Spatial distribution of artisanal goldmining in Ghana: Using machine learning and Google Earth Engine to quantify conversion of vegetation to gold mines

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Abstract

Gold mining has played a significant role in Ghana's economy for centuries. Regulation of this industry has varied over time and while large-scale mining is prevalent in the country, prevalence of artisanal mining, or *Galamsey* has escalated throughout Ghana in recent years. These mines are not only harmful to human health due to the use of Mercury in the amalgamation process, but also leave a significant footprint on terrestrial ecosystems, degrading and destroying forested ecosystems in the region. This study used machine learning and Google Earth Engine to quantify the footprint of artisanal gold mines in Ghana and understand how conversion of forested regions to mining has changed from 2002-2019. We used Landsat imagery and a random forest classification to classify areas of anomalous NDVI loss during this time period and used WorldView image collections to assess the accuracy of the model. We then used a 3-year moving average to calculate the year of maximum derivative NDVI values. We used this calculation to identify the year of conversion to mining. Within the study area of Southwestern Ghana, our analysis showed that approximately 35,000 ha of vegetation were converted to mining. The majority of this mining occurred between 2014 and 2017. Additionally, around 700 ha ha of mining occurred within protected areas defined by the World Database on Protected Areas. Often, artisanal mining appears to be co-located with rivers such as the Orin and Ankobra Rivers, demonstrating the potential of these mines to affect access to clean drinking water. Through the process of gold extraction, these mines leave a distinct footprint with a series of ponds following these major rivers. However, while the footprints of these ponds are spatially distinct, our model does not distinguish between active and inactive ponds if no remediation actions are taken following inactivity. Future research should work towards distinguishing between active and inactive mining sites to better understand current levels of mining activity in Ghana.

Spatial distribution of artisanal gold mining in Ghana: Using machine learning and Google Earth Engine to quantify conversion of vegetation to gold mines

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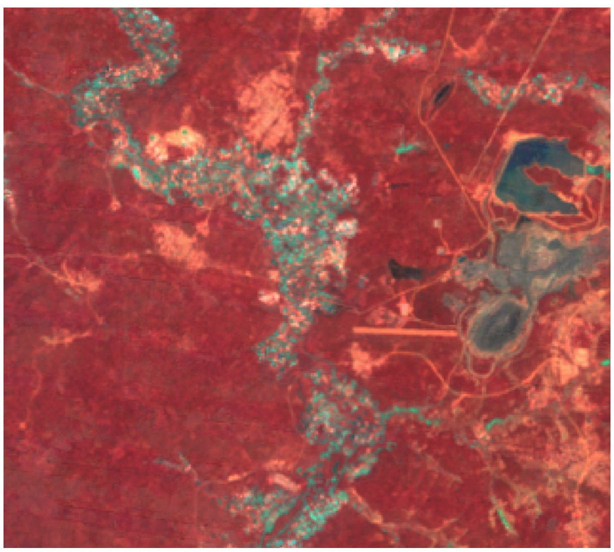
BACKGROUND

