SMALL-SCALE GOLD MINING STUDY • AUGUST 2024

Data to Monitor Environmental Impacts in Suriname

A collaboration between the Islamic Development Bank, the Inter-American Development Bank, the Global Partnership for Sustainable Development Data, and the Government of Suriname

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Acknowledgements

This document is a product of the work led by the Global Partnership for Sustainable Development Data in developing a case study to measure artisanal and small-scale gold mining (ASGM) impacts in Suriname. Under a demand-driven approach, several consultations with counterparts in Suriname identified the measurement of ASMG impacts as an area of interest for the country. With funding from the Islamic Development Bank and the Inter-American Development Bank, an assessment of capacity building needs and a skills development program to quantify the environmental impacts of ASGM in Suriname were conducted in association with Assimila.

From the Government of Suriname, we appreciate the strong collaboration of the Foundation for Forest Management and Forest Control (SBB for its acronym in Dutch), the General Bureau of Statistics (ABS for its acronym in Dutch), and the Planning Office (SPS for its acronym in Dutch), which provided constant support for this project.

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Executive summary

Artisanal and small-scale gold mining (ASGM) is prevalent in Suriname, and it has been difficult to fully monitor and characterize ASGM and its impacts on the environment, primarily due to the lack of data and the remoteness of affected regions. While the gold sector in Suriname represents more than 30 percent of the gross domestic product (GDP), 5 percent of which is associated with mining and quarrying activities, to date the strategies explored to address environmental sustainability have not been enough. To improve data availability, in the exercise described in this report, we combined remote sensing, which is the acquisition of information from a distance via sensors on satellites and aircraft, with machine learning methods to measure forest and waterbody land cover in 2019 and 2022. Recorded changes in the forest coverage and waterbody were used to estimate the environmental impacts of ASGM.

From the inception of this case study, the Global Partnership held several consultations with representatives of diverse institutions in Suriname to identify the thematic area of focus. Subsequently, an analysis of data and capacity needs was performed to plan a training in Earth observation (EO) and data analysis techniques for more than 30 public servants in Suriname, which was delivered by Assimila. Finally, co-creation sessions were held between Assimila and the Foundation for Forest Management and Forest Control to perform the pilot exercise.

In summary, for a delimited area of 674 square kilometer that was used as a pilot exercise, the main results show:

- An **increase of 47 percent in ASGM activities** in 2022 compared to 2019.
- A **total loss of 24.56 square kilometers of rainforest** between 2019 and 2022.
- An **increase of ~40 percent in water turbidity** between 2019 and 2022.
- An area of **5.86 square kilometers of rainforest experienced more than a 10 percent drop in vegetation health** between 2019 and 2022.

The data shows the rapid negative consequences of ASMG to the country's natural capital, with evidence on the impact of not monitoring these. For having a more sustainable process for small scale gold mining monitoring, specific considerations related to institutional capacity, institutional participation, IT infrastructure limitations and other technical aspects are formulated. Finally, a set of recommended next steps for the country are proposed: definition of an institutional framework for ASGM monitoring, capacity development and knowledge sharing, IT infrastructure investments and a data governance scheme for guaranteeing evidence based policy making.

About this partnership

This partnership between the Islamic Development Bank, the Inter-American Development Bank, and the Global Partnership for Sustainable Development Data, in collaboration with Suriname counterparts and Assimila, aimed to:

Facilitate coordination among national institutions to ensure a multi-stakeholder and collaborative approach to technical data solutions.

Create a common agenda to develop a case study on artisanal gold mining in Suriname.

Create medium- and long-term technical capacity on Earth observation data analysis and use for 16 entities in Suriname.[1]

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[1] Foundation for Forest Management and Forest Control; General Bureau of Statistics; National Planning Office; Ministry of Spatial Planning and Environment; Ministry of Agriculture, Animal Husbandry and Fisheries; Ministry of Public Works; Ministry of Natural Resources; Ministry of Land and Forest Management; Ministry of Defense – Suriname Air Force; Grasshopper Aluminum Company (Grassalco); Management Institute for Land Registration and Land Information System – GLIS; Coast Guard Suriname; Geological and Mining Services; Center for Agricultural Research; National Institute for Environment and Development in Suriname; and National Coordination Center for Disaster Management.

