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A review of the monitoring small scale mining by modern satellites

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Abstract

Satellite constellation to be used in remote sensing is a current trend to monitor from the space. We have some intermediate scale sensors to provide the ground surface resolution ranging from 30 to 5 meters, some of which are now free in charge and downloadable through the internet. LANDSAT satellites, for example, have the long term history over 40 years with similar specifications to be used for temporal changes of the earth surface. Higher resolution sensors ranging from 5 to 0.25 meters are currently charged data from providers which are used to analyze in detail more. In turn satellite images of some data searching providers have the resolution ranging from 5 to 1 meters which are partly free in charge, though the searching contents are opened for many contractors for their commercial activities. Some government activities of USGS to monitor artisanal small scale mining areas of Africa are recently published. An example of temporal change of Vietnamese alumina production area is tested for an example using LANDSAT image in the resolution of 15 and 30 meters as the intermediate range.

Keyword : ASM (Artisanal Small scale Mining), Satellite constellation, LANDSAT, World View

Introduction

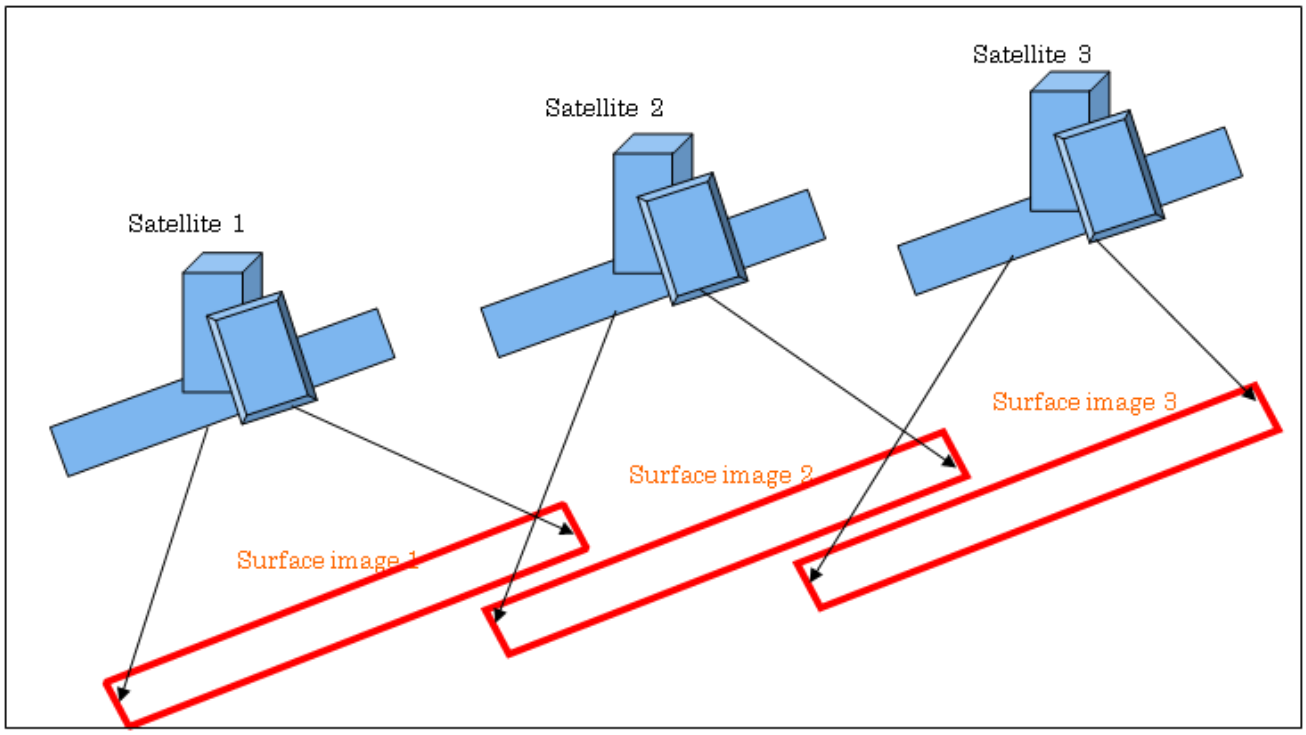
Satellite remote sensing is a method to monitor the physical target without touching of the surface. Satellite has many sensors which cover various wavelength of the electromagnetic field. The problem caused by remote distance from satellites is the limited resolution which was once a broad and ambiguous spatial resolution like as the first LANDSAT that had 79 meters at minimum recognition of the ground surface target. Recent advancement improves the spatial resolution to several centimeters by military satellite and up to 25 centimeters by commercial satellites. Spatial resolutions with several meters to 30meters are currently classified as “intermediate resolution” of ground surface. Earth observing satellites are classified into higher than a meter, intermediate, and lower resolutions over 100 to 1000 meters like as meteorological satellites. The data of higher resolution can be available with cost, while the representative data of intermediate resolution are currently free and downloadable in the case of LANDSAT TM and Hyperion hyper spectral sensors. Optical sensors like as TM can not penetrate to the underground, though microwave sensors like as SAR can detect some signatures up to several hundreds of meters.

