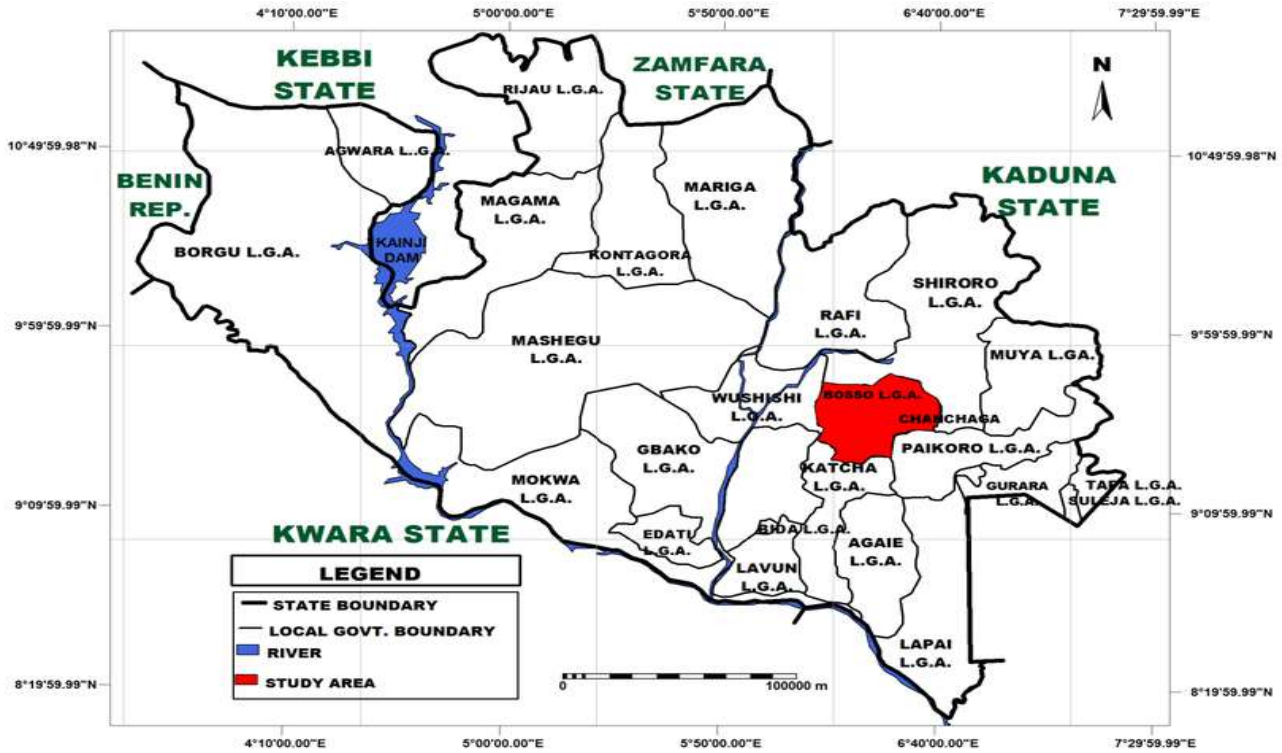

Figure 1: Location Map of Niger State Showing the Study Area. (Adopted from Abd'Razack and Muhamad 2013).
The coordinates of the selected study areas are given in the Table 1.

Table 1: Showing the Coordinates of the Selected Mine Sites

Mine Site	**Longitude**	**Latitude**
Tutugo	006° 34' 06.9" N	09° 30' 44.5" E
Paiko	006° 35' 01.9" N	09° 23' 52" E
Bosso	006° 35' 04.27" N	09° 35' 05.5" E

The study areas cover Atakumasa West and its environs. The area lies approximately between Lat. N07° 30' to N07° 34' and Long. E004° 37' to E004° 51' as shown in Figure 3. Covering an estimated area of 25km^2. The study area is located in Atakumasa West L.G.A of Osun State

and South West, Nigeria. The important settlements are Samuaje, and Isereyun and Okere Oloja.