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Abbreviations and Acronyms

Abbreviation	Description
ABS	General Bureau of Statistics
AOI	Area of Interest
ASGM	Artisanal and Small-scale Gold Mining
EO	Earth Observation
GDP	Gross Domestic Product
GIS	Geographical Information Systems
HFLD	High Forest Cover Low Degradation
IT	Information Technology
NIMOS	National Institute for Environment and Development in Suriname
SBB	Foundation for Forest Management and Forest Control
SPS	National Planning Office Suriname

Introduction

Suriname is one of the greenest countries on the planet. A large percentage of the country is covered by forest (92.21 percent in 2022).[2] Nevertheless, Suriname suffers the adverse environmental impacts of mineral extractions, including deforestation and river pollution. Mapping deforestation is critical to targeting interventions that address illegal gold mining, but this is frequently challenging, given the large spatial scale of the data that must be collected in remote, often dangerous areas.[3] Hence, EO data could be a very useful tool when monitoring the environment in Suriname. Protection of forests and biodiversity is becoming more and more important in pursuing the Sustainable Development Goals, which include several goals aimed at protecting the environment.

While the country has made some efforts to monitor artisanal and small-scale gold mining, unregulated activity has become common in small communities located in areas with limited resources. These communities rely on income generated from gold mining, making it difficult to persuade them to dedicate their economy to agriculture or non-extractive activities.

This report presents the current state of gold mining in Suriname and focuses on the results of a pilot exercise to monitor ASGM and quantify its environmental impacts in inner Suriname, including the capacity-development process, findings, and a policy call to mitigate environmental impacts.

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[2] Data on the KOPI statistical portal: https://www.gonini.org/SBB/index.php

[3] Achard, F., et al. (2010) ‘Estimating tropical deforestation from Earth observation data’, Carbon Management, 1(2), pp. 271–287. Available at: https://doi.org/10.4155/cmt.10.30.

Gold mining in Suriname

In 2020, according to Suriname's National Development Plan 2022–2026, the large-scale mining industry produced an estimated 24,000 kilograms of gold; small- and medium-scale mining companies produced about 15,000 kilograms. Collectively, the gold sector in Suriname:

- Contributed 21.5 percent of the country's GDP;
- Contributed 125 million USD to the state treasury;
- Provided formal employment to 2,829 people.[4]

The contribution of gold to GDP in Suriname increased after 2020, to 33.75 percent in 2022. This share comprises both gold mining as well as quarrying and manufacturing activities. Gold mining and quarrying activities alone contributed an estimated 4.8 percent to GDP in 2022.[5]

Despite the contributions of the gold sector to Suriname's economy, artisanal small-scale gold mining degrades the forest, resulting in declines in the biodiversity of ecosystems, severe mercury pollution that poisons the land and aquatic life in rivers and creeks, and water turbidity with health effects on the aquatic life system and on people who depend on that water.

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[4] National Planning Office Suriname (2021) 'Multi-annual development plan 2022–2026', December 20. Available at: https://www.planningofficesuriname.com/wp-content/uploads/2022/10/MOP-2022-2026-Volledig-FINAL-DNA-approved-Engels.pdf.

[5] Suriname General Bureau of Statistics (2023) 'Gross domestic product 2018–2022', September 1. Available at: https://statistics-suriname.org/wp-content/uploads/2023/09/NRsheet-2023-baseyear-2015-FINAL-1-september-2023-secured.pdf.

Mining was the largest driver (65 percent) of deforestation from 2000 to 2021, of which ASGM has the largest impact. (See Figure 1.).[6]

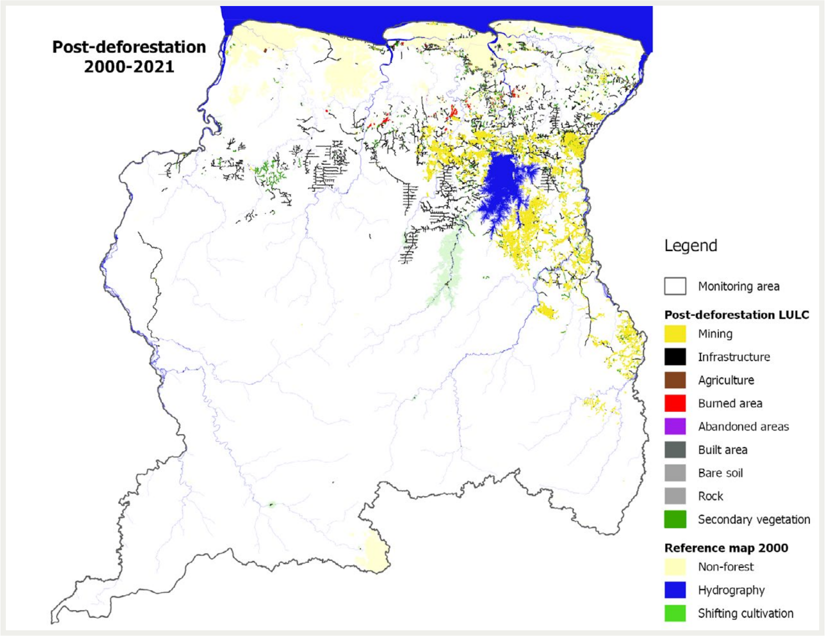

Figure 1. Drivers of deforestation in Suriname, 2000–2021.

