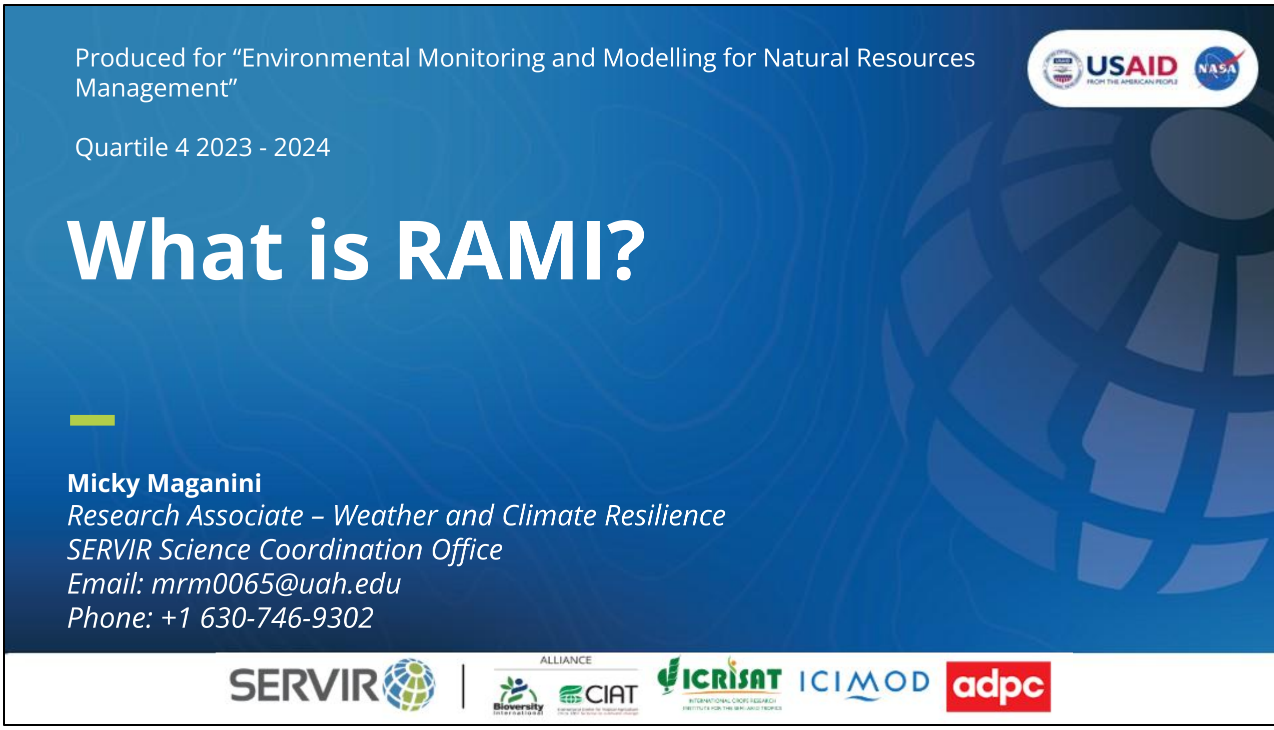


Introduction → RAMI → what RAMI  does

Hello everyone ,

My name is Micky Maganini, and I work for SERVIR, a U.S. Government organization and partner of ITC. Today I am going to introduce you to a web-based tool called RAMI that was developed by SERVIR. RAMI is a change detection algorithm used by SERVIR to monitor deforestation in the Amazon due to illegal gold mining.


Context

Before we learn more about RAMI, I want to provide some context about What SERVIR is.


joint program → hubs

SERVIR is a joint program between NASA and the US Agency for International Development. We develop solutions to address environmental challenges using earth observation data. We work with organizations around the world in five regional hubs to create these solutions.


SERVIR network → ITC & SERVIR

Beyond our regional hub institutions, we partner with organizations in the private sector, intergovernmental organizations, NGOs, and research institutions like ITC. ITC and SERVIR have partnered with each other since 2018 as both institutions apply earth observations to sustainable development on a global scale.

