UNITAR's Operational Satellite Applications Programme

Satellite Mapping of Artisanal and Small Scale Gold Mining in Central Kalimantan, Indonesia

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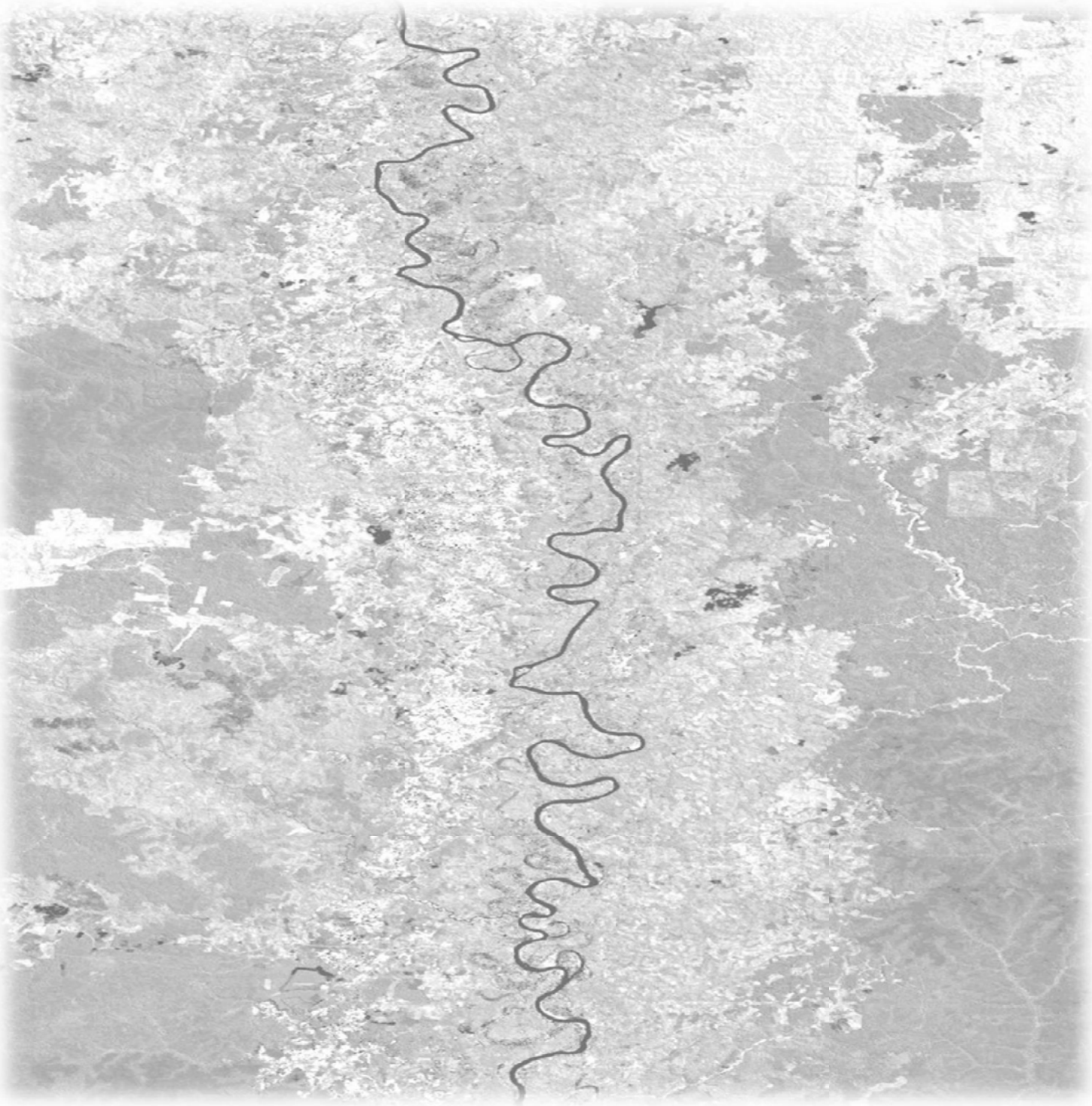

Abstract

This report examines the extent and nature of artisanal and small scale gold mining (ASGM) in Central Kalimantan, Indonesia. In the observed areas, landscape change analysis reveals general trends of decreasing dense vegetation/forest, substantial growth of agriculture, and varying degrees of increase for mine affected areas as well as exposed soils. The results of ASGM characterization indicate a variety of techniques employed including dredging, open pit mining, and rock mining. Nevertheless, evidence of active ASGM exploitation is more prevalent in some areas than others. This attests to the dynamic nature of ASGM in the Central Kalimantan region, which may be attributable to the continual discovery of new opportunities for mining, as well as the fact that ASGM is illegal in many of the areas where it occurs.