In terms of deforestation, there was an 84 percent increase in the deforestation rate due to gold mining in Suriname between 2000 and 2008 (19,020 ha) and 2008 and 2015 (35,099 ha).[7] (See Figure 2.) In order to map gold mining it is important to determine the Minimum Mapping Unit (MMU). The MMU indicates the minimum area that a class should cover in order to be mapped. This minimum area is set at 1 ha., which is expressed in a specific amount of pixels on a satellite image.

Mining also has deleterious effects on water. Based upon a very rough estimation procedure, Mathieu Rahm, then with ONF International, and his colleagues found that 2,197 km of Suriname's waterways were directly affected and 6,806 km were indirectly affected by gold mining[8] (Figure 3). Despite there is no more recent data, the results showed the impact of mining in water; and for updating measures quantifying this impact, we include water in this study.

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[6] Foundation for Forest Management and Forest Control Data Portal. Available at: https://kopi.sbb.sr/index.php?r=deforestationlanduselandcover2%2Findex

[7] Rahm, Mathieu, et al. (2015) Monitoring the impact of gold mining on the forest cover and freshwater in the Guiana Shield. Reference year 2014. REDD+ for the Guiana Shield Project and WWF Guianas. Available at: https://lps16.esa.int/posterfiles/paper1306/Gold_mining_final_report_EN_vfinale.pdf.

[8] Ibid.

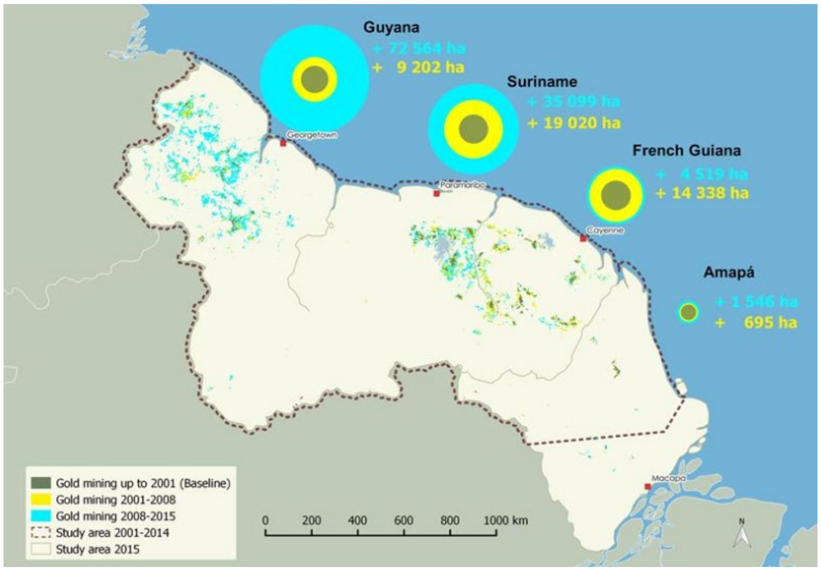

Figure 2. Deforestation caused by gold mining between 2001–2008 and 2008–2015, using a minimum mapping unit of 1 ha.

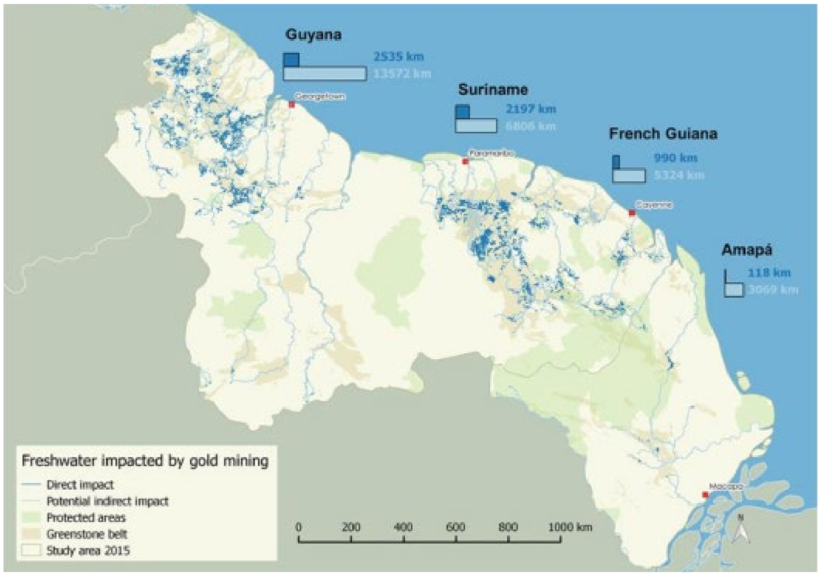

Figure 3. Direct and indirect impact of gold mining activities on freshwater through 2015.