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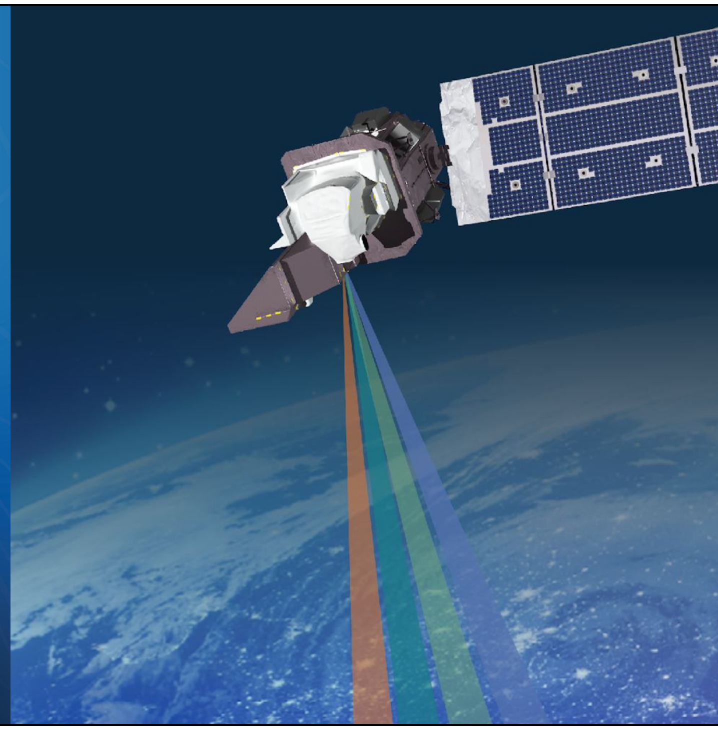
# What is RAMI?




RAMI – which stands for the Radar Mining Monitoring Tool, is a change detection algorithm implemented in Google Earth Engine. RAMI consists of a web portal where our end users can see areas that the tool is predicting have undergone change due to deforestation, as well as the code that it runs on. RAMI was co-developed by Conservacion Amazonica, Bosques en tus manos, and SERVIR-Amazonia, and delivers deforestation alerts to Peru's Ministry of the environment. The code is open source and is documented, allowing anyone to use the code for a separate ecological problem and/or geographic region

## The Problem

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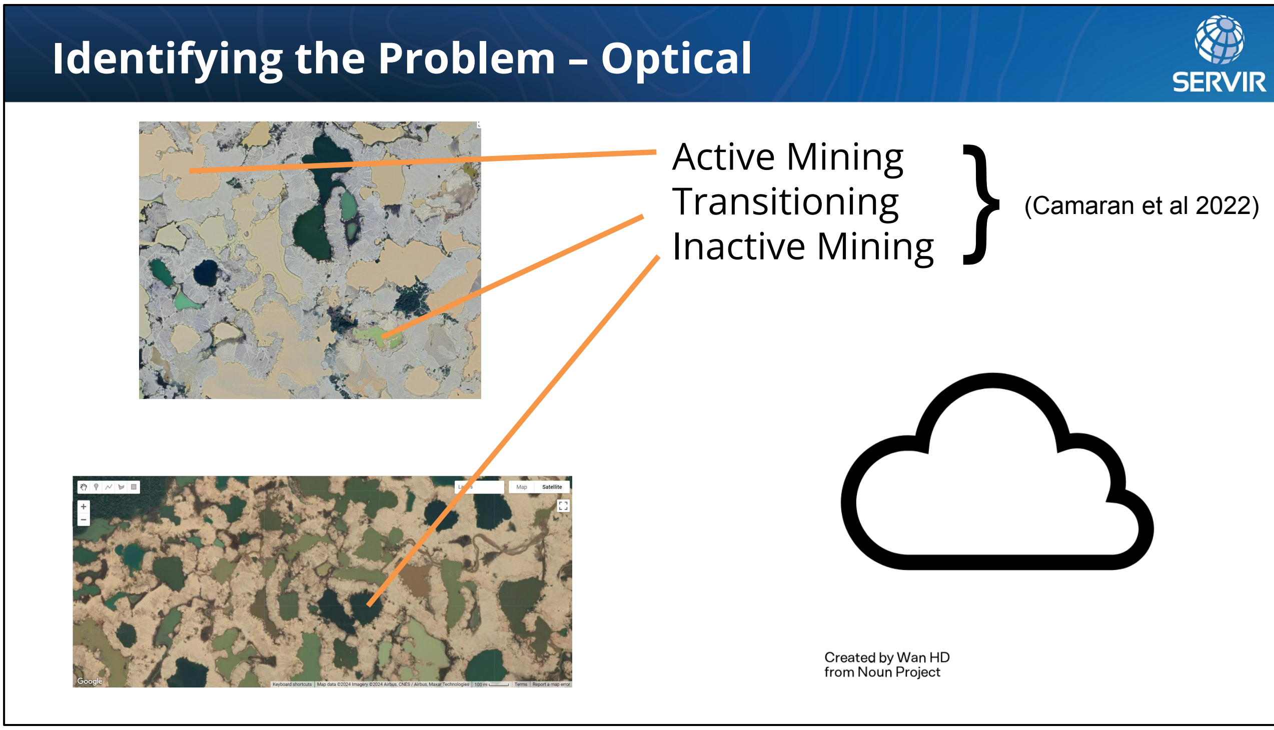
Image Credit: Ruth McDowell, NASA Earth Observatory


