International Journal of Multidisciplinary Studies and Innovative Research

ISSN: 2737-7172 (O), ISSN: 2737-7180 (P)
Volume 12, Number 01, pp. 1752-1762
DOI: 10.53075/Ijmsirq/09845736675759

Analysing Land Reclamation and Ecosystem Services in Small-Scale Surface Mining in the Asante Akim Central Municipal, Ashanti Region of Ghana

Isaac Kwasi Henyo[1], Benjamin Amoako-Attah[2]

[1,2]Department of Social Science Education, Faculty of education, Catholic University of Ghana, Fiapre-Sunyani

How to Cite
Isaac Kwasi Henyo, Benjamin Amoako-Attah (2024). Analysing Land Reclamation and Ecosystem Services in Small-Scale Surface Mining in the Asante Akim Central Municipal, Ashanti Region of Ghana. *International Journal of Multidisciplinary Studies and Innovative Research,* 12(1), 1752-1762. DOI: 10.53075/Ijmsirq/09845736675759

Abstract: This study was conducted in the Asante Akim Municipality using GIS and remote sensing to ascertain the extent of reclamation activities and their impacts on the ecosystem services of the forest in the Asante Akim Central Municipal. The study used satellite data from Landsat between the period of 20 years (2002-2022) and other essential data. The LULC analysis was carried out in QGIS software and pixel recalcination was performed to identify the mined areas. The Invest computer software was used to assess the ecosystem services. The results from the study showed that within the 20 years period in the study area, LULC constitutes Close Forest (21606.46 ha), Open Forest (71751.74 ha), Agricultural lands (22617.90ha), Water (2174.833ha), Bare Soil/mining site (19431.908 ha) and Built-up (10063.869 ha). It was found from the study that the major land use conversion was from Close Forest to open forest (5620.8 ha), open forest to Agricultural lands (14212.642 ha), and Agricultural lands to either bare soil (1686.726 ha) or Built-up (9902.859 ha). Moreover, the extent of reclamation activities over the ten (10) year period was approximately 2461.7025 ha representing 1.7% of total landscape. The reclamation activity was marginal with little or no effects on the improvement on the ecosystem. Finally, five ecosystem parameters assessed (Phosphorus export, Carbon Storage, Nitrogen export and Sediments export.) showed that the reclamation activity was insignificant to warrant a change in the ecological services. It is recommended that The Ministry of Lands and Natural resources in collaboration with Environmental Protection Agency in Ghana should intensify their campaign against small-scale miners who do not comply with the compulsory reclamation of mining site policy in Ghana.

Keywords: Galamsey, Digital Elevation Model, Landsat images, Land Use Land Cover

1. INTRODUCTION

Reclamation, the process of restoring mined areas for various uses, is essential for environmental recovery (Tetteh, 2010; Asiedu, 2013). Small-scale mining (SSM) is vital to Ghana's economy, employing millions of people and contributing significantly to gold and diamond production in Ghana (Minerals

Commission, 2019). Ecosystem services (ES) play a crucial role in human well-being (; Guerry et al., 2015; Heink et al., 2019). Healthy ecosystems are essential for life on earth (Heink et al., 2019). Ecosystem services are valuable benefits derived from natural sources like forests, woods, and plantations (Gouhari et al., 2021). These services provide both direct and indirect contributions to human well-being (Ruslan et al., 2022).

Ecosystem services, integral to human well-being, encompass a diverse range of functions provided by natural systems (Guerry et al., 2015). Provisioning services, such as the production of food, water supply, and timber, form the foundation for human sustenance and economic activities. Regulating services, including climate regulation and flood control, contribute to environmental stability. Cultural services, such as recreational opportunities and spiritual values associated with landscapes, enhance cultural and emotional well-being. Supporting services, like biodiversity support and soil formation, underpin the resilience and functionality of ecosystems. Habitat services provide critical spaces for wildlife and genetic resources essential for breeding programs. Pollination services, nutrient cycling, water purification, and other ecological functions collectively contribute to the intricate web of services ecosystems offer. Recognizing and preserving these ecosystem services are essential for sustainable resource management, conservation efforts, and the overall health of our planet.