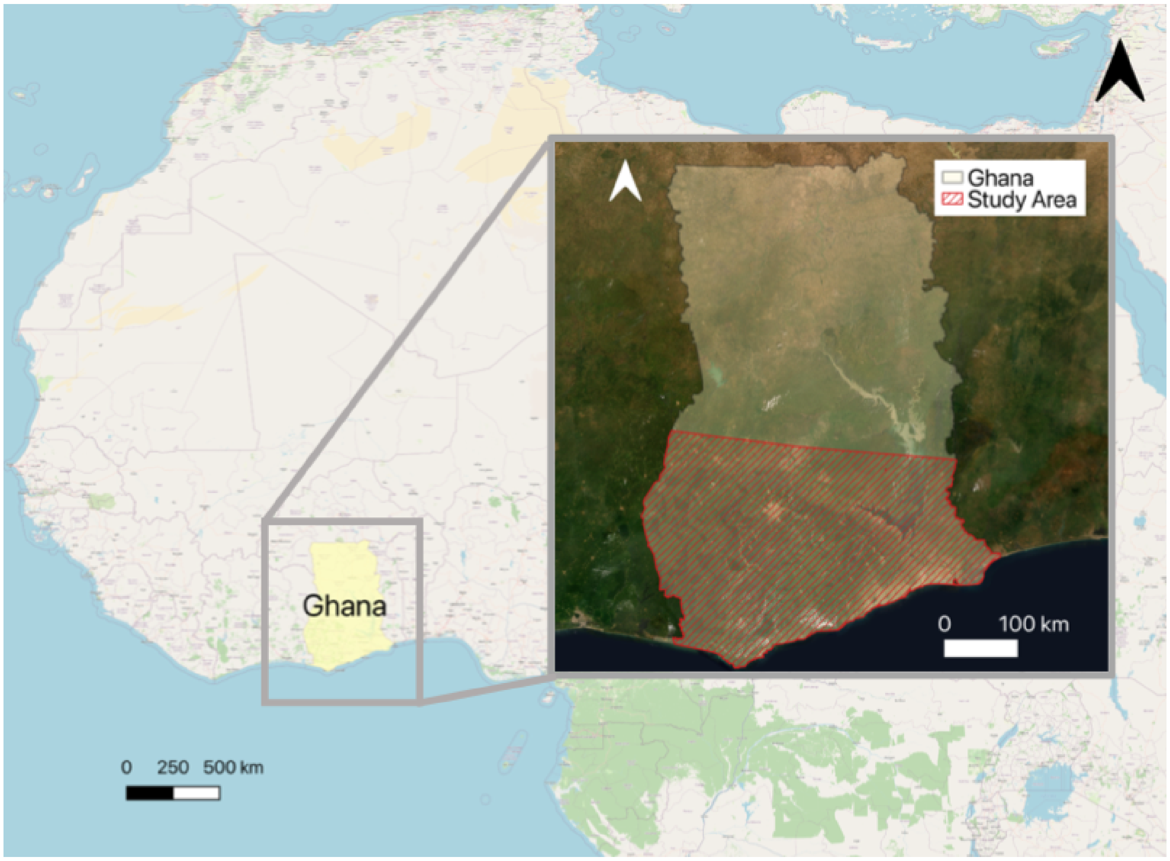
Objectives:

1. Explore the use of Landsat 5 TM, Landsat 7 ETM+, and Landsat 8 OLI to identify landcover conversion to artisanal gold mining
2. Quantify the spatial footprint of artisanal gold mining in Ghana
3. Quantify annual trends of land cover conversion to mining from 2007-2017

Mining precious metals like gold has been a part of local economies for thousands of years and globally remains a highly valued commodity. In West Africa, gold mining is conducted by way of industrial-scale mines, as well as smaller artisanal mines, also known as Galamsey. While this industry has provided economic benefits to indigenous communities in Ghana, the environmental and health impacts of this industry can be devastating (Hilson 2002). This research focuses on applying optical satellite data to explore patterns of artisanal mining in Ghana.