You have an advantage to use free and open data to contribute to monitor the surface phenomena in detail for time series analysis in the minimum cost. LANDSAT series satellites have the long history since 1972 to present for more than 40 years. You can observe the seasonal and surface change at the special target area year by year. LANDSAT TM since 1982 has the spatial resolution of 30 meters and 15 meters since 1999, so that you can not see the details of surface ground like as higher resolution data like as 25 centimeters, though you can recognize the surface change classified by spectral bands which contributes the characteristic change of surface with smaller area.

Modern satellite constellation to focus the problem

Satellite data were once delivered by a single satellite for each like as recent ASTER sensor of TERRA satellite. It means the sensor oriented approach to analyze the ground surface, which prevents the advanced capability of analysis of monitoring the earth. If you have cloud coverage at the target area, you should wait for a long time to get the cloud free data or you have to combine some data with different time or even different seasons. The ground surface trace along the satellite orbit, or swath, does not cover all areas of earth surface in a short time of a year. You may possibly loose to get the important signature at the area only by a single satellite system. Then some satellites like as French SPOT employ the changeable looking camera to monitor the different angle of observation which gives the different resolutions and complex operations that creates other problems. The limitations of sensors such as resolutions of spatial, spectral, signal, and temporal give the limitations of analysis and less capability.

Modern technique has improved the limitation of single satellite problem to use satellite constellation (group) system which is composed of several satellites that have mostly similar characteristics. Canadian RADARSAT, for example, has a constellation system of SAR using three similar satellites to cover all areas of Canada and the arctic region in short time to enable to give early warning of hazard quickly as illustrated in Fig. 1. The international mission of SARSAT for disaster prevention uses some national satellites like as Indian’s and geostationary meteorological observing satellites combined with telecommunication satellites to enable to give search and rescue at hazardous phenomena in whole world within 24 hours (NOAA,



Parameter / Mission	RADARSAT-1,1995	RADARSAT-2,2007	3 RCM (RADARSAT Constellation Mission), 2018
Altitude	793-821 km	798 km	592.7 km
Inclination	98.6º	98.6º	97.74º
Orbital period	100.7 minutes	100.7 minutes	96.4 minutes
Descending node	6:00 hours	6:00 hours	6:00 hours ±15 minutes
Ascending node	18:00 hours	18:00 hours	18:00 hours
Sun-synchronous	14 orbits per day	14 orbits per day	15 orbits per day

Fig.1 A simple example of satellite constellation (Illustrated from the reference, ESA, 2015).

2015). Unlike free and open data category, the satellite constellation of Digital Globe's gives higher resolution up to 33cm at ground surface and several spectral bands from 1.2 to 3.7 meters of multispectral bands from 0.4 to 2.3 micrometers, which gives you better recognition capability for artificial and geological characteristics of surface ground observed from space (Marchisio, 2014).

Satellite constellation is expected to provide not only the necessary data but also the solution of problems needed. The trend of satellite constellation changes the world to use satellite remote sensing from the sensor oriented approach to the solution oriented approach. The data which does not solve problems can be treated as useless for which consumers do not want to pay more. The solution oriented method can be available in the case of the locations of the artisanal small scale mining because one of the major problem of the artisanal small scale mining is to affect the environment by digging of surface and underground to destroy the natural river water system with the ecology and by poisonous mercury in wider area compared to the intermediate and large scale of mining that can be detected sometimes by satellite even in the intermediate resolution. In the case of large and intermediate scale mining, the monitoring by satellites is currently a common method using the spectral change by iron and hydro oxide minerals (D'Alessandro, *et al*., 2003). This is the fundamental method to be applied in higher resolution sensors as well and even to observe small scale mining sites. Hyperion hyperspectral images provide 242 spectral bands ranging from 0.355 to 2.395 in micro meter which provide to identify materials more in detail.