The vital role of ecosystems and biodiversity in providing various advantages to humanity, emphasizing the connection between people and the natural world. The expanding economy fuels increased mineral resource demand, necessitating the monitoring of land cover changes and their impact on earth's ecological, environmental, and socioeconomic systems for sustainable development. Surface mining's primary aim is to extract minerals by removing surface soil and rock (Erener, 2011). Unlike underground mining, which uses tunnels or shafts, surface mining can harm ecosystems, alter the hydrological cycle, and lead to various ecological and environmental issues, such as subsidence, flora and soil degradation, surface and groundwater contamination, and biodiversity loss (Feng et al., 2019; Zhu et al., 2020). To mitigate these environmental impacts of SSM and ensure sustainable mining practices, Ghana has established regulations, including License Agreement and Regulation 23 of the Environmental Assessment Regulations, 1999. These regulations mandate the responsible reclamation of mined lands to their maximum beneficial value post-resource exploitation. Despite these regulations, an audit report on reclamation of mined areas in Ghana (2021) revealed shortcomings in the execution of reclamation activities. Often, the focus is primarily on restoring the land for its potential economic value, while overlooking the critical human and ecosystem services that these lands provide. This oversight threatens not only the livelihoods of local communities but also the integrity of the ecosystem services that sustain them. In light of these challenges, this study was be conducted in the Asante Akim Central Municipal in the Ashanti Region of Ghana. The primary objective was to comprehensively assess reclamation activities and their impacts on the ecosystem services of the forest adopting GIS and remote sensing technology.

2. MATERIALS AND METHODS

Study Site

The Asante Akim Central Municipal District, formerly Asante Akim North District, obtained municipal status in 2008 with Konogo as its administrative capital. Located in the eastern part of the Ashanti region, it connects major highways to the national capital city and shares borders with adjacent districts. Covering about 300 square kilometers, the area has a semi-equatorial climate with two rainy seasons (May-July and September-November) and a dry harmattan season (December-April). The average annual temperature is consistently high at 26 degrees Celsius.

The region has valuable semi-deciduous forests, but extensive deforestation has occurred due to logging, bushfires, and poor agricultural practices (GSS, 2014). Approximately 50% of the population engages in agriculture. The 2021 census recorded a total population of 91,673, with most households in the municipality involved in agricultural farming, primarily poultry. The area is known for gold mining, with one major corporation operating in Konongo and Obenimase, as well as small-scale mining. Large-scale quarrying opportunities exist in the Dwease–Praaso region, known for its substantial granite deposits.

3.2 Data Collection

The primary data was collected for specific locations in the study area using GPS instruments. The secondary data included Digital Elevation Model from which slope was derived, shapefiles of settlement (urban and village/hamlets), forest reserves and Landsat satellite images. Table 3.1 shows the dimensions of the data that were used in the study.

Table 3.1. Data types and Data Sources

Data	Data Source	Data Type
Settlement (urban and villages/hamlets)	Land Use and Spatial Planning Authority (LUSPA)/ KNUST-GIS laboratory	Secondary
Forest Reserve	KNUST-GIS laboratory	Secondary
Roads	KNUST-GIS laboratory	Secondary
Landsat Satellite image	United State Geological Survey (USGS)	Secondary
DEM	United State Geological Survey (USGS)	Secondary
Study Area (Asante Akim Municipal)	Land Use and Spatial Planning Authority (LUSPA)	Secondary
Mining Block	Ghana Mineral Commission	Secondary

The QGIS 3.14 was used for all data extraction, editing, management, land use and land cover classification. All raster and vector data types were converted into a common coordinate system which is the Universal Transverse Mercator (UTM) zone 30N and a shapefile format acceptable by the software. However, the InVEST 3.11 was used to quantify the impact of the reclamation activities on the forest ecosystem services.

The hetrogeneity of the the forest ecosystem was assesd using the Zonal statistcis. This approcah allows for computation of mean of the biophysical indicators and averaging of the various services each land use types provides. To provide effective analysis of the ecosystem that the forest provides, the multilayer regression analysis was carried out factoring in the amount of precipitation, and the percentage of land covered by forests

3. RESULTS

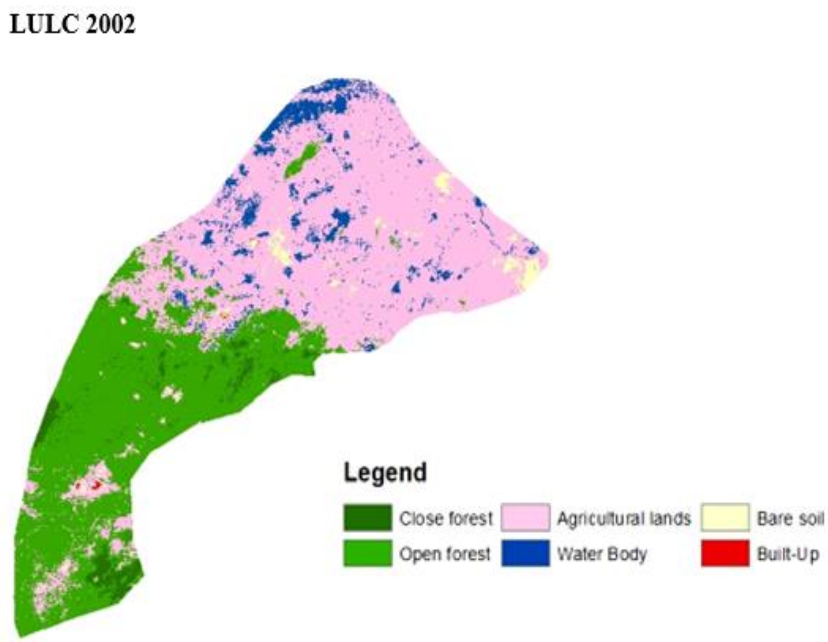
3.1 Land Use Land Cover (/LULC) in the Asante Akim Central Municipality