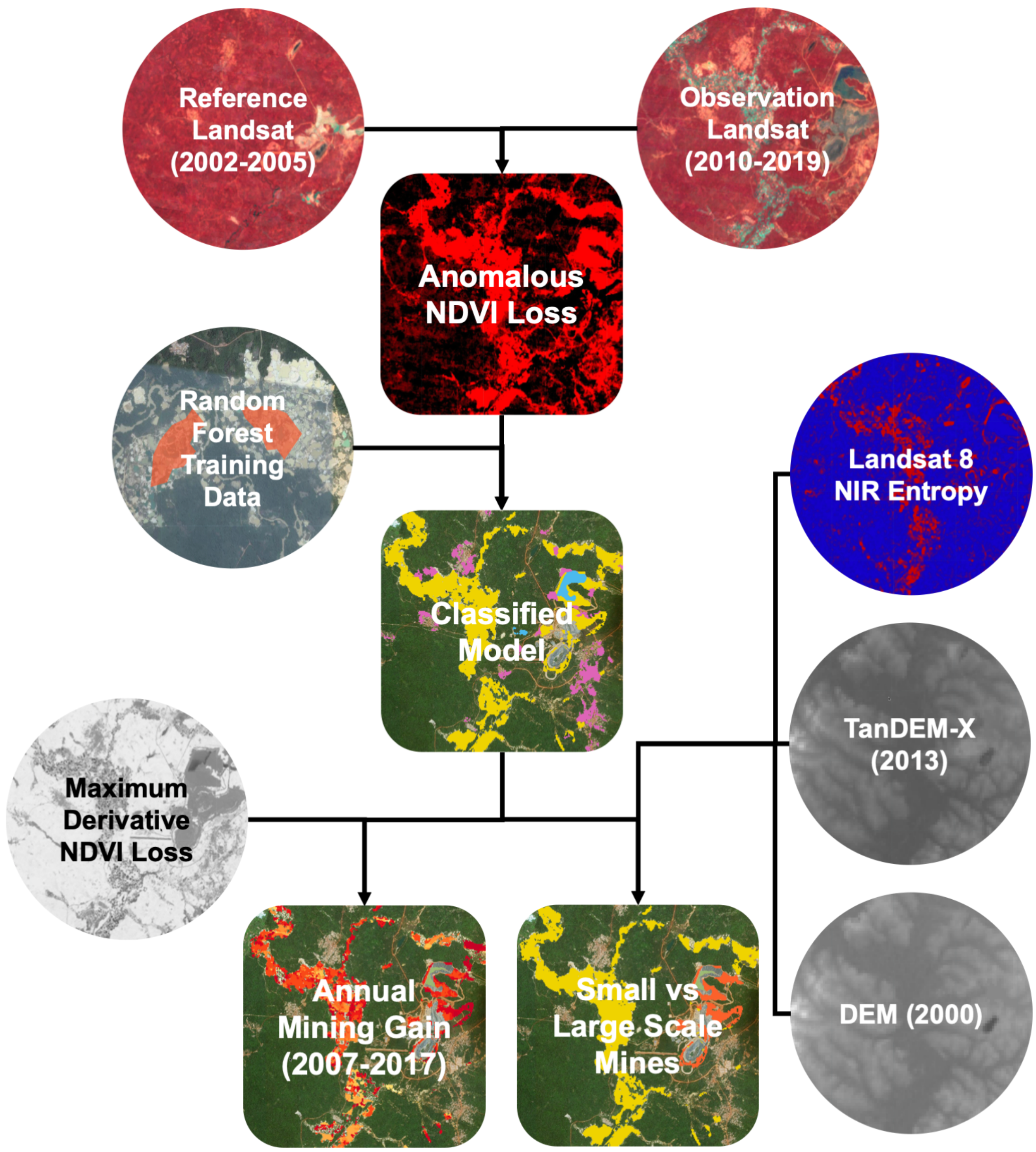


Example of false color composite Landsat imagery over a mining region



Map of Study Area

METHODS

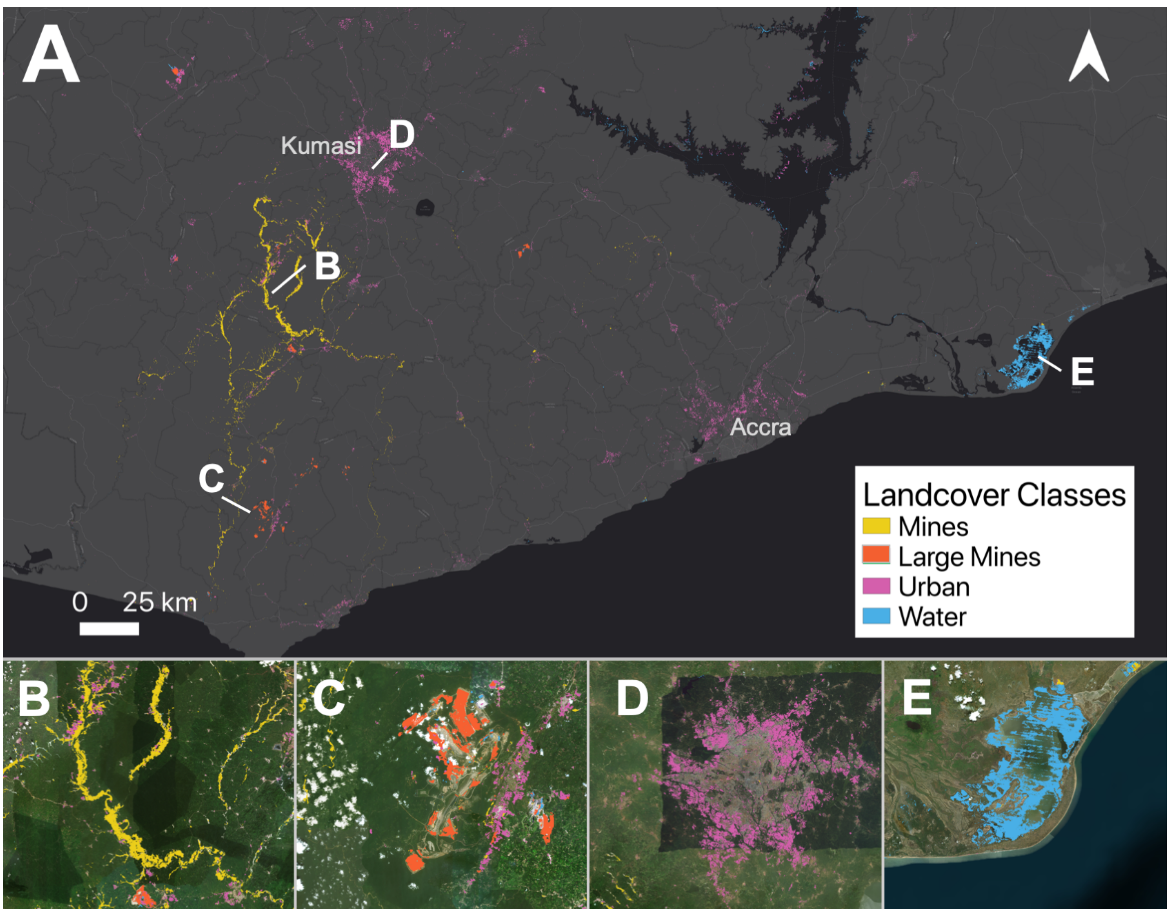


NDVI change anomalies were detected using historical Landsat 5 TM, 7 ETM+, and 8 OLI image collections. An imagery timestack for 2010-2019 was compared to a reference period of 2002-2005. A mean NDVI loss of 0.15 of more was considered as substantial and prolonged disturbance. A random forest classification was used to classify these loss areas as Mining, Urban, Water, or Other loss. Large scale mines were separated from artisanal mines with an additional random forest classification.