Some satellite images of data searching providers have the resolution ranging mostly from 5 to 1 meters which are partly free in charge for browsing. The problem is the searching contents are traced and opened for many contractors for their commercial activities that means your interesting locations with the contents of searching are free to be distributed for many commercial activities.

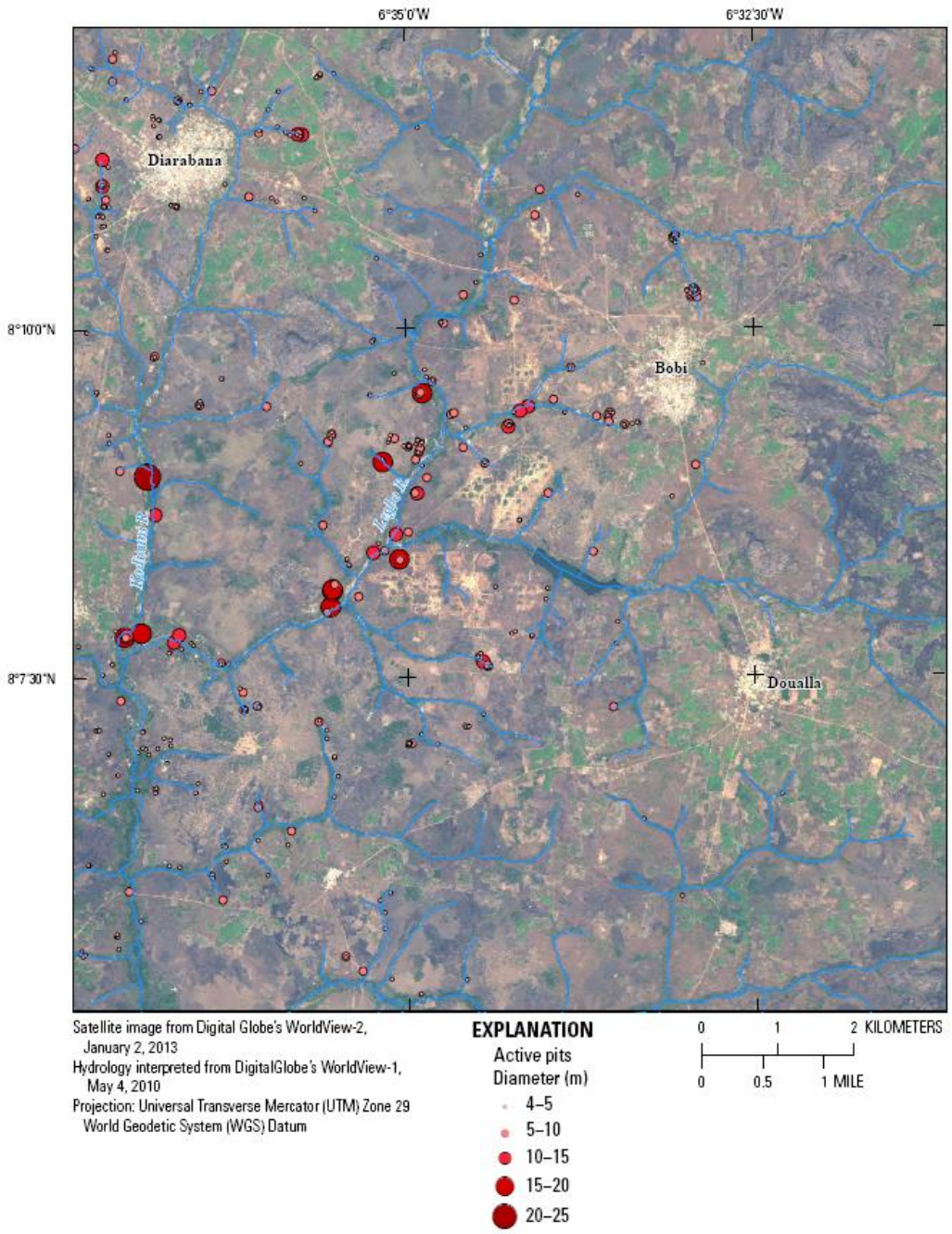


Fig.2 Number of 5- to 25-meter pits in the Bobi/Diarabana area of Côte d'Ivoire in 2013(Chirico and Malpeli, 2013; Fig.21).