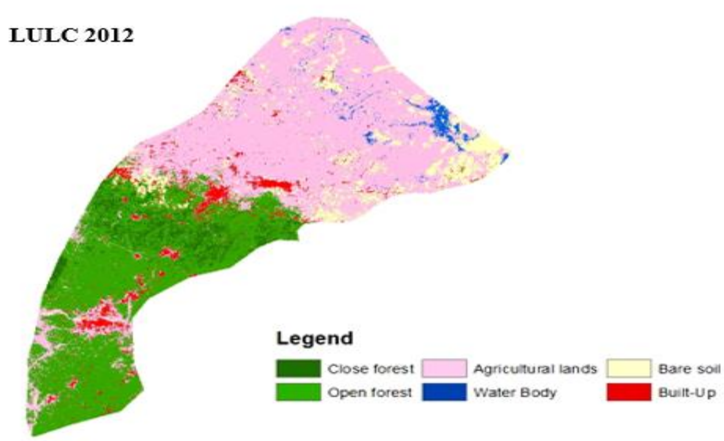
This section considers the land use land cover in the study area. It also demonstrated the trend in land use over the 20 years period in the study area. Table 1 provide details of the land use land cover while figure 1 shows the spatial distribution of LULC.

Table 4.1: Land use land cover in the study area

	Year					
	2002		**2012**		**2022**	
	Ha	**%**	**Ha**	**%**	**Ha**	**%**
Close Forest	77811.30	52.7	45204.84	30.6	21606.46	14.6
Open Forest	53887.230	36.4	66044.45	44.7	71751.74	48.6
Agricultural Lands	8405.2575	5.6	17304.750	11.72	22617.90	15.3
Water Bodies	4436.730	3.0	4139.050	2.0	2174.833	1.5
Bare Soil/mining site	2945.182	1.9	17304.750	5.0	19431.908	13.2
Built-Up	161.010	0.1	7462.462	5.1	10063.869	6.8
Total	**147646.710**	**100.0**	**147646.710**	**100.0**	**147646.710**	**100.0**

Table I provides a comprehensive overview of land cover changes in the specified area for the years 2002, 2012, and 2022, presenting data in hectares (Ha) and percentages (%). Notable trends emerge from the comparative analysis of these findings. Firstly, close forest cover witnessed a substantial decline, decreasing from 52.7% (77,811.30 Ha) in 2002 to 30.6% (45,204.84 Ha) in 2012 and further to 14.6% (21,606.46 Ha) in 2022, indicating potential deforestation or land use alterations. In contrast, open forest cover consistently increased from 36.4% (53,887.23 Ha) in 2002 to 48.6% (71,751.74 Ha) in 2022, suggesting afforestation or natural regeneration. Agricultural lands also expanded over the years, rising from 5.6% (8,405.26 Ha) in 2002 to 15.3% (22,617.90 Ha) in 2022, likely due to agricultural expansion. Conversely, water bodies decreased from 3.0% (4,436.73 Ha) in 2002 to 1.5% (2,174.83 Ha) in 2022, indicating environmental changes or shifts in hydrology. Notably, bare soil/mining sites surged from 1.9% (2,945.18 Ha) in 2002 to 13.2% (19,431.91 Ha) in 2022, highlighting significant mining activities or land disturbances. Lastly, built-up areas expanded from 0.1% (161.01 Ha) in 2002 to 6.8% (10,063.87 Ha) in 2022, signifying urban development and infrastructure growth