Artisanal and small-scale gold mining

In the 1990s, artisanal and small-scale gold mining became an attractive income generation activity for Maroons living in eastern Suriname, home to many of the country's gold deposits.[9] Around the same time, increasing numbers of Brazilian miners (garimpeiros), who were confronted with more stringent restrictions on small-scale gold mining in their own country and in French Guiana, moved into Suriname. These forces resulted in an exponential increase in deforestation in Suriname and Guyana.[10]

For a large share of households in the interior, gold mining is a primary source of family income. In many of these areas, it is one of the only employment alternatives, especially for people with few employable skills.[11] It is predicted that after the economic and COVID-19 crises, more people will see the informal artisanal mining sector as a way to generate income. Increasing gold market prices also may make gold mining even more attractive.

When small-scale miners start their operations, they typically don't utilize on-site trees, but simply fell and burn them. The miners have no information about the ecological importance of soil and its possible use for reforestation purposes.[12] Small-scale mines are often revisited and re-mined once or several times. Because small-scale gold miners fail to extract an estimated half to two-thirds of the gold in the soil, the exploitation of old mining sites is economically viable when mining efficiency improves and the gold price rises.[13] The amount of small-scale mining being conducted on old sites versus new locations has never been estimated. Table 1 is an overview of policies related to small-scale gold mining in Suriname.

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[9] Heemskerk, M. (2000) Gender and gold mining: the case of the Maroons of Suriname. Available at: https://www.researchgate.net/publication/252250581_Gender_and_Gold_Mining_The_Case_of_the_Maroons_of_Suriname.

[10] Dezécache, C., et al. (2017) 'Gold rush in a forested El Dorado: deforestation leakages and the need for regional cooperation', Environmental Research Letters, 12(3). Available at: https://doi.org/10.1088/1748-9326/aa6082.

[11] NIMOS, SBB, and UNIQUE (2017). Background study for REDD+ in Suriname.

[12] Ibid.

[13] Peterson, G. D., and Heemskerk, M. (2001) 'Deforestation and forest regeneration following small-scale gold mining in the Amazon: the case of Suriname', Environmental Conservation, 28(2), pp. 117–126. Available at: https://doi.org/10.1017/S0376892901000121.

Table 1: Summary of policies and plans relevant for small-scale gold mining

Artisanal and small-scale gold mining

Regulating policies and laws	Mining Decree (1986), Extractive Industries Transparency Initiative (EITI—member since 2017), Minamata Convention (ratified 2018), and the Environmental Framework Law (2020).
National Development Plan 2022-2026	(Re)organize the informal gold sector. Delimit specific areas for small-scale mining. Implement gold mining without the use of toxic substances. Establish a rehabilitation plan for areas already degraded.
National Development Plan 2017-2021	Regulate small-scale gold mining activities aiming for improvement of the technology used, limited area for the activities and for reduction of the impact on the environment.
National REDD+ Strategy	In the context of REDD+, the government will focus on regulation and organization of small-scale gold mining activities so that they are carried out in a more controlled way, in a restricted area, with improved technology and with reduced impact on the environment.
Ongoing project	A Global Environment Facility–funded project, Improving Environmental Management in the Mining Sector of Suriname, with Emphasis on Artisanal and Small-scale Gold Mining, was implemented in 2018 with a completion target of 2025.

Despite ASGM's prevalence in Suriname, it has been difficult to monitor primarily due to the remoteness of the affected regions. As a result, to date the strategies explored to address environmental sustainability have been limited. Remote sensing, which is the acquisition of information from a distance via sensors on satellites and aircraft, is a solution to this challenge. Remote sensing and earth observation data excel at detecting events and practices in hard-to-reach areas, which can increase data availability to inform more precise policies for environmental sustainability.