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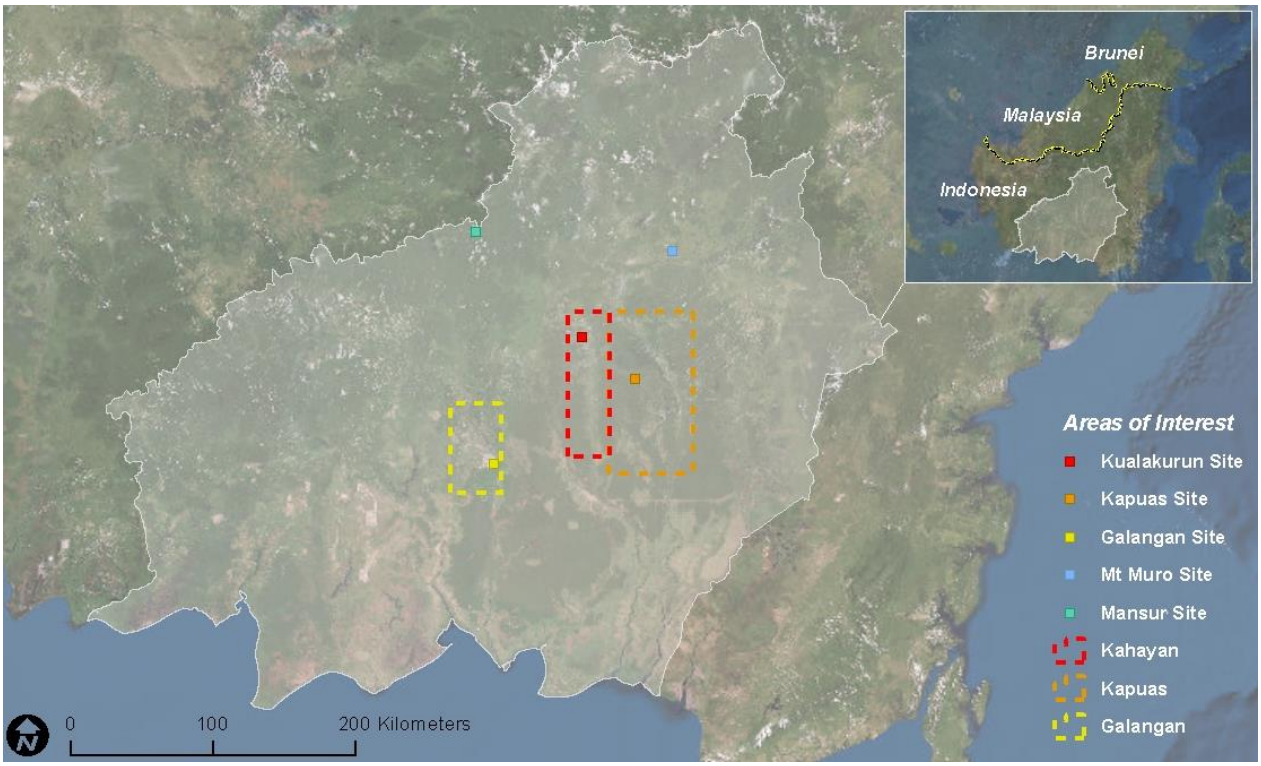
1. Introduction

Artisanal and small scale gold mining is a widespread activity that has contributed to deforestation in Indonesia. ASGM in Indonesia consists of techniques such as dredging and open pit mining in which forest and vegetation are cleared. The most significant environmental consequences of ASGM include mercury emissions into the atmosphere and surface waters, as well as deforestation, the loss of organic soil and aquatic habitat, and hydrologic regime changes associated with river siltation and land degradation[1]. This report by the United Nations Institute for Training and Research Operational Satellite Applications Program (UNITAR-UNOSAT) seeks to support to the United Nations Environment Program (UNEP) Chemicals and Waste Branch in assessing the extent and nature of artisanal and small scale gold mining in Central Kalimantan, Indonesia. In addition, the report describes potential methods for longer term monitoring of ASGM activities in Indonesia using satellite imagery.

2. Study Area

Central Kalimantan is one of five provinces in Kalimantan, the Indonesian portion of Borneo. Whereas mining had previously been limited to areas along rivers and streams, during the 1990s more widespread ASGM activities emerged in this region. The map below illustrates the location of Central Kalimantan on the island of Borneo, and displays the areas of interest examined in this report. Land cover classification and change analysis were performed for the larger areas, and ASGM equipment as well as techniques were examined for the smaller sites.

Map 1: Overview Map of Analyzed Areas of Interest in Central Kalimantan, Indonesia



[1] Telmer K., Stapper D. (2007) Evaluating and Monitoring Small Scale Gold Mining and Mercury Use: Building a Knowledge-base with Satellite Imagery and Field Work. UNIDO Project EG/GLO/01/G34 Final Report.