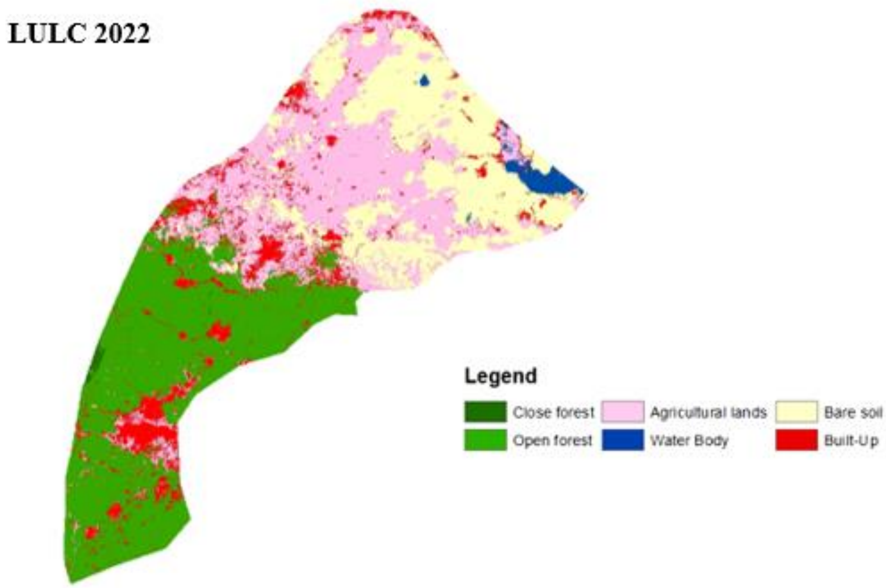


Figure 1: Land use land cover in the study area

3.2 The Extent of Reclamation Activities Among Small-scale Mining in the Asante Akim Central Municipal

This section examined the extent of small-scale mining and reclamation activities in the study area (Table 2 and figure 2).

Table 2: Small Scale mining Activities

Land Use Classes	Year					
	2002		2012		2022	
	Ha	%	Ha	%	Ha	%
Mining Area	0.0	0.0	17304.7500	11.8	14843.0475	10.1
Non-Mined Area	147646.710	0.0	130341.9600	88.2	132806.9925	89.9
Total	**147646.710**	**100.0**	**147646.710**	**100.0**	**147646.710**	**100.0**

In terms of mining activities in the study area, land use class termed "Mining Area" was non-exist (0.0%) in 2002. However, it occupied 11.8% (17304.7500 ha) in 2012 but the rate of increase dropped in 2022 to 10.1% (14843.0475 ha) partly due to reclamation activities and other government measures that were instituted against mining activities. In 2002, prior to the introduction of mining activities in the area the total land cover of Non-Mined Area was 147646.710 ha (100%) but decreased to 130341.9600 ha (88.2%) and gained marginally in 2022 to 132806.9925 ha (89.9%)