Image Credit: Center for Remote Sensing and Geographic Information Services

But the problem of small scale gold mining is not unique to the Peruvian Amazon. Small-scale gold mining is extremely prevalent in Ghana, where a practice called “Galamsey”, meaning to gather and sell, has grown in popularity in recent years. Thus, SERVIR’s West Africa Hub – hosted at the Center for Remote Sensing and Geographic Information Services (CERSGIS) in Ghana – are working to identify and quantify mining activities.Ghana is the seventh largest producer in the world, 35% of which is done in small-scale mines. According to the international institute for environment and development, the majority of galamsey workers are poverty-driven, and operate informally due to barriers associated with obtaining a license (McQuilken et al 2016). This gives rise to environmental and socil problems including the pollution of water bodies, and degradation of farmland and vegetation. In terms of the deforestation, artisanal mining caused seven times more deforestation than industrial efforts in the period from 2007 - 2017. A team at East Carolina and Ghana Space Science and Technology institute found that over 40,000 hectares were lost due to artisanal gold mining between 2005 and 2019 (Barenblitt et al 2021). In terms of the negative human impact, Galamsey involves the use of mercury to extract the gold from the soil. This has resulted in the contamination of the white Volta, the largest river in North Ghana. According to a study by the Tama foundation and CSIR-Ghana, there were levels above the EPA maximum for lead, mercury, cadmium, chemical oxygen, and arsenic in the river. These heavy materials can contaminate drinking water for entire communities, causing kidney problems, and neurological disorders to those continuallyl exposed.




The process of alluvial gold mining involves the removal of forest cover and topsoil, excavation, and the use of water to extract the gold from the loose sediment. Mining ponds are easily identifiable in optical imagery by their distinctive spatial and spectral patterns. The use of water to extract gold from the topsoil results in these mining ponds, the different colors of which indicate the stage at which mining is.

Chalky clay ponds indicate active mining, dark green lakes indicate inactive ponds, and light green ponds are recently active The problem with trying to monitor mining in this region using optical imagery is the persistent presence of clouds.