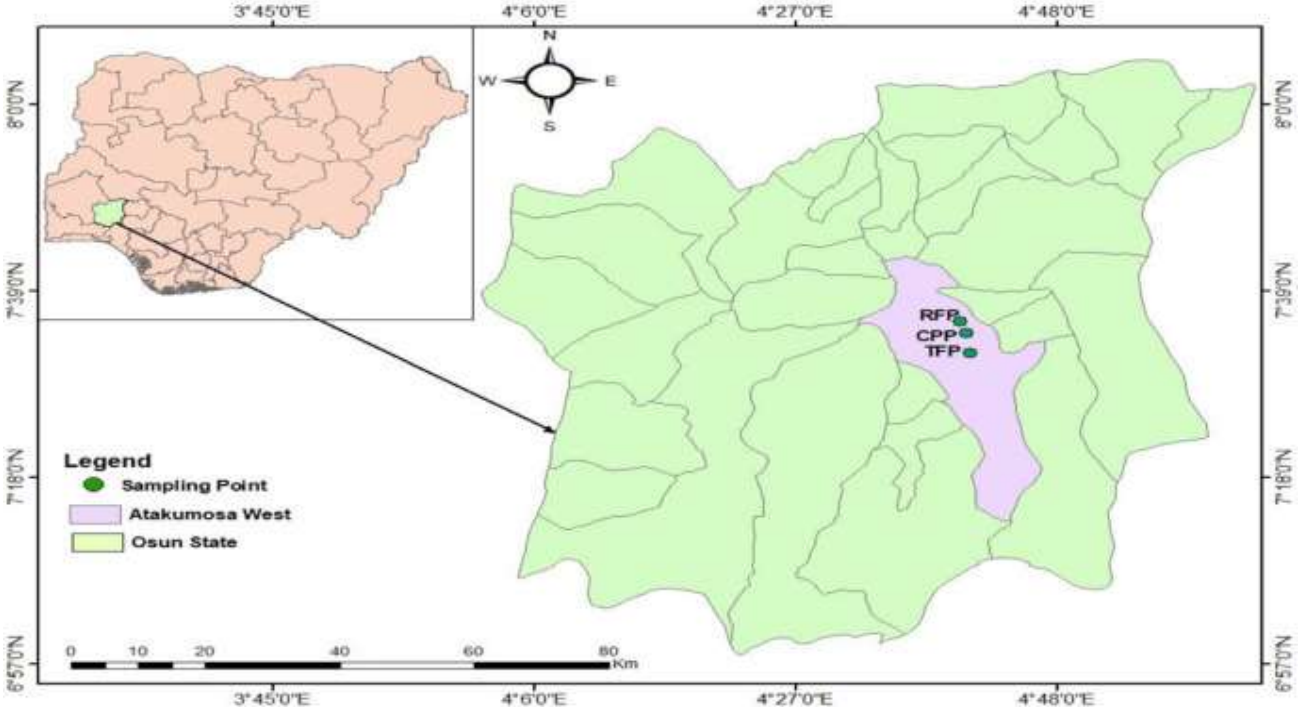

Figure 2: Location Map of Nigeria and Osun State Showing the Study Area. (Adopted from Emmanuel *et al.*, 2020)

The coordinates of the selected study areas are given in the Table 2:

Table 2: Showing the Coordinates of the Selected Mine Sites

Mine Sites	**Longitude**	**Latitude**
Samuaje	004° 50' 40.4" E	07° 33' 49.2" N
Isereyun	004° 39' 07" E	07° 35' 16" N
Okere Oloja	004° 37' 08" E	07° 35' 49" N

MATERIALS AND METHOD

To achieve the study objective, the proposed steps as shown in Figure 3 was adopted for data collection, visualization and analysis.