Geospatial and EO data to monitor the environment in Suriname

EO data offers an invaluable tool when monitoring the environment and can "have a transformational impact on many of humanity's most significant challenges."[14] EO plays a vital role in environmental monitoring because it associates space with statistics, both as a direct measurement as well as assisting in other statistical calculations.[15] This is possible because EO data is gathered on scales that are unparalleled by other survey techniques, collects a wide variety of data types that measure unique physical characteristics of the environment, and is normally free to use and open source.[16]

EO is able to monitor the environment through sensors onboard orbital satellites that are capable of measuring electromagnetic signals of discrete portions of the Earth's surface. Different types of land cover emit different types of electromagnetic radiation, so that you can analyze the response of a region and categorize the likely land cover found within that region. For example, if a region emits a high proportion of near infrared light and a low proportion of visible light, then this is a strong indication that it is covered by healthy and photosynthetically active vegetation or forest. Therefore, EO can be particularly useful at quantifying land degradation (Sustainable Development Goal indicator 15.3.1), by mapping the changing proportions of different land cover types in a region.[17]

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[14] United Nations Statistical Commission (2017) Earth observations for official statistics: Satellite Imagery and Geospatial Data Task Team report, UNStats, December 5. Available at: https://unstats.un.org/bigdata/task-teams/earth-observation/UNGWG_Satellite_Task_Team_Report_WhiteCover.pdf.

[15] Anderson, K., et al. (2017) 'Earth observation in service of the 2030 Agenda for Sustainable Development', Geo-spatial Information Science, 20(2), pp. 77–96. Available at: https://doi.org/10.1080/10095020.2017.1333230.

[16] Anderson, K., Ryan, B., Sonntag, W., Kavvada, A., & Friedl, L. (2017). Earth observation in service of the 2030 Agenda for Sustainable Development. Geo-spatial Information Science, 20(2), pp. 77-96. Available at: https://doi.org/10.1080/10095020.2017.1333230.

[17] Teich, I. (2019) 'Combining Earth observations, cloud computing, and expert knowledge to inform national level degradation assessments in support of the 2030 Development Agenda', Remote Sensing, 11(24), 2918. Available at: https://doi.org/10.3390/rs11242918.

Land cover classification and environmental monitoring with EO data has become easier and more accurate in recent years. Open-source machine learning models are becoming more prevalent in the field and can more accurately distinguish between the spectral signatures of differing land cover types.[18] The freely available EO data itself has increased in quality within the past decade, in particular the Sentinel 2 constellation (dubbed Sentinel), which comprises two twin platforms; Sentinel 2A & Sentinel 2B. This constellation provides unparalleled data quality, which helps provide more accurate tools to discriminate between land cover types, and the spatial resolution of the data has improved, which means smaller-scale changes can be detected.[19]

The relevant data is freely available and of sufficient quality that it can distinguish fine-scale land cover patterns in Suriname, as demonstrated in Figure 4. This figure is a red-green-blue (RGB) composite image acquired on September 17, 2019, and is one of 72 images acquired in 2019 by the platform, where you can see detailed patterns of the land cover in Suriname's capital city, Paramaribo.

Figure 4. 2019 RGB image of Paramaribo.

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[18] Vali, A., Comai, S., and Matteucci, M. (2020) 'Deep learning for land use and land cover classification based on hyperspectral and multispectral earth observation data: a review', Remote Sensing, 12(15), 2495. Available at: https://doi.org/10.3390/rs12152495.

[19] Forkuor, G., et al. (2018) 'Landsat-8 vs. Sentinel-2: examining the added value of Sentinel-2's red-edge bands to land-use and land-cover mapping in Burkina Faso', GIScience and Remote Sensing, 55(3), pp. 331–354. Available at: https://doi.org/10.1080/15481603.2017.1370169.

Monitoring gold mining in Suriname through EO

Using EO for ASGM monitoring is invaluable to decision-making. The environmental impacts of gold mining have been analyzed in various studies but often lack real-time data. Improving skills and governance mechanisms for evidence-based decision-making will result in policies oriented to mitigate natural disasters and better address the social needs of communities. Table 2 provides examples of potential outputs and methods implemented in Suriname for gold mining monitoring.

Table 2: Potential outputs and methods for monitoring ASGM in Suriname

Results of EO analysis, 2023	
Output	**Method**
Annual high resolution land cover classification maps for Suriname	Train a machine learning classifier to categorize EO data pixels into discrete land cover classes—e.g., water, forest. Apply this model to the entire spatial area of Suriname.
Annual quantitative statistics of total gold mining coverage, including change over time	Using the annual land cover classifications, find the total number of pixels classified as gold mining and multiply by the area of each pixel. This can be done separately for each annual classification to get total annual area coverage of gold mining, which can be compared over time.
Highlighted regions of newly established gold mining areas and areas of significant change	By using the annual classifications, find areas where there has been a significant change of many connected pixels from forest coverage to gold mining.