# Identifying the problem – SAR

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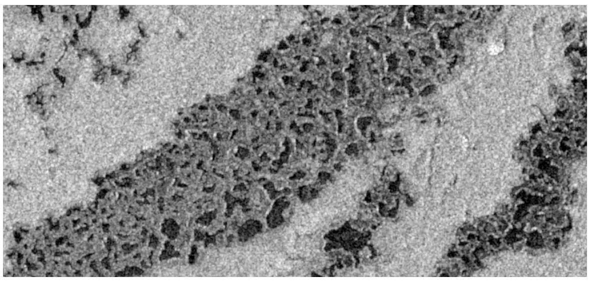

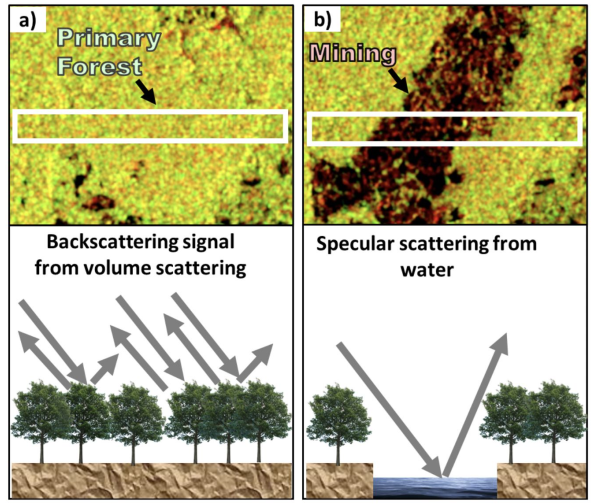


Image Credit: Franz Meyer, SAR handbook

Synthetic Aperture Radar (or SAR) allows us to “see through” clouds, which allows SERVIR-Amazonia to monitor gold mining in the rainy season when cloud cover is persistent.  On the left you can see what mining ponds look like in SAR imagery. SAR backscatter is based on the roughness and moisture content of the signal. For surfaces with an equal moisture content, rougher structures will appear brighter than smoother surfaces. Thus, as we can see on the left, we can identify forest as white, the mining ponds as black, and the soil in between the mining ponds as dark gray.

RAMI takes advantage of this backscatter difference between canopy and water, using a change detection algorithm to identify regions that initially have a high backscatter, then transition to a lower backscatter. So while the backscattering signal from forested areas are strong due to volume scattering, the backscattering signal from areas where gold mining is occurring is weak due to specular scattering of the water. This is shown by the schematic on the right side, where the VV band of the SAR data is assigned to the red and blue channel, and the VH band is assigned to the green channel. Areas that appear yellow here are showing a strong backscatter, whereas those darker areas are showing a weak backscatter.

## RAMI Workflow

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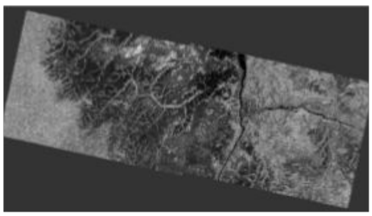
Step 1: Create a Time Series of SAR Images → Step 2: Apply Omnibus Q-test Algorithm → Step 3: Post-processing



$$\ln Q = n\left(pk \ln k + \sum_{i=1}^{k} \ln |X_i| - k \ln \left|\sum_{i=1}^{k} X_i\right|\right),$$

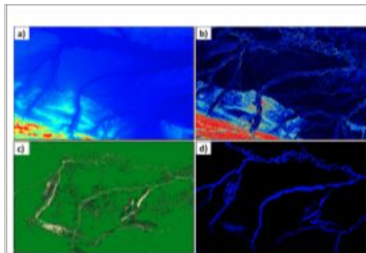



**Fig. A1.8.9** Layers used to filter false positives alerts: a) SRTM elevation, red color shows areas over 1000 meters above sea level; b) SRTM slope, red color shows areas with slope over 15 degrees; c) Hansen Global Forest Change, green color shows forested areas updated to 2020; d) JRC Yearly Water Classification History, blue color shows the maximum extent of water surface detected from 1984 to 2020.