2012

2022

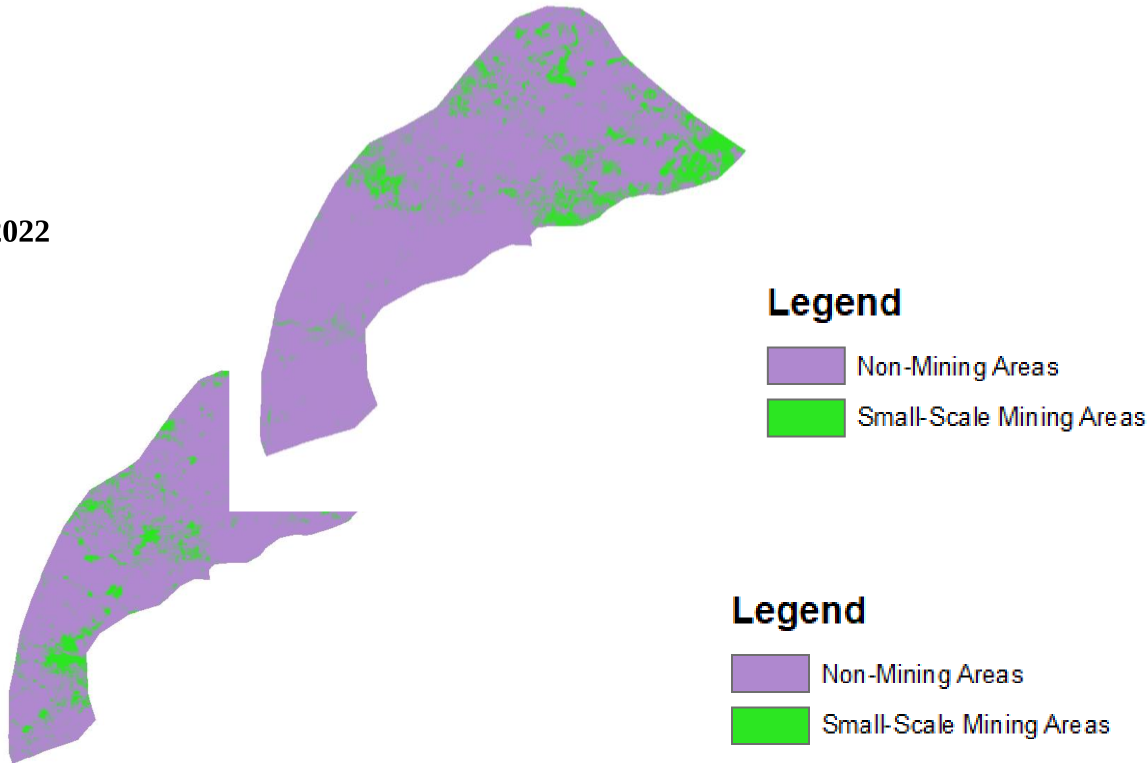


Figure 2: Classified Images of Small-Scale mining Activities in the Study Area

Table 4.3: Extent of Reclaiming Activities

Land Use Class	**2012**		**2022**			
	Ha	**%**	**Ha**	**%**	**Difference (ha/%)**	**Remarks**
Mining Area	17304.75	11.8	14843.04	10.1	-2461.7025**(1.7)**	Loss
Non-Miming Area	130341.96	88.2	132806.99	89.9	2465.0325**(1.7)**	Gain
Total	**147646.710**	**100.0**	**147646.710**	**100.0**		

Table 3 provides a snapshot of reclamation activities in the studied area for the years 2012 and 2022, measured in hectares (Ha) and percentages (%), along with the difference in Ha and corresponding remarks. Notably, the data reveals a decline in mining area from 11.8% (17,304.75 Ha) in 2012 to 10.1% (14,843.04 Ha) in 2022, signifying a reduction of 1.7% (2,461.70 Ha). This indicates ongoing efforts to reclaim and rehabilitate previously mined land, potentially for environmental restoration or alternative land uses. Conversely, non-mining areas increased from 88.2% (130,341.96 Ha) in 2012 to 89.9% (132,806.99 Ha) in 2022, representing a gain of 1.7% (2,465.03 Ha), possibly reflecting the expansion of reclaimed or repurposed land. Although, a loss in the rate of coverage of mining area between 2012 and 2022 has been observed as result of reclamation works, it was marginal.

3.3 Assessing the ecosystem services of the reclaimed forest mined areas using GIS and Remote Sensing

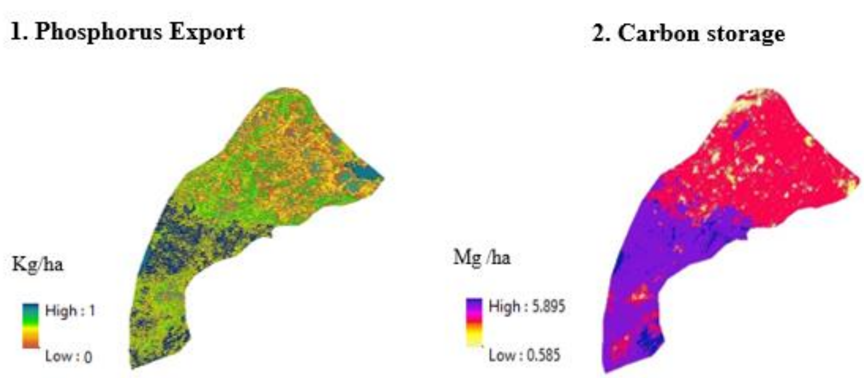
Ecosystem services production varied across the landscape (Table 4), with the southern locations of the landscape having lower ecosystem services production than the northern areas (Figure 3).

Table 4.4: Biophysical features of ecosystem service in the study area.

Land Use Classes	**Phosphorus Export (Kg per ha)**	**Carbon Storage (mg per ha)**	**Nitrogen Export (Kg per ha)**	**Sediments Export (kg per ha)**	**Water Yield (mm per ha)**
Close Forest	0.002	5.0	0.48	101	581
Open Forest	0.002	4.8	0.37	123	634
Agricultural Lands	0.061	3.5	2.56	562	721
Bare Soil/mining site	0.001	0	2.78	982	1057
Built-Up	0.0413	1.0	1.65	0.18	871

The Phosphorus Export shows that Close Forest has 0.002 Kg per ha, Open Forest has 0.002 Kg per ha and Agricultural Lands have 0.061 Kg per ha. Meanwhile, Bare Soil/mining site has as low as 0.001 Kg per ha and Built-Up recorded 0.0413 Kg per ha. On Carbon storage (mg per ha), Close Forest recorded 5.0 mg per ha, Open Forest has 4.0 mg per ha and Agricultural Lands recorded 3.5 mg per ha. On the contrary, Bare Soil/mining site had 0.0 mg per ha and Built-Up recorded 1.0 mg per ha.