Examples to use satellite constellation in mining area

The satellite constellation systems were frequently applied in the dangerous area of conflict minerals where rebels were active in civil wars to seek diamonds and gold that continue to date (Chirico and Malpeli, 2014; Malpeli and Chirico, 2015). Chirico and Malpeli of USGS show the hole pits created by digging of artisanal mining in the areas of Côte d'Ivoire (Fig. 2 and Fig. 3.). The shape of pits can be detected by the circle morphology with recognizable dark in brightness along small rivers with time-series analysis for the developments. In order to obtain conflict minerals from pits, people of the artisanal mining use a lot of water so they tend to appear along water rivers or even small streams which can be detected by satellite remote sensing mainly in the intermediate resolution like as LANDSAT or Hyperion. Digital elevation model (DEM) can assist to extract the water stream systems, too.

For example in Vietnam, a test study is now reported in this section of temporary change of development of the area of an alumina factory by monitoring of LANDSAT TM (Fig.4, Fig.5). Lam Dong States of Vietnam is located in the south that is well known area of recent development of bauxite. TM data can be available almost every year and the every season since 1982

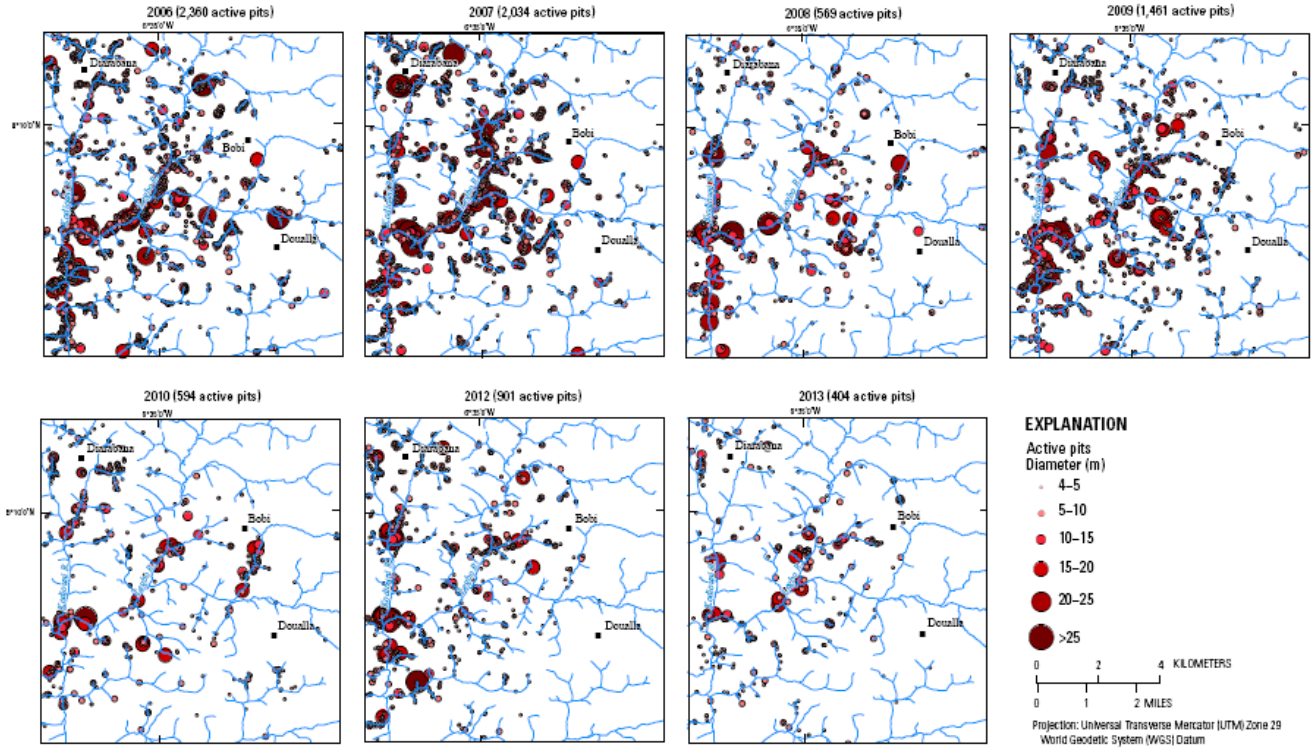


Fig.3 Number of 5- to 25-meter pits per year in the Bobi/Diarabana area of Côte d'Ivoire (Chirico and Malpeli, 2013 ; Fig.22).