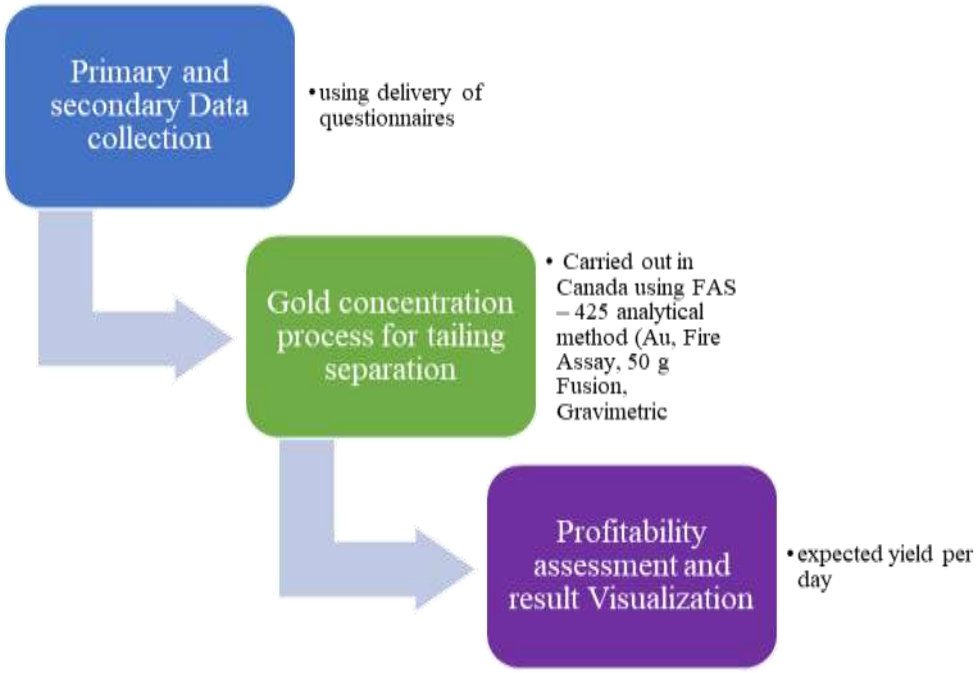

Figure 3: Study objective flow sheet

Data Collection from Artisanal Miners

The collection of primary data was conducted by means of field observations and the delivery of questionnaires. The survey was conducted using a sample frame consisting of 120 artisanal miners who were identified and questioned. Field observations and interviews were conducted to obtain primary data. In order to gather supplementary material for the study, interviews were conducted with personnel from the Federal Ministry of Mines and Steel Development, the State Bureau of Solid Mineral Resources, as well as select traditional leaders and licensed small-scale miners within the region. The study collected data pertaining to the characteristics of artisanal miners, their operational revenue, production expenses, and factors limiting profitability. The decision to utilize a questionnaire survey was motivated by the need to obtain a broader range of perspectives, which would not be feasible through interviews with a limited number of participants. Additionally, employing a questionnaire survey would enable the aggregation of responses, so ensuring that the collected data accurately reflects the collective interests and opinions of the community. The researchers utilized a multi-state selection procedure to pick a total of 120 artisans, whose data were then utilized in this study. The assay findings of the collected samples were subjected to analysis.

Collection and Preparation of Rock Samples

Six samples were collected from both alluvial deposits in Osun state and elluvial deposits in Niger state. The purpose of sample preparation was to ensure that the laboratory processes a pulp representative of the whole sample which passed through a required meticulous care to produce a homogeneous sub-sample for analysis. The elluvial deposit samples were crushed to 70% passing 2mm, then a representative split is taken and pulverized to 85% passing 75µm. The alluvial deposit samples (Soil and sediment) were dried and then screened to the desired

mesh size. The undersized (-) fraction was analyzed and the oversized (+) fraction was discarded.

Concentration of Alluvial Gold Deposits in Osun State

Samples from the alluvial deposits in Osun state were sent to MSAALABS in Canada for FAS – 121 analytical method (Au, Fire Assay, 50 g Fusion, AAS, Trace Level). Samples pulp were mixed with a combination of chemical reagents. The mixture was heated at high temperature resulting in the formation of a lead button and slag. The lead button which contains the gold was cupelled at high temperature. The lead was absorbed by the cupel and leaves behind a bead that contains the gold. The bead was acid digested at 50 g fusion and analyzed by instrumental finish method.