Nitrogen Export (Kg per ha) was 0.48 Kg per ha for Close Forest, 0.37 Kg per ha for Open Forest and 2.56 Kg per ha for Agricultural Lands. Also, it was higher (2.78 Kg per ha) at Bare Soil/mining site and 1.65 Bare Soil/mining site at Built-Up areas. Sediments Export (kg per ha) was relatively low in Close Forest (101 kg per ha), Open Forest (123 kg per ha) and Agricultural Lands (562 kg per ha). It was higher at Bare Soil/mining sites (982 kg per ha) but was least at Built-Up area (0.18 kg per ha). In terms of Water Yield (mm per ha), forested areas like Closed Forest (581 mm per ha), Open Forest (634 mm per ha) and Agricultural Lands (721 mm per ha) recorded the lowest followed by Built-Up areas which recorded 871 mm per ha. Bare Soil/mining site had the highest record of 1057 mm per ha of Water Yield



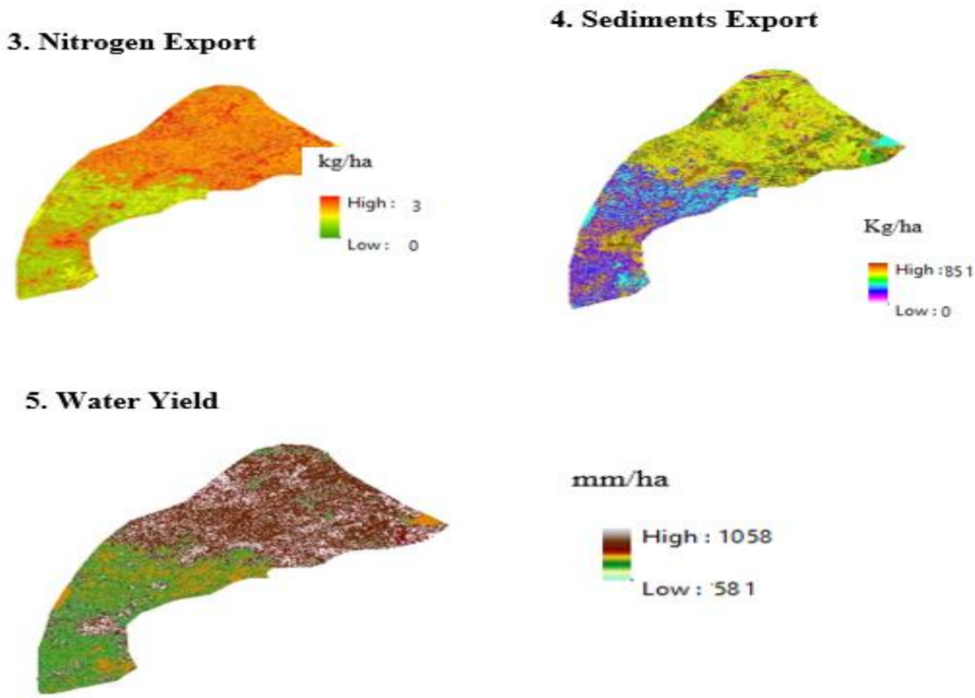


Figure 3: Classification of Biophysical features of ecosystem service in the study area

Different land cover types produced different amount of ecosystem services. Close Forest, Open Forest and Agricultural Lands forming the forested areas generally produced greater ecosystem services than the other land cover types; they are associated with highest carbon storage and lowest water yield, sediment export, and nutrient export (Phosphorus Export and Nitrogen Export). In contrast, Bare Soil/mining site and Built-Up constituting barren lands provided the lowest amount of ecosystem services by producing lowest carbon storage and highest water yield, sediment export, and nutrient export.

4. DISCUSSION

The findings of the study showed that within the 20 years period in the study area, LULC constitute Close Forest (21606.46 ha) Open Forest (71751.74 ha), Agricultural lands(22617.90ha), Water(2174.833ha), Bare Soil/mining site (19431.908 ha) and Built-up (10063.869 ha). It was discovered from the study that major land sue conversion were from Close Forest to open forest (5620.8 ha), open forest to Agricultura lands (14212.642 ha), and Agricultural lands to either bare soil (1686.726 ha)/ Built-up (9902.859 ha). The trend observed of LULC in this study is similar to previous studies conducted in the Ashanti region of Ghana where the study area is located. For instance, Abass et al., (2019), observed significant land use and land cover changes (54.6% urbanization) in thirty years (1986 -2016) with negative repercussions for food crop production. Toure et al., (2020), also observed residential land use (64%) increase in the Kumasi metropolis whiles Takyi, et al., (2022), found an overall increase in the built-up areas by 24.13% (55.81 km2) from 1986 to (2015). The study reveals substantial land use and land cover changes over the 20-year period in the study area, with notable consequences for both the environment and society. The conversion of Close Forest to Open Forest signifies a significant loss of natural habitat, raising concerns about biodiversity decline. The expansion of Agricultural lands at the expense of Open Forest suggests potential impacts on soil quality, water resources, and biodiversity. Urbanization and infrastructure development, as indicated by the transformation of Agricultural lands to Built-up areas, call for careful urban planning to mitigate environmental impacts. Mining activities, reflected in the conversion of Agricultural lands to Bare Soil/mining sites, highlight the need for sustainable practices and environmental regulations. The findings underscore the importance of water resource management, consideration of ecosystem services, and awareness of climate change implications. The study emphasizes the necessity for well-informed policies and planning strategies that balance economic development with environmental conservation, ensuring a sustainable and resilient future for the study area.