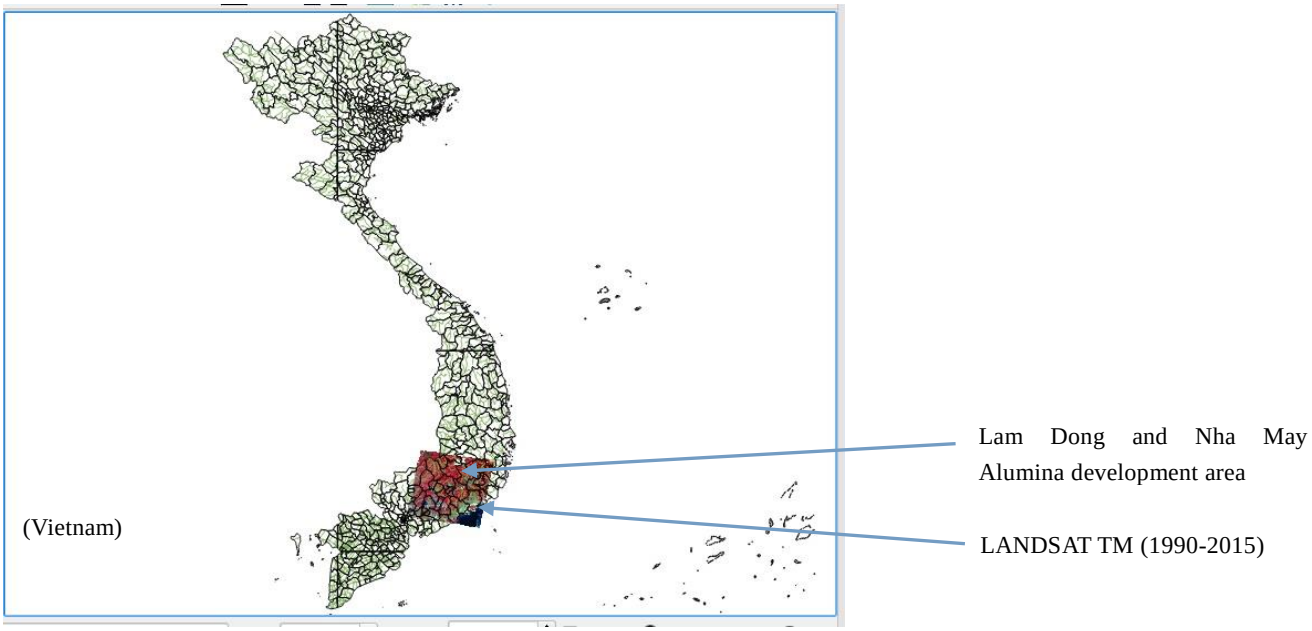


Fig.4 Location of LANDSAT TM image used in South Vietnam.

after LANDSAT 4. The problem is the presence of cloud by the monsoon climate in the area with thick cloud coverage which prevents to see the ground surface, though you can obtain better images within for several years observations. The orbital position of TM is the path 124 and the row 52, which includes the coordinate 11°39' 03" of North and 107°48' 21" of East. Dates of TM are on 13 February 1990 (L5), 13 January 1996 (L5), 03 February 2001 (L7), 25 February 2006 (L5), 14 November 2014 (L8), and 18 February 2015 (L8). L8 indicates LANDSAT 8, for example.

Although the target area is not in the artisanal small scale mining, but you may grasp the general idea how to use satellite