Concentration of Elluvial Gold Deposits in Niger State

Samples from the elluvial deposits in Niger state were sent to MSAALABS in Canada for FAS – 425 analytical methods (Au, Fire Assay, 50 g Fusion, Gravimetric). Samples pulp was mixed with a combination of chemical reagents. The mixture was heated at high temperature resulting in the formation of a lead button and slag. The lead button which contains the gold was cupelled at high temperature. The lead was absorbed by the cupel and leaves behind a bead that contains the gold. The bead was acid digested at 50 g fusion and analyzed by gravimetric method. Acid or 'near total' digestion uses a combination of hydrochloric, nitric, perchloric and hydrofluoric acids.

Comparison of the concentrations in Osun and Niger States

Descriptive statistics such as cross tabulation, graphs and percentages were used in the analysis of the relationship and the differences between the concentrates from all the site locations in the Osun and Niger states.

The level of profitability in the study areas

The level of profitability in the study areas were determined using the expected yield per day, cost of gold/gram, the average cost of production and the average production rate in Osun state (Isereyun, Samuaye and Okere Oloja Villages) and Niger State (Tutugo, Paiko and Bosso Villages).

RESULTS AND DISCUSSIONS

Alluvial Gold Recovery in Osun

To assess the operation cost, recovery rate at each case study mine, the following data were collected. The survey carried out at Isereyun Village revealed that local miners recovered an average of 5g of gold per day as presents in Table 3. Likewise, Tables 4 and 5 show the data collected from Samuaye Village and Okere Oloja respectively in Osun State.

Table 3: Data Collected from Isereyun Village in Osun State

Data Collected	**Response**
Estimated production per day	2000 kg
No. of Laborer	Three (3)
Cost of Transportation per day	₦5,000:00
Cost of Fuel per day	₦10,000:00
Other Materials	₦15,000:00
Total Cost of Production	₦30,000:00
Expected yield per day	Five (5) grams/day
Cost of gold/gram	₦34,000:00

Table 4: Data Collected from Samuaye Village in Osun State

Data Collected	**Response**
Estimated production per day	1500 kg
No. of Laborer	Two (2)
Cost of Transportation per day	₦6,000:00
Cost of Fuel per day	₦12,000:00
Other Materials	₦20,000:00
Total Cost of Production	₦38,000:00
Expected yield per day	Six (6) grams/day
Cost of gold/gram	₦34,000:00

Table 5: Data Collected at Okere Oloja Village in Osun State.

Data Collected	**Response**
Estimated production per day	1500 kg
No. of Laborer	Two (2)
Cost of Transportation per day	₦4,000:00
Cost of Fuel per day	₦8,000:00
Other Materials	₦15,000:00
Total Cost of Production	₦27,000:00
Expected yield per day	4.7 grams/day
Cost of gold/gram	₦34,000:00

Eluvial/Rock Gold recovery in Niger State

The data collected at Tutugo Village were shown in Table 6 while Tables 7 and 8 show the data collected at Paiko Village and Bosso Community respectively in Niger State.

Table 6: Data Collected at Tutugo Village in Niger State.

Data Collected	**Response**
Production Rate Per Day	500 kg
No. of Laborers	Ten (10)
Cost of Transportation per day	₦12,000:00
Cost of Fuel per day	₦20,000:00
Extraction of source rocks	₦40,000:00
Grinding / Milling	₦18,000:00
Others	₦35,000:00
Expected yield per day	20 grams/day
Cost of Gold per gram	₦34, 000.00

Table 7: Data Collected at Paiko Village in Niger State.

Data Collected	**Response**
Production Rate Per Day	400 kg
No. of Laborers	Seven (7)
Cost of Transportation per day	₦9,000:00
Cost of Fuel per day	₦18,000:00
Extraction of source rocks	₦16,000:00
Grinding / Milling	₦15,000:00
Others	₦30,000:00
Expected yield per day	16 grams/day
Cost of Gold per gram	₦34, 000.00

Table 8: Data Collected from Bosso Community in Niger State.