The case study

Considering the data needs and the potential that EO has for increasing measurements to monitor ASGM, a pilot exercise to measure the environmental impact of ASGM for the years 2019 and 2022 was conducted by identifying land cover change—for example, from forest cover to the deforestation associated with ASGM.

The area of interest (AOI) for this pilot was delineated collaboratively with Suriname counterparts. The one that was identified had a variety of land cover types, including significant rainforest as well as the northern tip of Lake Brokopondo. This area encompasses 674 square kilometers. The area centered over Brokopondo has a good mix of lake/permanent waterbody coverage, shows evidence of significant ASGM activities that were clearly visible from inspecting historic high-resolution satellite imagery, and intersected with multiple Sentinel-1 and Sentinel-2 overpass tracks. Figure 5 displays the location of the AOI within Suriname.

Figure 5. Location of the area of interest (green dotted line).

Once the AOI was established, the next step in carrying out the case study was to download the data. This was done by ordering ImageCollections from the Google Earth Engine, in which the entire temporal data record for multispectral Sentinel-2 was downloaded for the study years 2019 and 2022. These two years were picked because they have complete data records over Suriname and are significantly separated in time so as to fully capture the change in ASGM activity in the region. In addition to Sentinel-2 data being downloaded, the associated "s2cloudless" dataset was also downloaded. This is an accompanying dataset that makes cleaning the Sentinel-2 data of cloud cover far easier.

The processing involved to derive annual land cover maps in the region was identical for both study years. The first step focused on deriving annual composites of band reflectance and other spectral indices, to summarize the temporal behavior of a pixel's reflectance. The data was cleaned by opening the s2cloudless layers in conjunction with the band data and removing the influence of clouds from the temporal profiles of each pixel. A machine learning classifier was then trained using a labeled dataset created from a shapefile provided by the Foundation for Forest Management and Production Control. All participants found the XGBoost classifier to yield the best results. The trained classifier was then applied to the entire AOI to give annual land cover classifications containing the labels "water," "forest," and "ASGM."

Key findings

- A significant increase of 47 percent in ASGM activities in 2022 compared to 2019.
- A loss of 24.56 km2 of rainforest between 2019 and 2022.
- An increase of ~40 percent in water turbidity between 2019 and 2022.
- An area of 5.86 square kilometers of rainforest experienced more than a 10% drop in vegetation health between 2019 and 2022.

The key findings from the pilot project were derived by comparing the changes in spatial distribution of the land cover types in the different years. In 2019, a total of 494,950 pixels were classified as ASGM, whereas in 2022 there was a significant **increase of 47 percent in ASGM activities.**

The most salient finding was the significant drop in forest land cover of 24.56 km^2 between 2019 to 2022, due to expansion of ASGM. Figure 6 shows the total deforested area; **5.5 km^2 of this deforestation was found within 500 meters** of Lake Brokopondo and along the banks of the Suriname River. This development is especially hazardous given the impacts of deforestation on water quality, including the increased risk of riverbank erosion and increased runoff of soil substrate into the water, both of which are extremely consequential for water quality.

Impacts on water quality are evident when analyzing the turbidity of the Suriname River. Turbidity is the degree to which a liquid is clear, where higher values indicate more polluted water, from either organic or non-organic sources. The Normalized Difference

Turbidity Index (NDTI) proposed by Jean Pierre Lacaux and colleagues is capable of measuring the relative turbidity of water bodies;[20] when applied to the AOI, it showed significant increases of ~40 percent in NDTI between 2019 and 2022 in some locations downstream of ASGM in the Suriname River.

The Normalized Difference Vegetation Index (NDVI) is a simple spectral index that indicates a pixel's photosynthetic health. This index works on the principle of measuring the relative difference in reflectance between the visible and near infrared portions of the electromagnetic spectrum. Healthy vegetation normally absorbs the majority of radiation in the visible portion of the electromagnetic spectrum for photosynthesis and reflects most of the near infrared radiation. When analyzing the trend of NDVI in the AOI, there was a significant drop in NDVI in areas surrounding the ASGM. **The finding that a total of 5.86 square kilometers of rainforest experienced more than a 10 percent drop in vegetation between 2019 and 2022** is likely due to the **higher-order effects of mining activity** on the remaining rainforest around the mines—for example, from **chemical pollution or micro-climatic edge effects.**[21]

See full visualizations of the pilot in the html file available here.