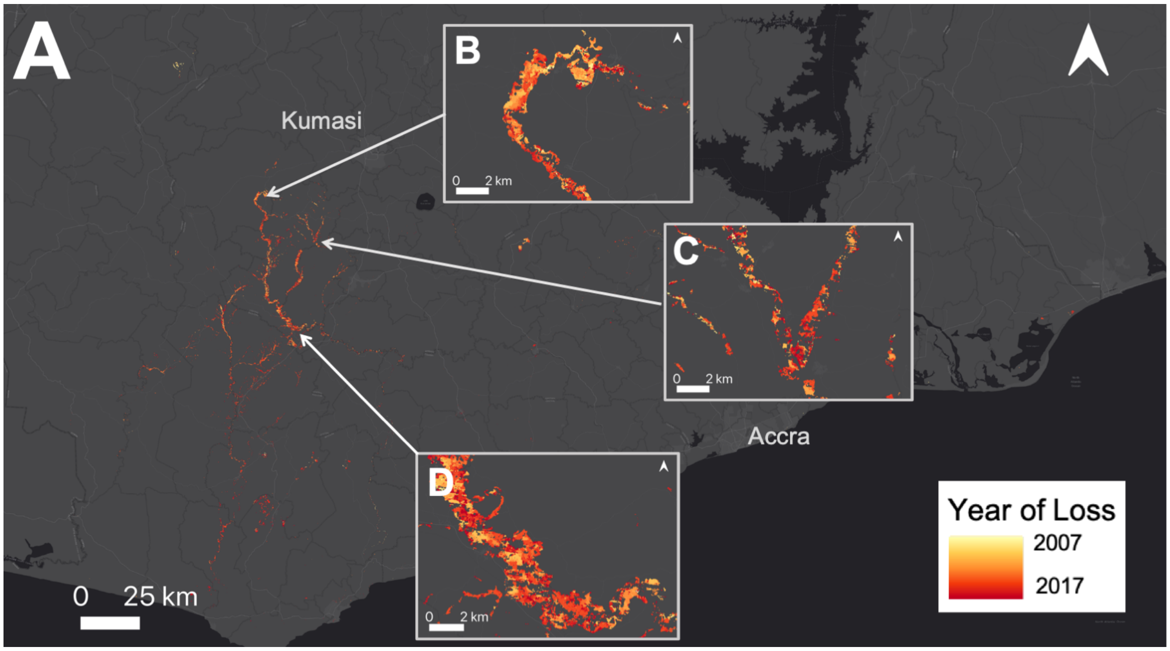
Within areas of loss maximum derivative NDVI was calculated. A 3-year moving average was calculated from 2007-2017. Results were assessed using Collect Earth and a confusion matrix, which yielded accuracy metrics.

LANDCOVER CLASSES AND ANNUAL TIMESERIES

[VIDEO] https://www.youtube.com/embed/eB2d6aX96EI?rel=0&fs=1&modestbranding=1&rel=0&showinfo=0