Here we can see the general workflow of RAMI. Our first step is to pre-process the SAR data (specifically masking SAR images acquired at an incidence angle less than 31 or greater than 45 degrees), then creating a time series of mosaic of SAR images for a given time, region, and orbit pass. In Step 2, we apply the omnibus Q-test algorithm to our time series to generate change alerts. In Step 3 we will filter and eliminate potential false positive alerts coming from other activities with the same temporal pattern as the mining activity (e.g. natural forest loss by river expansion or water over bare soil during the rainy season). We do this by filtering out alerts that occur at an elevation above 1000 meters, in areas with a slope greater than 15 degrees, areas where there is not forest, and areas that were identified as water bodies. The elevation postprocessing step is taken due to the fact that in the Madre De Dios region, mining occurs in lowland areas. The slope step is taken because radiometric terrain correction is not applied to our SAR data, so steep regions show distortions. The forest step is employed using the Hansen Global Forest Change dataset, and the water step is taken via the JRC Global Surface Water Dataset. The water step is to remove false alerts that occur due to natural forest loss due to changes in river morphology.

Limitations

Because RAMI  is an unsupervised change detection algorithm, the physical cause of detected changes must be inferred from prior knowledge. Second, RAMI is not radiometric terrain corrected because it uses Google Earth Engine. Flores-Anderson et al 2023 found that using RTC products is essential to minimize geolocation errors. Finally, since we use SAR and not optical imagery, we are not able to distinguish between the different stage of the mining life cycle. We can only determine when the forest has been cleared and replaced with water.

## RAMI Use Cases

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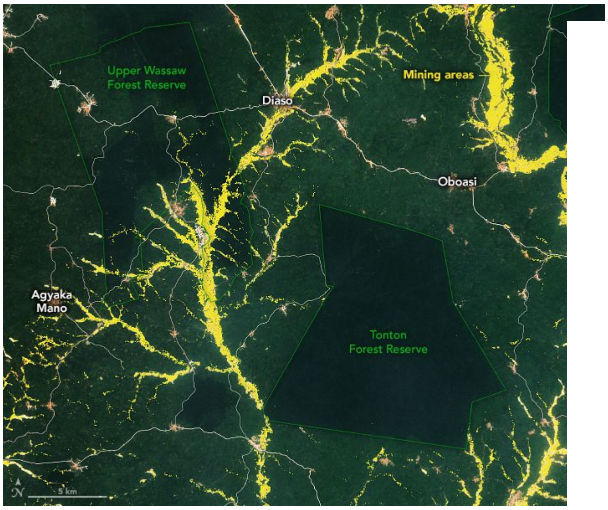


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GHANA

So how can we mitigate this issue? While the price of gold continues to rise, poverty-stricken Ghanaians will continue to turn to Galamsey. These unlicensed mining operations are not filled when the mining is complete. Thus, CERSGIS and SERVIR West Africa have develloped a platform where governments can examine where gold mining is occurring recently to curb artisanal activities and reform past mining sites so they do not contaminate the water. The Galamsey service uses a methodology similar to RAMI, using Sentinel-1 time series imagery. to identify areas where gold mining is occurring. A mobile app also allows people to report illegal mining they see. Together with A Rocha Ghana, the CERSGIS and SERVIR team shave met with community leaders and showed how Galamsey is affecting the landscape and resources