Data Collected	**Response**
Production Rate Per Day	500 kg
No. of Laborers	Eight (8)
Cost of Transportation per day	₦15,000:00
Cost of Fuel per day	₦20,000:00
Extraction of source rocks	₦38,000:00
Grinding / Milling	₦16,000:00
Others Cost	₦36,000:00
Expected yield per day	18 grams/day
Cost of Gold per gram	₦34, 000.00

Result of Cost and Production rate from Study location

Cost and Rate of Production for Alluvial Gold Deposit in Osun State

The computation of the cost and rate of production per day at Isereyun, Samuaye, and Okere Oloja Villages was conducted utilizing Tables 3, 4, and 5. The daily production cost at Isereyun village amounts to ₦30,000:00, encompassing expenses related to transportation, fuel, and other materials. Concurrently, the production rate is at 5 grams per day. The daily production cost at Samuaye Village amounts to ₦38,000:00, with a production rate of 6g per day. The Okere Oloja Village incurs a production cost of ₦27,000:00, with a daily production rate of 4.7g. In contrast, the elluvial deposits in Niger state exhibit varying daily production rates. Specifically, the production rates at Tutugo, Paiko, and Bosso are 20g, 16g, and 18g per day, respectively.

Cost and Rate of Production for Elluvial Gold Deposit in Niger State

Cost and rate of production assessment for elluvial gold deposits help determine the economic viability, optimize resource utilization, and plan efficient mining operations, leading to higher profitability and reduced financial risk. The computation of the daily production cost and rate in Tutugo, Paiko, and Bosso Villages was conducted by utilizing Tables 6, 7, and 8. The daily production expenses at Tutugo village, encompassing transportation, fuel, source rock extraction, grinding/milling, and other materials, amount to ₦125,000:00. The output rate is at 20g per day. The daily manufacturing cost at Paiko Village amounts to ₦98,000:00, while the

daily production rate is at 16g. At Bosso Community, the entire cost of production per day is ₦95,000:00, while the rate of output is 18g.

Concentration of alluvial gold deposits in Osun State

The concentrations of alluvial gold deposits in Osun state (Isereyun, Samuaye and Okere Oloja Villages) were carried out using FAS – 121 analytical methods (Au, Fire Assay, 50 g Fusion, AAS, Trace Level) as shown in Table 9.