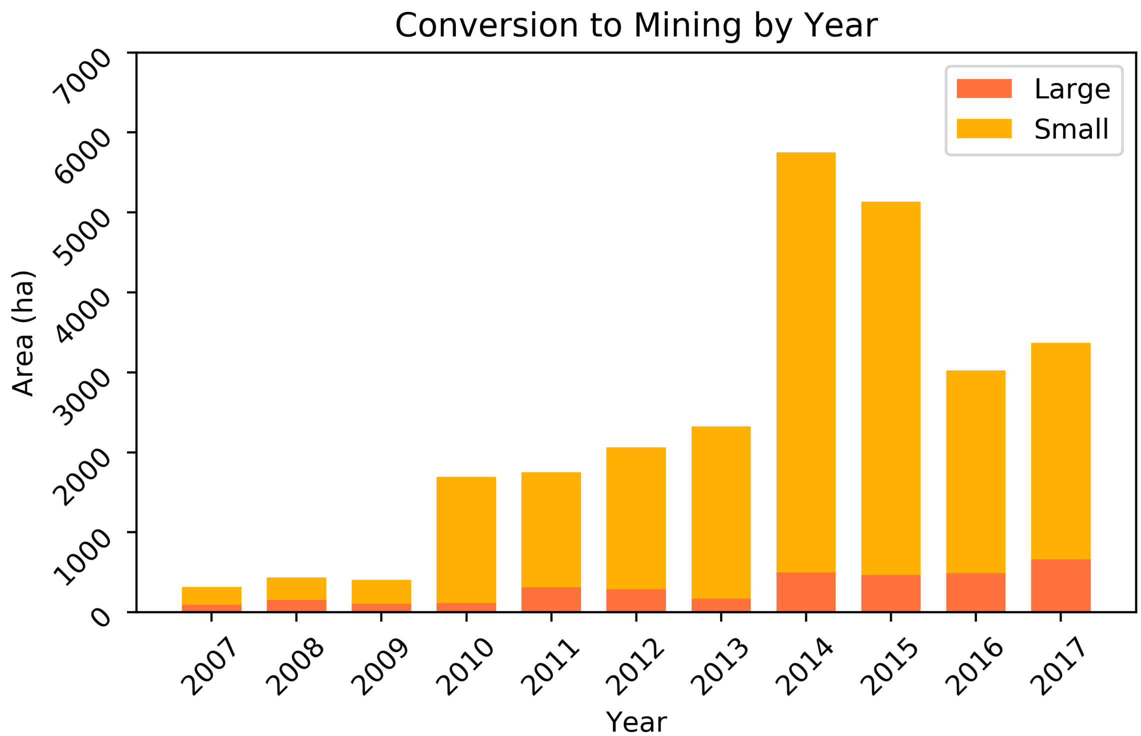


A) Land cover classification results from Random Forest model; B) Example artisanal gold mining region and land cover classification; C) Example industrial gold mining region and land cover classification; C) ESRI Satellite imagery of Kumasi and urban land cover classification; E) Classification of Anlo-Keta Lagoon Complex



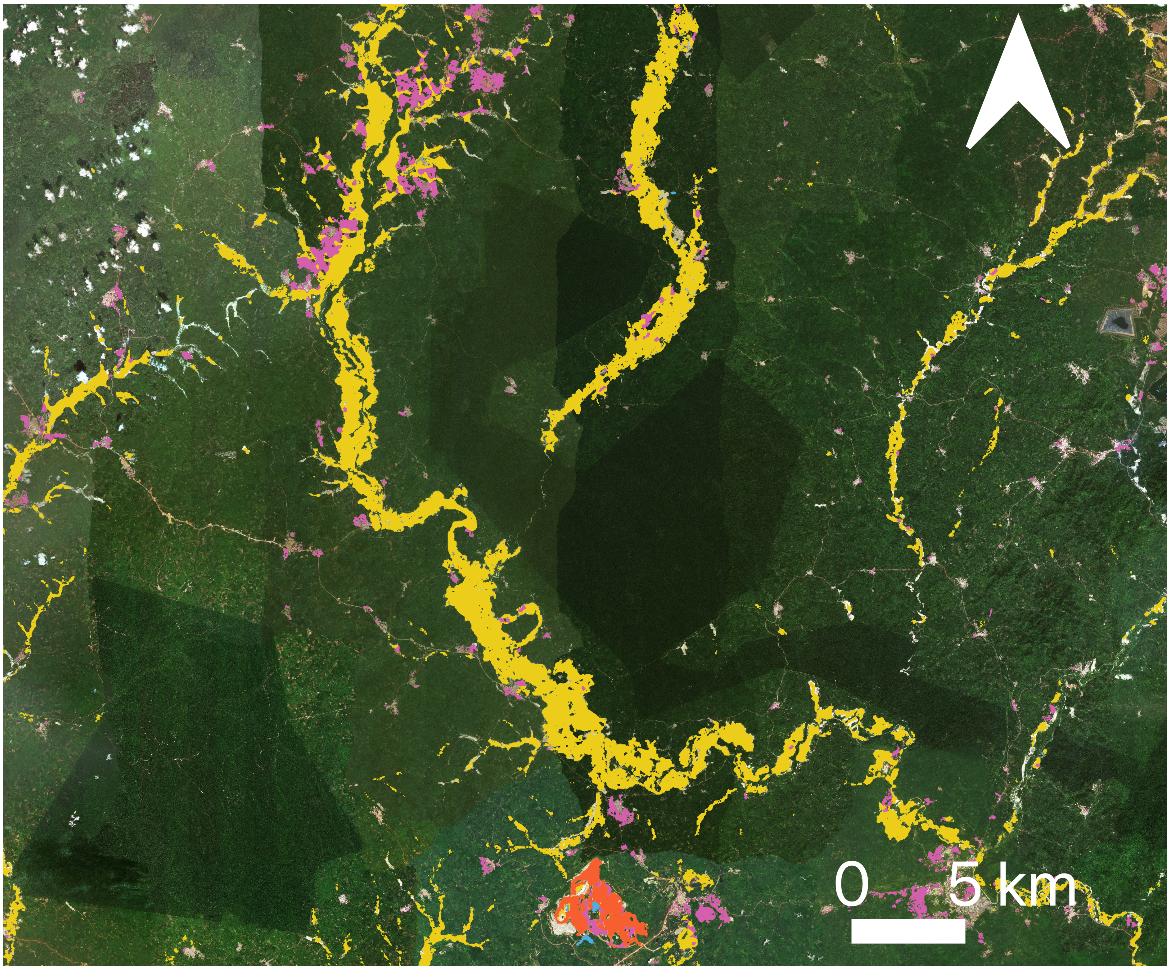
New mining activity by year from 2007-2017

MODEL RESULTS



Between 2002 and 2019, a total of 47,414.2 ha were converted to gold mining. The accuracy assessment demonstrates that the overall model was 84.2%. Much of the mining followed rivers, primarily the Ofin and Ankobra Rivers.