3. Methods

To understand the impacts and nature of ASGM in the study area, UNITAR-UNOSAT conducted satellite imagery analysis to determine the extent of ASGM activities, their contribution to deforestation and evolution over time. Satellite imagery was also used to identify present-day techniques of small scale gold mining in Central Kalimantan. The UNITAR-UNOSAT analysis is comprised of two main products:

- Landscape Change Analysis
- ASGM Characterization

3.1 Landscape Change Analysis

Landscape change analysis for two different time periods was conducted for three areas of interest in the Central Kalimantan region. This process first involved the definition of these locations, followed by the selection and acquisition of satellite imagery, processing of the imagery, land cover classification, and finally analysis of changes occurring between the two time periods.

3.1.1 Areas of Interest Definition

UNITAR-UNOSAT analyzed satellite imagery collected over the Central Kalimantan region. Three main areas of interest were selected based upon the availability of relatively cloud free satellite imagery, and indications of ASGM activities in the imagery. Preliminary information provided by UNEP on possible locations of interest for the study were also taken into consideration. The following areas of interest, shown in *Map 1*, were chosen given the particular interest in land cover changes associated with mining.

AOI-1: Upper Kahayan Catchment Area

The examined area of the upper Kahayan catchment is located within parts of the Gunung Mas and Kapuas regencies, as well as the Palangka Raya municipality. ASGM activities here consist of alluvial dredging in the riverbank as well as further inland. This area has been heavily deforested as a result of alluvial mining along the catchment.

AOI-2: Kapuas Catchment Area

The analyzed Kapuas catchment area is situated east of the upper Kahayan catchment, primarily within the Kapuas regency as well as parts of the Barito Utara regency and Palangka Raya municipality. ASGM in this region also includes riverbank and catchment area dredging which has resulted in deforestation.

AOI-3: Galangan Site and Katingan Catchment Area

Located to the southwest of the other AOIs, this area is situated in parts of the Katingan and Kotawaringin Timur regencies. It consists of a heavily mined region around the town of Kareng Pangi where large landscape impacts have occurred. ASGM activities have also expanded in the form of alluvial mining along the nearby Katingan watershed.

In order to estimate the recent extent of ASGM activities as well as the evolution, impacts and landscape changes associated with them, satellite imagery from two different time periods was analyzed for each area of interest. Multispectral scenes from the NASA Landsat satellite series were acquired from various dates

between 2002 and 2015 (see *Table 1*). These images are freely accessible and provided by the United States Geological Survey (USGS)[2].

Table 1: NASA Landsat Satellite Imagery Acquired for ASGM Analysis

Area of Interest	Sensor	Date	Resolution
AOI-1 Kahayan	Landsat-8	3 August 2015	30 m
	Landsat-5	7 August 2005	30 m
AOI-2 Kapuas	Landsat-8	3 August 2015	30 m
	Landsat-5	7 August 2005	30 m
AOI-3 Galangan and Katingan	Landsat-8	24 September 2014	30 m
	Landsat-7	26 May 2002	30 m

3.1.2. Image Processing

Radiometric Calibration

Due to the difference of imagery dates, sensors, and acquisition conditions, a radiometric calibration was performed to allow for a consistent comparison of the images. First the original digital values on the images were converted to values of top-of-atmosphere reflectance. The conversion was done using the software ENVI 5.3 based on information about gain, offset, solar irradiance, sun elevation, and acquisition time defined in the metadata of the imagery. Since differing atmospheric conditions existed for each of the images, the effects of atmospheric scattering were removed using the Dark Object Subtraction method as implemented in ENVI 5.3.

Cloud Cover Extraction

The Central Kalimantan region experiences high cloud cover throughout the year. Therefore, some portions of the analyzed areas were unfortunately obscured by clouds. Areas in the imagery obstructed by clouds were excluded from the land cover classifications. In order to do an automatic extraction of the cloud obscured areas a threshold based method was used to extract the clouds from the thermal bands and the cloud shadows from the infrared channel.

3.1.3. Land Cover Classification

To measure land cover changes, a land cover classification was performed for the different areas of interest using a supervised classification methodology. In the supervised classification method the experience and criteria of the analyst, supported by any available ground information, is used to define the classes by which the land surface is categorized. In order to define different classes the spectral characteristics of land cover present in the imagery were considered, as well as other aspects such as texture, size and position of the different classes.

Once the classes were defined, training fields for each of them were selected in the imagery. These training fields are areas in the imagery chosen for representing characteristics of the different classes well. The training classes are used to assign a land cover class to every pixel in the imagery, according to the algorithm used. For this analysis UNITAR-UNOSAT used the minimum distance classifier method as implemented in ENVI 5.3. *Table 2* provides details of the types of land cover classes used in the analysis.