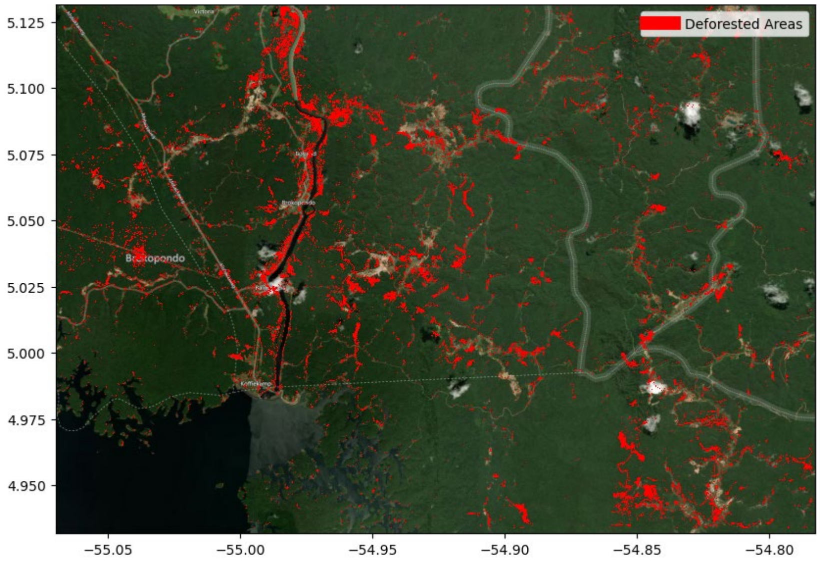

Figure 6. Composite image displaying the spatial distribution of deforested areas across the AOI (ESRI Basemap – 2022).

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[20] Lacaux, J. P., et al. (2007) 'Classification of ponds from high-spatial resolution remote sensing: application to Rift Valley Fever epidemics in Senegal', Remote Sensing of Environment, 106(1), pp. 66–74. Available at: https://doi.org/10.1016/j.rse.2006.07.012.

[21] Garate-Quispe, J., et al. (2023) 'Influence of distance from forest edges on spontaneous vegetation succession following small-scale gold mining in the Southeast Peruvian Amazon', Diversity, 15(6), art. 793. Available at: https://doi.org/10.3390/d15060793.

Policy recommendations and lessons learned

This pilot using EO data analysis highlights a loss of primary forest, vegetation, and water quality, with big impacts on Suriname's ecosystem. It demonstrates a need for better policies to protect the environment but also a clearer understanding of their impacts for the future. The use of various chemicals and methods for gold extraction is creating a big gap for reforestation in the country, which exacerbates other effects on river pollution and security concerns for communities where livelihoods are based on artisanal gold extraction.

Data driven policy decisions require timely data to monitor the impact in the environment, this pilot is only an example of the capabilities of data and how they create visualizations to represent realties and changes on the land and dynamics on the activities of gold mining. Having a **more sustainable process for small scale gold mining monitoring** should be a priority for the national government, and for establishing this process the following are key elements:

Institutional and national capacity considerations

This pilot was able to increase capacities through in-person training and co-creation sessions to carry out the data analysis along with a group of institutions. More than 30 participants representing 12 organizations of Suriname's government joined the training, and a maximum of 9 participants joined the co-creation sessions in 2023. In a pre-training survey, 46 percent of respondents noted that they had not used their existing knowledge and experience to understand or solve environmental issues related to land cover and land use changes primarily because **they do not have the training to do so.** This insight helped the Global Partnership to create a training program to strengthen EO skills in the country

> *"I learned techniques of using remote sensing data and the use of script and codes.... [With] the knowledge that I gained in this course, I will be able to use automated processes in my current work and introduce this type of analysis in my current work."*
>
> **— CLIFTON SABAJO OF CELOS , TRAINING PARTICIPANT, JUNE, 2023**

with a particular focus on land cover and changes due to gold mining. While in the pre-training assessment, learners recorded basic knowledge and skill level in Earth observation and processing analysis (48 percent), the post-training assessment saw that 57 percent of participants recorded familiarity with these skills, which is a 9 percent increase. However, the level of knowledge recorded before the training was based on perception of knowledge.

Institutional participation for the case study

Engaging participants within the ASGM case study was crucial for gathering training data and fostering a collaborative environment. Nevertheless, the participation was limited to two organizations, which limited the impact of the case study in terms of creating additional skills and deriving findings with more diverse perspectives. To ensure inclusive participation, any further activities could consider some incentives and strategies. For instance, some participants expressed a need for financial support in order to allocate time to the case study. Another approach could be to provide a longer time period to address potential future case studies where one of the main outputs is a scientific publication. This will incentivize academic participants to get involved and will generate a sense of ownership.