Over the course of the study period, the extent of mining more than quintupled from 8,635.5 ha to 47,414.2 ha. Across the study period, the majority of mining conversion occurred in 2014 (5,785.2 ha) followed by 2015 (5,264.9 ha) and 2017 (3,444.9 ha).

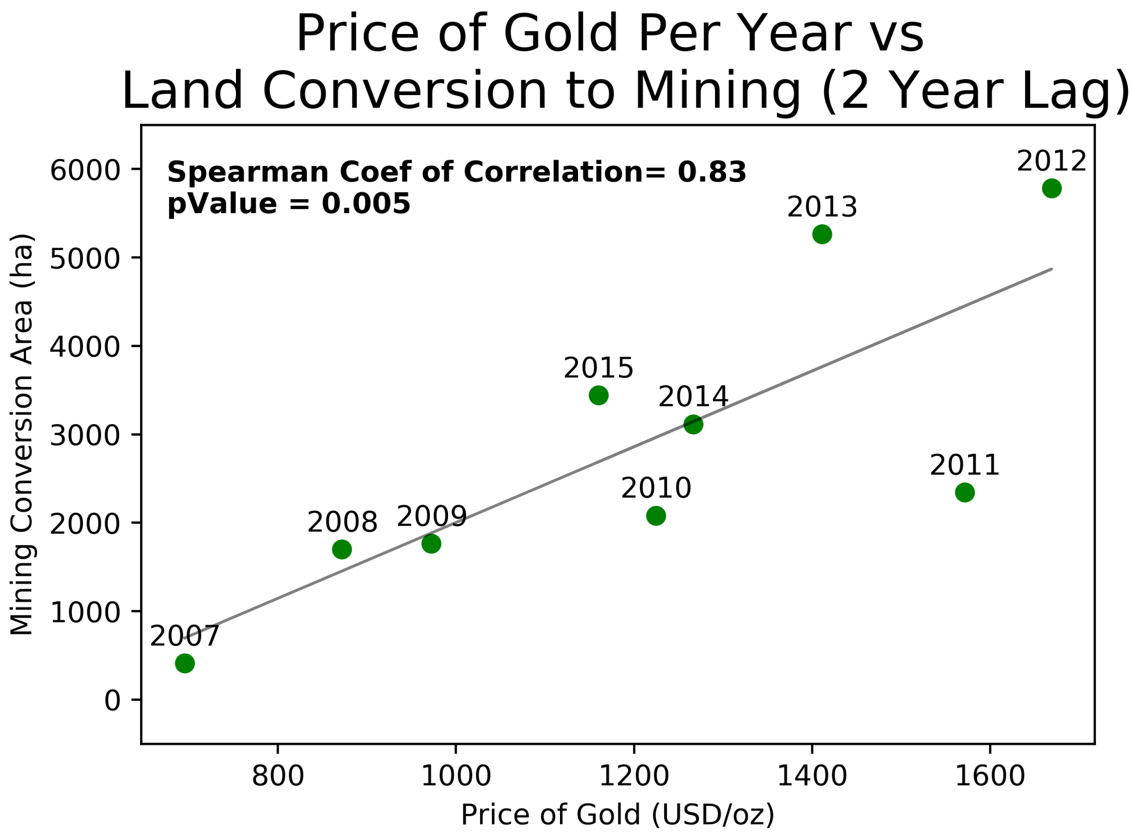


Example of landcover classification of an artisinal mining area

IMPLICATIONS

Our model demonstrates the notable footprint that the accumulation of smaller, artisanal mines leaves on the Ghanaian landscape, especially in comparison to larger, industrial mines.