The findings from the study revealed that small-scale mining areas within the Asante Akim Municipal between 2012-2022 constitute approximately 17304.75 ha (11.8%) and non-mining area cover approximately 130341.96ha (88.2%) of land use. It was, however, noted that the extent of reclamation activities over the ten (10) year's period was approximately 2461.7025 ha representing 1.7% of total landscape. It was a marginal reclamation with little or no effects on the improvement on the ecosystem. The findings of this study collaborate that of Bansah et al., (2016), where they found only 8% of mined areas in Ghana were reclaimed. Similarly, Schueler et al., (2011), observed few reclamations of small-scale mining site which had negatively affected the land use in the Western region of Ghana. Additionally, Kumi-Boateng et al., (2020), observed about 15 small-scale and 8 clusters of Artisanal mining sites with almost 12% of the total land scape of Tarkwa-Nsuaem Municipality of Ghana forest mined without any reclamation.

The study's outcomes regarding small-scale mining areas within the Asante Akim Municipal area between 2012-2022 carry significant implications for both environmental conservation and sustainable land use management. The substantial proportion of land dedicated to mining activities, compared to non-mining areas, underscores the extensive impact of small-scale mining. However, the findings also raise concerns about the limited extent of reclamation activities, suggesting that current efforts have only marginally affected the landscape, with minimal improvements to the ecosystem. This implies a need for more comprehensive and effective reclamation strategies to address the environmental degradation associated with mining. The stark contrast between mining and non-mining areas emphasizes the importance of implementing and enforcing sustainable land use practices, necessitating stricter regulations, robust monitoring mechanisms, and increased community involvement. Addressing these issues is crucial for ensuring the long-term ecological integrity and resilience of the Asante Akim Municipal area.

The ecosystem assessment conducted with the InVEST modeling showed that the reclamation was insignificant to warrant a change in the ecological services. Even in the best-case scenario for reclamation, when all of the grasslands and barren areas are turned back into forests, the improvement of the regulating ecosystem services was not made by the reclamation operation. Gurung et al., (2018), observed similar pattern when they conducted an ecosystem services assessment of forestry-based reclamation of surface mined areas in the north fork of the Kentucky River Watershed. Also, Sun et al., (2017), noted poor reclamation of 32,346 ha of loss in coastal wetlands resulted in US$ 806 million year−1 loss in ecosystem service in the Lianyungang city of Eastern China. The study's outcomes underscore a significant implication regarding the reclamation efforts assessed through InVEST modeling. The findings reveal that the undertaken reclamation activities had limited impact on ecological services, even under an optimistic scenario. This suggests that relying solely on the current reclamation approaches may not be sufficient to induce substantial improvements in regulating ecosystem services. The implication emphasizes the necessity for a re-evaluation of existing reclamation strategies and the exploration of additional measures to effectively restore and enhance ecological services. This insight is crucial for guiding future land management decisions, emphasizing the need for more comprehensive and targeted approaches to ensure the sustained health and functionality of the ecosystem.

5. CONCULUSION

This study provides valuable insights into land use and land cover (LULC) changes in the Asante Akim Central Municipal area over a 20-year period. The results indicate a significant transformation in land cover, with Close Forest, Open Forest, Agricultural lands, Water bodies, Bare Soil/mining sites, and Built-up areas comprising the landscape. Notably, transitions from Close Forest to Open Forest, Open Forest to Agricultural lands, and Agricultural lands to either bare soil or Built-up areas were observed.

Furthermore, the study sheds light on the extent of small-scale mining activities in the Asante Akim Municipal area, with mining areas covering approximately 11.8% of the land, while non-mining areas constitute the remaining 88.2%. However, the extent of reclamation efforts over a decade was marginal, representing only 1.7% of the total landscape. These findings corroborate existing research that indicates limited reclamation of mined areas in Ghana, which negatively impacts land use and ecosystem services. The assessment of ecosystem services using GIS and Remote Sensing revealed that the reclamation activities had an insignificant effect on regulating ecosystem services. Even under the best-case scenario where grasslands and barren areas were restored to forests, the improvement in ecological services was not substantial. This aligns with similar patterns observed in other studies, highlighting the challenges of achieving meaningful reclamation and the subsequent loss of ecosystem services.