The government should focus on:

Creating a group of institutions to foster and promote EO data analysis on ASGM and provide official reports to the government. Some of those organizations could be the Foundation for Forest Management and Production Control, the National Institute for Environment and Development, the General Bureau of Statistics, the National Planning Office, and the Ministry of Natural Resources.

Widening the case studies to address not one environmental issue in Suriname but different related ones—for example, rolling ASGM, forest degradation, and land use change into a single study. This could motivate more institutions and organizations to participate. Additionally, engaging private industry could be relevant, though addressing potential industry requirements such as climate risk disclosure might be needed within the study.

Making participants freely available to dedicate time to future studies. At the beginning of this process, participants reported limited time to engage in the case study. This needs to change. Additionally, there is a need to create a clear set of roles and responsibilities for a monitoring mechanism on ASGM.

IT Infrastructure limitations

The use of Earth observation technologies often requires high-end computing infrastructure, given the data volume and processing involved. The ASGM case study used some cloud computing resources to allow participants to process a significant amount of EO data and developed machine learning algorithms. However, the case study highlighted the need for training in the use of distributed cloud computing. This kind of technology is ideal to provide processing and storage capacity to process high-resolution images that can be accessed and analyzed from a web browser. Another advantage of using distributed cloud computing to identify ASGM activities is that nowadays images can be acquired and processed in near-real time; inadequate computing infrastructure can delay the availability of critical information. In addition, creating cloud computing capacities improves the scalability of EO applications, allowing for the acquisition and analysis of vast amounts of data—for example, at the country level. The ASGM case study in fact allowed the processing of small areas with the capability to process large-scale regions. The recommendation here is to **improve existing cloud computing skills to aid the generation of various EO-derived environmental data products**, not only those related to ASGM.

Other technical recommendations

One key limitation of the training was the participants' limited technical familiarity with scripting and handling EO data within a Python environment. This is a key skill when manipulating large datasets and training machine learning classifiers.

As such, it is recommended that participants are:

Less dependent on this knowledge and use alternative tools to carry out the EO data handling and machine learning, rather than doing it all themselves. This should be done with the aid of a graphical user interface, which should either be built in-house or supplied using off-the-shelf tools like the Semi-Automatic Classification Plugin for QGIS.

The key requirements of such a tool would be to automatically clean Sentinel-2 data and create annual composites at the discretion of the user by experimenting with various cloud probability cleaning thresholds. Then the users can draw polygons pertaining to the training data regions, and finally automatically classify the full AOI using features chosen by each user.

This would reduce the technical overhead around manually handling the data and also make the session more interactive, as users could experiment more freely with different feature combinations and temporal aggregations.

The Semi-Automatic Classification Plugin for use with QGIS, while useful for this task, does not contain all the tools needed for the preprocessing and generation of annual composites. Therefore, data could be prepared before the practical, where premade data could comprise of pre-compiled annual spectral composites, which would avoid participants having to clean and aggregate the EO data themselves.

What comes next?

The pilot comes at a critical moment in Suriname. ASGM is growing in the country and needs to be scrutinized by the government. This initial exercise on the EO data analysis has some findings on consequences of the phenomenon of ASGM in Suriname. The group that joined the training and co-creation sessions can be a starting point for further analysis of gold mining and to initiate a knowledge-sharing platform among them.

Suggestions for next steps include:

Institutional framework for ASGM monitoring

Leadership from the government to create a group for ASGM monitoring using real-time data. This can rely on the technical leadership of institutions integrated with expertise in using EO, such as the Foundation for Forest Management and Forest Control, and should include a governance structure for coordination of this group with clear definitions of roles, responsibilities, and membership as established by law, as stated in the National Development Plan 2022–2026.

Capacity development and knowledge sharing

There are new trends and technologies that can be applied at the country level. These tools and methods, along with an analysis of available paid and free data, should be incorporated for better planning for the whole EO national strategy beyond ASGM. Training additional staff can provide a more sustainable environment, since the number of people currently working on data is very small.

IT infrastructure

Investments in IT infrastructure for data processing and hosting should be made to facilitate access, use analysis, and dissemination of information for upcoming cases studies and reporting purposes.

Evidence-based decision-making

This report has a strong focus on data, but the purpose of data is not to be published or made available. Its ultimate goal is to be used, particularly for decision-making. The framework established with institutions in Suriname to monitor ASGM must include the end user of data with clear data needs, indicators, and frequency of data dissemination, among other things.

For more information:

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