The most active years of mining during our study period occurred recently, with 50.3% of mining activity occurring between 2014 and 2017. An unprecedented rise in the price of gold correlates with the conversion to mining after a two year lag ($r = 0.83$, $p = 0.005$).



Correlation between price of gold and land conversion to mining two years later. Points indicate the price of gold in the labeled year and area of mining conversion two years later. Comparison of land conversion to mining and global price of gold (USD/ oz), Retrieved September 15, 2020 from www.gold.org/data/gold-price.

Often, artisanal mines appear to be co-located with major rivers, particularly the Ofin and Ankobra Rivers. The amalgamation process to remove gold from sediments can result in heavy metal contamination. While earlier case studies in Ghana indicate that Hg in the water supplies has been within the range of suggested levels from WHO, increased mining activity will likely increase Hg concentrations in nearby water resources (Cobbina 2013; Donkor et al. 2006). Additionally, Mining activity sometimes diverts streams and rivers, limiting clean water access for downstream users and causing die-off of fish, which affects access to food as well as livelihoods outside of mining (Gilbert and Albert 2016).

AUTHOR INFORMATION

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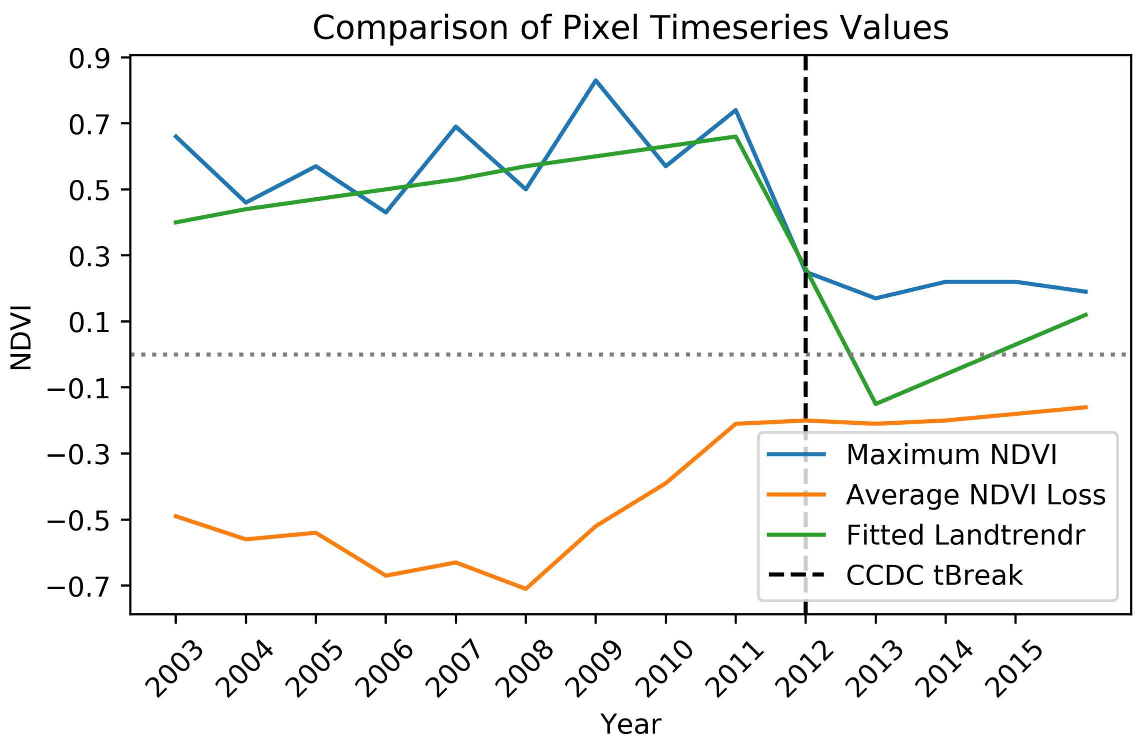

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