[2] Sources to obtain Landsat imagery include http://earthexplorer.usgs.gov and http://glovis.usgs.gov

Table 2: Land Cover Classification Categories for Landsat Satellite Imagery Analysis

Category	Land Cover Class	Description
1	*Dense Vegetation/Forest*	Areas dominated by trees/very dense vegetation formation. Includes peatland forests.
2	*Shrub/Disturbed Forest*	Areas dominated by shrub/non-dense vegetation formation.
3	*Agricultural Areas*	Includes large scale palm oil plantations and cultivated areas.
4	*Water*	Areas of open water.
5	*Exposed Sands/Mining*	Exposed and highly reflective sands/mining tailings.
6	*Affected Waters/Mining Pits*	Ponds and filled pits within mining areas and waters with high turbidity.
7	*Exposed Soils*	Bare soil resulting both from vegetation clearing and burning.

The fifth class – Exposed Sands/Mining – refers to highly reflective deposits that are formed as a result of ASGM tailings. Often located within these areas of exposed sands is an accumulation of affected waters which form ponds or pits, identified within the sixth class – Affected Waters/Mining Pits. The fifth and sixth land cover classes thus represent a direct consequence of ASGM and can be considered as mine affected landscape. The seventh class – Exposed Soils – indicates a precursor for both mining and agricultural activities and is therefore identified separately from the fifth class.

3.2 ASGM Characterization

ASGM characterization was performed using high-resolution satellite imagery with a pixel size of 50 centimeters. Imagery was reviewed to directly identify visible ASGM activities by determining common equipment and landscape changes associated with ASGM. Techniques employed for ASGM activities in the Central Kalimantan region of Indonesia vary. According to a 2007 United Nations Industrial Development Organization (UNIDO) project report[3], the following methods have been observed in the country.

Dredge: Commonly used on rivers, dredges are powerful machines that excavate earthen materials underwater with a scoop, suction pipe, bucket, or other tool. Sluice boxes may be used in conjunction with dredges to separate gold from gravel or sand. Dredging can result in elevated water sediment loads and subsequently an increased dispersal and transport of naturally occurring mercury.

Open Pit: In the open pit method forest is first clear-cut and burned, followed by the use of pumps and hoses to transform sediment into a slurry which is then pumped over carpet covered sluices. Tailings may then form sizeable sand domes and water accumulates in ponds or moves into rivers.

Ball Mill: The ball mill method consists of digging tunnels or shafts along veins that contain gold. Ore of a relatively high grade is dug by hand, collected for transport to hammer and ball mills, and subsequently crushed so that gold can then be extracted using an amalgamation of mercury and cyanide.

[3] Telmer K., Stapper D. (2007) Evaluating and Monitoring Small Scale Gold Mining and Mercury Use: Building a Knowledge-base with Satellite Imagery and Field Work. UNIDO Project EG/GLO/01/G34 Final Report.

3.2.1 Sub-Areas of Interest Definition

As indicated in *Map 1*, five principal sub-areas of interest in the Central Kalimantan region were selected for ASGM characterization based on availability of imagery with regards to cloud cover, the presence of ASGM signs, and information provided by UNEP. For each location below, an area of roughly 26 square kilometers was examined for evidence of ASGM activity visible in high-resolution satellite imagery.

AOI-1: Kualakurun

Kualakurun is located in the upper Kahayan catchment area, specifically in the southeastern part of the Gunung Mas regency.

AOI-2: Kapuas

Located in the central northern part of the Kapuas regency, this area is part of the larger Kapuas catchment.

AOI-3: Galangan

This is a portion of the Galangan catchment area situated in the central part of the Katingan regency, roughly seven kilometers west of Kasoengan.

AOI-4: Mt Muro

Mt Muro is situated in the southern portion of the Murung Raya regency.

AOI-5: Mansur

Mansur is located in the northeastern corner of the Katingan regency.

For these areas, UNITAR-UNOSAT analyzed high-resolution satellite imagery collected by the GeoEye-1 and WorldView-2 satellites between 2013 and 2015. Details of the imagery selected for each of these areas of interest are specified in the table below. Images were collected by DigitalGlobe, Inc. and purchased through Kongsberg Satellite Services (KSAT).

Table 3: High Resolution Satellite Imagery for ASGM Characterization Analysis

Area of Interest	***Sensor***	***Date***	***Resolution***
AOI-1 Kualakurun	WorldView-2	23 June 2014	50 cm
AOI-2 Kapuas	GeoEye-1	7 June 2015	50 cm
AOI-3 Galangan	WorldView-2	22 September 2013	50 cm
AOI-4 Mt Muro	GeoEye-1	9 August 2015	50 cm