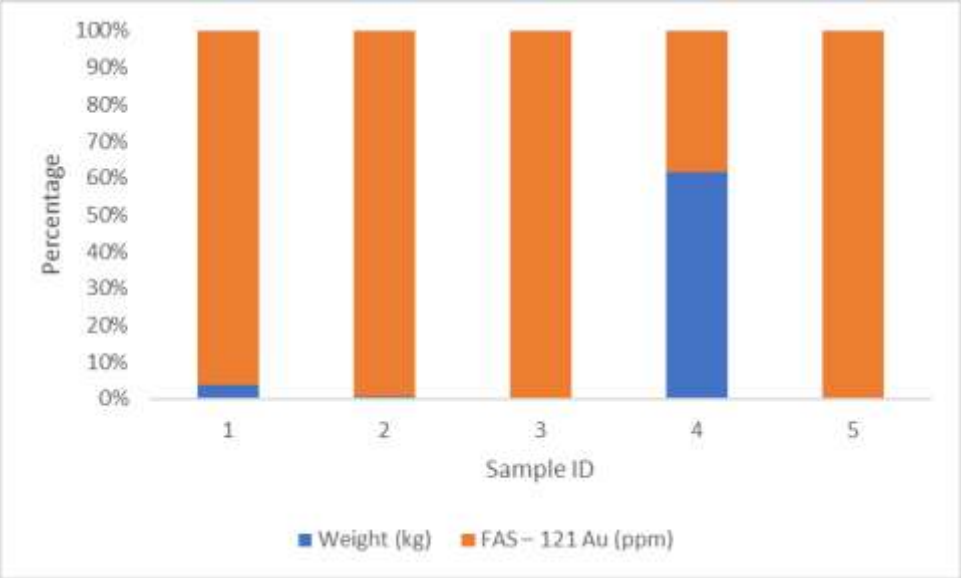

Figure 4: Concentration of Alluvial Gold in Isereyun Village

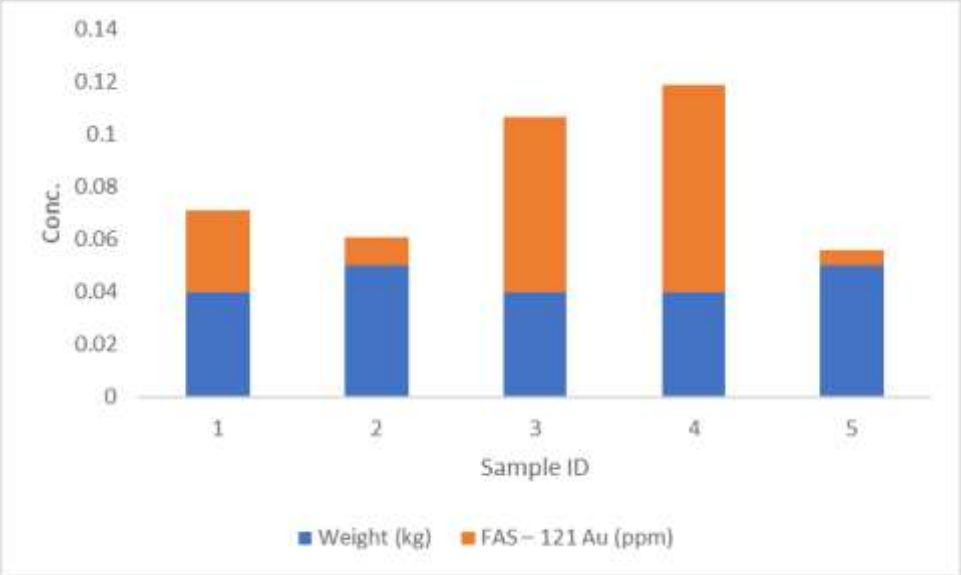

Figure 5: Concentration of Alluvial Gold in Samuaye Village

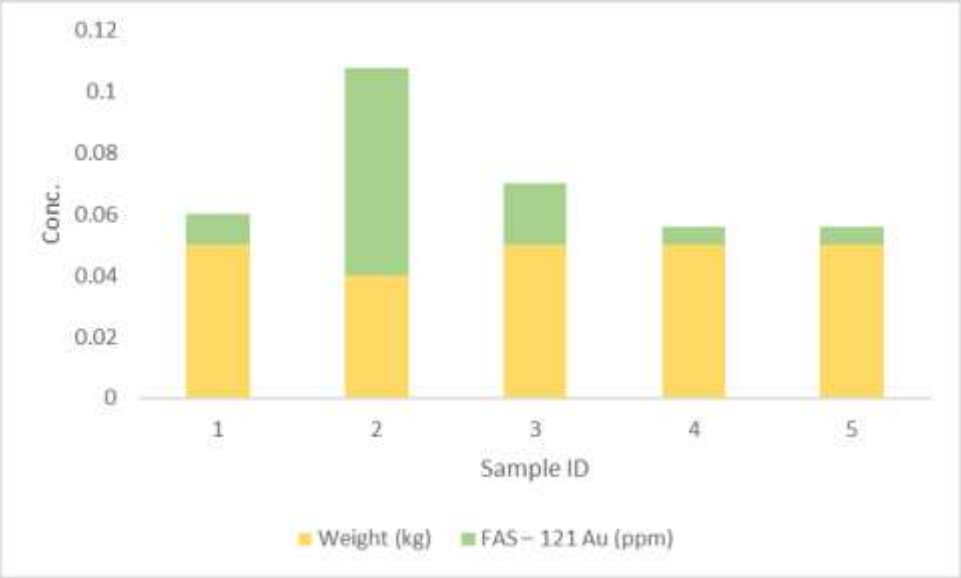

Figure 6: Concentration of Alluvial Gold in Okere Oloja Village

Concentration of Elluvial Gold deposits in Niger State

The concentrations of elluvial gold deposits in Niger state (Tutugo, Paiko and Bosso Villages) were carried out using FAS – 425 analytical methods (Au, Fire Assay, 50 g Fusion, Gravimetric) as shown in Table 10.