# References


1. Alaska Satellite Facility. “Introduction to SAR.” HyP3, https://hyp3-docs.asf.alaska.edu/guides/introduction_to_sar/. Accessed 22 May 2023.
2. Asner, G. P., Llactayo, W., Tupayachi, R., and Luna, E. R. (2013). Elevated rates of gold mining in the Amazon revealed through high-resolution monitoring. *Proceedings of the National Academy of Sciences*. doi:10.1073/pnas.1318271110.
3. Basu N, Horvat M, Evers DC, Zastenskaya I, Weihe P, Tempowski J. A State-of-the-Science Review of Mercury Biomarkers in Human Populations Worldwide between 2000 and 2018. Environ Health Perspect. 2018 Oct;126(10):106001. doi: 10.1289/EHP3904. PMID: 30407086; PMCID: PMC6371716.
4. Barenblitt, Abigail, et al. "The large footprint of small-scale artisanal gold mining in Ghana." *Science of the Total Environment* 781 (2021): 146644.
5. Becerra M, Villa L, Nicolau AP, Herndon KE, Novoa S, Martín-Arias V, Dyson K, Walker K, Tenneson K, Saah D (IN REVIEW – 2024). Creating near real-time alerts of gold mining in the Peruvian Amazon using Synthetic Aperture Radar. Environmental Research Communications. Submitted – in Review.
6. Brooks WE, Sandoval E, Yepez MA, Howell H (2007) Peru Mercury Inventory. 2006: U.S. Geological Survey Open-File Report 2007-1252. Available http://pubs.usgs.gov/of/2007/1252/. Accessed 2009 Dec 15. 55 p
7. Camalan, S., Cui, K., Pauca, V. P., Alqahtani, S., Silman, M., Chan, R., ... & Lutz, D. A. (2022). Change detection of amazonian alluvial gold mining using deep learning and sentinel-2 imagery. Remote Sensing, 14(7), 1746.
8. Caballero Espejo J, Messinger M, Román-Dañobeytia F, et al (2018) Deforestation and forest degradation due to gold mining in the Peruvian Amazon: A 34-year perspective. Remote Sens 10:1903. https://doi.org/10.20944/preprints201811.0113.v1
9. Csillik, Ovidiu & Asner, Gregory. (2020). Aboveground carbon emissions from gold mining in the Peruvian Amazon. Environmental Research Letters. 15. 014006. 10.1088/1748-9326/ab639c. S0376892901000121
10. Espejo, J. C., Messinger, M., D, F. R., Ascorra, C., and Luis, E. (2018). Deforestation and forest degradation due to gold mining in the Peruvian Amazon: a 34-year perspective. *Remote Sensing* 10 (1903), 1–17. doi:10.20944/preprints201811.0113.v1
11. Gerson, J.R., Szponar, N., Zambrano, A.A. et al.(2022). Amazon forests capture high levels of atmospheric mercury pollution from artisanal gold mining. Nat Commun 13, 559 . https://doi.org/10.1038/s41467-022-27997-3
12. Gerson, J.R., Szponar, N., Zambrano, A.A. et al.(2022). Amazon forests capture high levels of atmospheric mercury pollution from artisanal gold mining. Nat Commun 13, 559 . https://doi.org/10.1038/s41467-022-27997-3
13. Kellendorfer, Josef. “Chapter 3: Using SAR Data for Mapping Deforestation and Forest Degradation.” The Synthetic Aperture Radar (SAR) Handbook: Comprehensive Methodologies for Forest Monitoring and Biomass Estimation, edited by Africa Ixmucane Flores-Anderson et al.
14. McQuilken, James, and Gavin Hilson. "Artisanal and small-scale gold mining in Ghana: Evidence to inform an action dialogue'." (2016).
15. Riehl, C. (2020). Operation Mercury and Illegal Mining in Latin America. *John Hopkins, Foreign Policy Institute*
16. “Stretch Function.” Stretch Function-ArcGIS Pro | Documentation, https://pro.arcgis.com/en/pro-app/latest/help/analysis/raster-functions/stretch-function.htm. Accessed 22 May 2023.
17. U.S. Congress, Senate, Senate Foreign Relations Subcommittee on the Western Hemisphere, Transnational Crime, Civilian Security, Democracy, Human Rights, and Global Women’s Issues, *Illicit Mining: Threats to U.S. National Security and International Human Rights*, 116th Congress, 1st sess., 2019, https://www.foreign.senate.gov/imo/media/doc/120519_Glenn_Testimony.pdf.
18. Vallejos, P. Q., Veit, P., Tipula, P., & Reytar, K. (2020, October). Undermining Rights: Indigenous Lands and Mining in the Amazon. World Resources Institute. https://www.wri.org/publication/undermining-rights12
19. Villa, Lucio, et al. “Chapter A1.8: Monitoring Gold Mining Activity Using SAR .” Cloud-Based Remote Sensing with Google Earth Engine: Fundamentals and Applications, edited by Jeffrey A Cardille


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