The following recommendations are made for policy and implementation considerations based on the findings from the study;

a) The Ministry of Lands and Natural resources in collaboration with Environmental protection Agency in Ghana should intensify their campaign against small-scale miners who do not comply with the compulsory reclamation of mining site policy in Ghana.
b) The renewal mining license should be granted to only small-scale miners who comply with the reclamation of their mining sites.
c) A conscious effort should be embarked on by the Forestry Commission of Ghana in collaboration with other stakeholders to help restore the ecosystem services on reclaimed lands.
d) Regulation of land use land cover in the study are must be enforced to protect the close forest.

Author's Contribution

Isaac Kwasi Henyo, was in charge of manuscript writing, proof reading, editing and validation of study results. Benjamin Amoako-Attah served as the geospatial analyst for this research work and was responsible for overseeing the data collection, analysis, interpretation of results.

Acknowledgments

We thank Rev. Fr. Augustine Owusu-Addo, Dean of the Faculty of Education, Catholic University of Ghana for his useful comments.

REFERENCES

Asiedu, J.B.K., 2013. Technical report on reclamation of small-scale surface mined lands in Ghana: a landscape perspective. *American Journal of Environmental Protection*, 1 (2), 28-33.

Atta, S.K. and Tholana, T., 2022. Cost competitive analysis of large-scale gold mines in Ghana from 2007 to 2016. *Mineral Economics*, 35 (1), 53-65.

Bansah, K.J., Sakyi-Addo, G.B. and Dumakor-Dupey, N.K., 2016. Post-Mining Reclamation in Artisanal and Small-Scale Mining. In *International Conference & Exhibition on Advanced and Nanomaterials* (pp. 172-179).

Erener, A., 2011. Remote sensing of vegetation health for reclaimed areas of Seyitömer open cast coal mine. *International Journal of Coal Geology*, 86 (1), 20-26.

Fedele, G., Locatelli, B., & Djoudi, H. 2017. Mechanisms mediating the contribution of ecosystem services to human well-being and resilience. Ecosystem services, 28, 43-54.

Feng, W., Zhang, Q., Hu, G., & Huang, J. X. 2014. Mining network data for intrusion detection through combining SVMs with ant colony networks. *Future Generation Computer Systems*, 37, 127-140.

Feng, Y., Wang, J., Bai, Z. and Reading, L., 2019. Effects of surface coal mining and land reclamation on soil properties: A review. *Earth-Science Reviews*, 191, 12-25.

Gouhari, S., Forrest, A. and Roberts, M., 2021. Cost-effectiveness analysis of forest ecosystem services in mountain areas in Afghanistan. *Land Use Policy*, 108, 105670.

Guerry, A.D., Polasky, S., Lubchenco, J., Chaplin-Kramer, R., Daily, G.C., Griffin, R., Ruckelshaus, M., Bateman, I.J., Duraiappah, A., Elmqvist, T. and Feldman, M.W., 2015. Natural capital and ecosystem services informing decisions: From promise to practice. *Proceedings of the National academy of sciences*, 112 (24), 7348-7355.

Gurung, K., Yang, J. and Fang, L., 2018. Assessing ecosystem services from the forestry-based reclamation of surface mined areas in the north fork of the Kentucky River Watershed. *Forests*, 9 (10), 652.

Heink, U. and Jax, K., 2019. Going upstream—How the purpose of a conceptual framework for ecosystem services determines its structure. *Ecological Economics*, 156, 264-271.

Kumi-Boateng, B. and Stemn, E., 2020. Spatial analysis of artisanal and small-scale mining in the Tarkwa-Nsuaem Municipality of Ghana. *Ghana Mining Journal*, 20 (1), pp.66-74.

Schueler, V., Kuemmerle, T. and Schröder, H., 2011. Impacts of surface gold mining on land use systems in Western Ghana. *Ambio*, 40 (5), 528-539.

Schueler, V., Kuemmerle, T. and Schröder, H., 2011. Impacts of surface gold mining on land use systems in Western Ghana. *Ambio*, 40 (5), 528-539.

Sun, X., Li, Y., Zhu, X., Cao, K. and Feng, L., 2017. Integrative assessment and management implications on ecosystem services loss of coastal wetlands due to reclamation. *Journal of Cleaner Production*, 163, S101-S112.

Tetteh, E.N., 2010. Evaluation of land reclamation practices at AngloGold Ashanti; Iduapriem Mines Ltd, Tarkwa. Master of Science Thesis. Kwame Nkrumah University of Science and Technology, Kumasi-Ghana.

Zhu, D., Chen, T., Zhen, N. and Niu, R., 2020. Monitoring the effects of open-pit mining on the eco-environment using a moving window-based remote sensing ecological index. *Environmental Science and Pollution Research*, 27, 15716-15728.