Table 10: Concentration of Elluvial Gold Deposits in Niger State.

Location	Sample Type	Weight (kg)	FAS – 425 Au (ppm)
Tutugo Village	Pulp	0.03 0.06 0.05 0.04 0.04	16.9 16.3 16.7 17.5 17.1
Paiko Village	Pulp	0.04 0.05 0.04 0.04 0.05	19.4 19.6 19.2 19.3 19.5
Bosso Village	Pulp	0.05 0.04 0.05 0.05 0.05	17.6 17.5 17.8 17.7 17.4

Comparison of The Concentrations in Osun And Niger States

The comparison of the concentrates from the alluvial deposits in Osun and Niger states were carried out using a bar chart diagram as shown in Figure 4. The graph indicated that the elluvial

deposit in Niger state have higher concentrates of gold than that of alluvial deposit in Osun state.

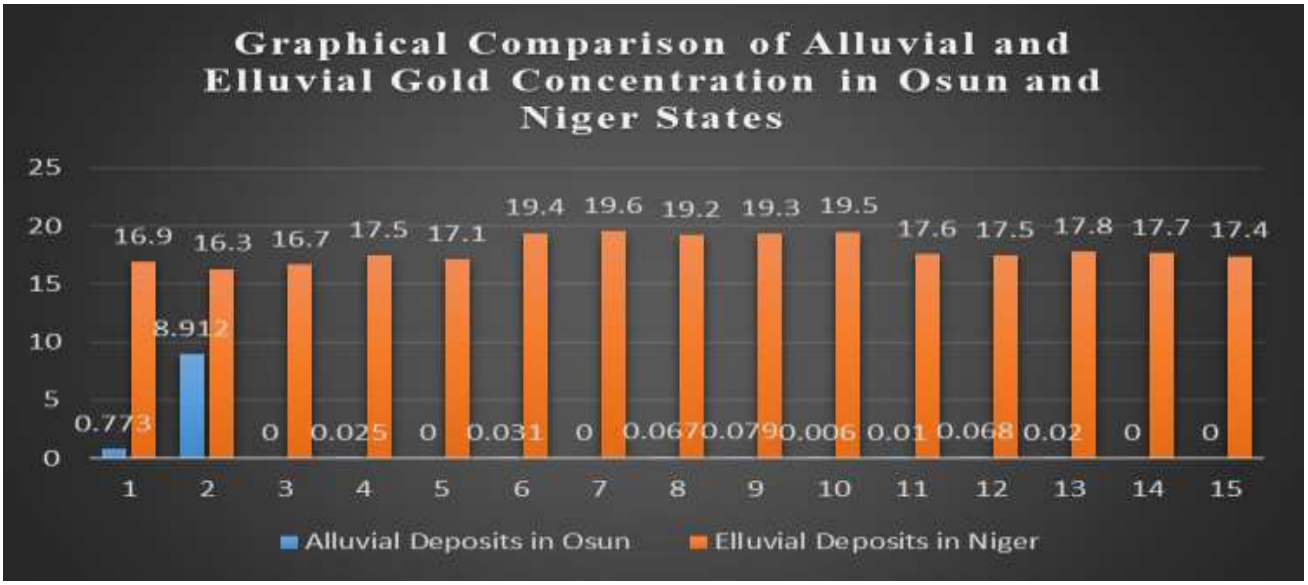

Figure 7: Graphical Comparison of Alluvial and Elluvial deposit in Osun and Niger States

Profitability Assessment Result

The level of profitability in the study areas were determined based on the expected yield per day, the cost of production per day and the cost of gold per gram for each of the locations as describe in the following subsections

Profitability Assessment for Alluvial Gold Deposit in Osun State

The level of revenue per day at Isereyun Village was estimated as ₦30,000, Selling Cost at ₦170,000, and a profit of ₦140,000 per day on the local mining exploitation. The result shows that the level of profitability is 3.67 times the cost of production which is approximately 400 %.

The level of revenue per day at Samuaye Village was estimated as ₦38,000, the Selling Cost as ₦228,000 and profit margin of Profit ₦190,000. Therefore, the level of profitability is five times, the cost of production which is 500 %. The level of profitability per day at Okere Oloja Village was estimated as ₦27,000. Therefore, the level of profitability is 2.91 times, the cost of production which is approximately 300 %.

Profitability assessment for Elluvial Gold Deposit in Niger State

The daily profitability level at Tutugo Village was projected to be ₦125,000, with sales amounting to ₦680,000 and a revenue of ₦555,000. Hence, the profitability level is 3.44 times greater than the production cost, which amounts to nearly 300%. The daily profitability level in Paiko Village was assessed to be ₦98,000, with a selling cost of ₦544,000, resulting in a profit of ₦446,000. The findings indicate that the profitability level is 3.55 times greater than the cost of production, equivalent to around 400%. The daily profitability level at Bosso Village was projected to be ₦95,000:00, with a selling cost of ₦612,000 and a total income of

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₦517,000. Hence, the profitability threshold is 5.44 times the production cost, equivalent to nearly 500%.

CONCLUSION

The evaluation of production costs associated with alluvial and elluvial gold deposits in Nigeria holds significant importance in the realms of resource management, revenue creation, and the pursuit of sustainable development. The promotion of transparency, attraction of investment, and enforcement of responsible mining practices are crucial factors for fostering economic progress. The primary objective of this research endeavor was to evaluate the production costs associated with alluvial and elluvial gold deposits within the designated study areas. Additionally, the study aimed to assess the production rates of these deposits, determine the concentration levels of alluvial and elluvial gold within the study areas, compare the concentration levels between the two types of deposits, and ascertain the profitability levels within the study areas. The production costs of alluvial gold deposits in Osun state were calculated to be ₦30,000:00, ₦38,000:00, and ₦27,000:00 in Isereyun, Samuaye, and Okere Oloja Villages, respectively. Similarly, the production costs of elluvial gold deposits in Niger state were determined to be ₦125,000:00, ₦98,000:00, and ₦95,000:00 in Tutugo, Paiko, and Bosso Villages, respectively. The average production rates of alluvial deposits in Osun state were found to be 5 g per day in Isereyun village, 6 g per day at Samuaye, and 4.7 g per day at Okere Oloja community. The concentration of alluvial gold deposits in Osun state varies between 0.025 and greater than 10 parts per million (ppm), as determined by the FAS – 121 Au Fire Assay, 50 g Fusion, AAS Trace Level analytical method. Similarly, the concentration of elluvial gold deposits in Niger state ranges from 16.3 ppm to 19.6 ppm, as determined by the FAS – 425 Au Fire Assay, 50 g Fusion, Gravimetric analytical method. The analysis of gold concentration in the two states reveals that the elluvial gold deposits in Niger state exhibit higher concentrations compared to the alluvial gold deposits in Osun state. This disparity may be attributed to the fact that elluvial deposits primarily serve as host rocks for gold deposits. The profitability of alluvial gold resources in Osun state varies between 300% and 400% after accounting for production costs. Similarly, the profitability of elluvial gold deposits in Niger state ranges from 300% to 500% after considering the cost of production.

Recommendations

Base on the outcome of the research conducted, the following recommendations can be recommended for artisanal miners and future investors:

(a) Artisanal Miners should invest more on elluvial gold deposits
(b) Future investors should see elluvial gold deposits mining as an area with a low risk of investment.

Conflicts of interest

The authors declare no conflict of interest.

Ethical statement

Authors state that the research was conducted according to ethical standards.

Funding body
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