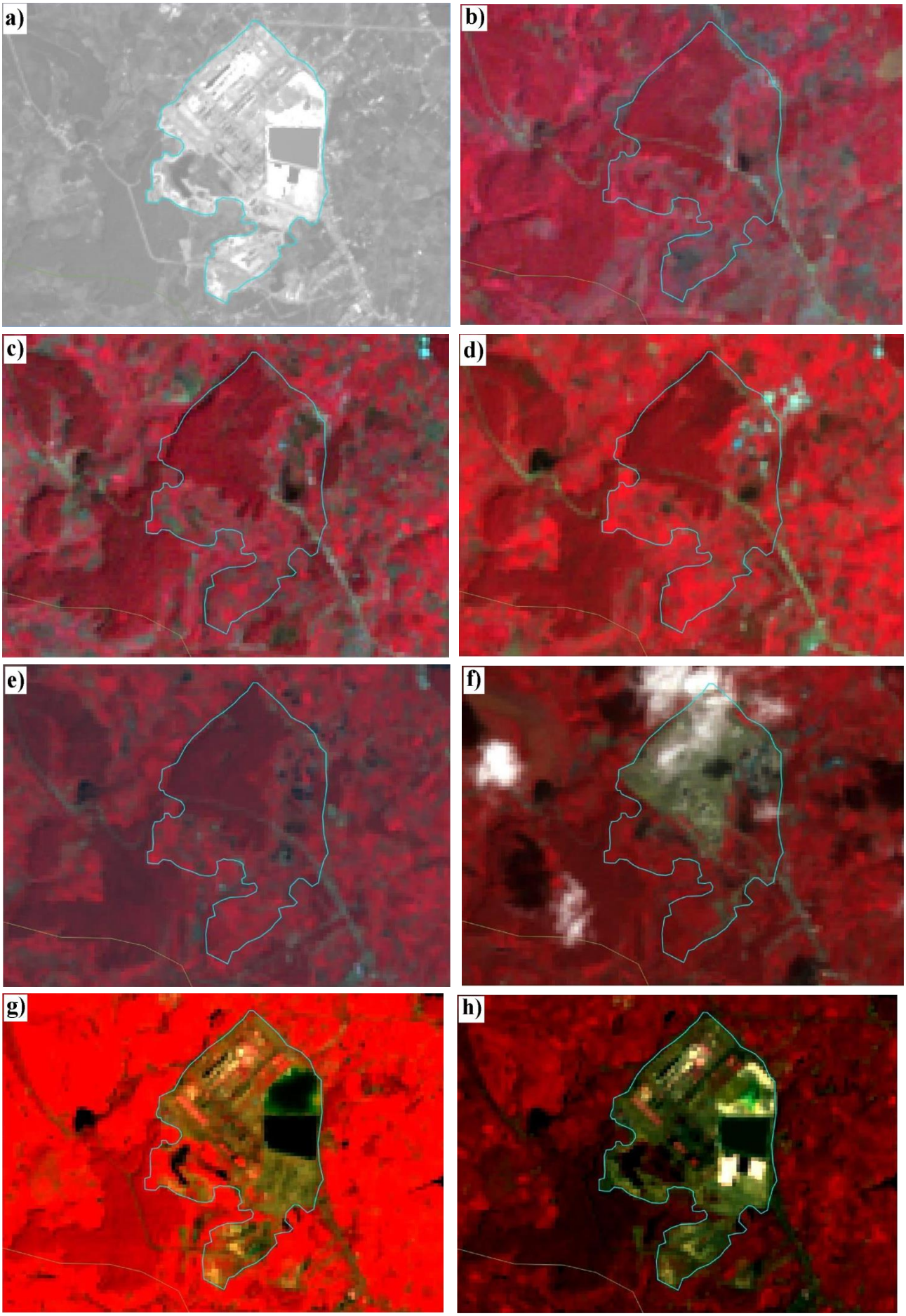

a)
b)
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Fig.5 Temporal change of Nha May Alumina factory development in Lam Dong state of South Vietnam.
a) TM Band 8 image of Nha May area in 2015-February-18. Light blue line is an outline of the factory area that used in the following images. The spatial resolution is 15 in meters. b) TM RGB=432 image of Nha May area in 1990-February-13. Before the development, the area is in a tropical rain forest. The spatial resolution is 30 in meters as follows. c) TM RGB=432 image of Nha May area in 1996-January-13. East margin was partly exploited. d) TM RGB=432 image of Nha May area in 2001-February-03. Some preliminary houses can be seen as in construction in east area. White spots are cloud. e) TM RGB=432 image of Nha May area in 2006-February-25. Not much difference is seen as in 2001 image but some constructions advanced a little bit more. f) TM RGB=432 image of Nha May area in 2010-February-04. Clouds partly cover this area, but you may see the north half development were well constructed. g) TM RGB=543 image of Nha May area in 2014-November-14. Most facilities are well constructed to operate. h) TM RGB=543 image of Nha May area in 2015-February-18. The construction almost completed.

images in time series. 15 meters ground surface resolution is intermediate class and not enough to detect smaller scale mining pits, but enough to detect some surface change around the artisanal small scale mining. Fig.5a shows the single band image of the recent feature of surface ground by TM band 8 which resolution is 15 in meters. Others from Fig.5b to Fig.5h are by multi band images of TM from visible to near infraredspectra bands known as false color composite images with 30 meters of resolution. According to Fig.5b to Fig.5h, this area was mostly in natural forest with less development before 1990, but some development were conducted after 1996, especially after 2001. You may see some surface change by time to be analyzed more using image processing technique to depict the environmental change of the surrounded area. The method can be applied to the area of the artisanal small scale mining.

The application to treat TM image is by QGIS of free and open source software system (QGIS, 2015). If you provide the digital elevation model (DEM) which are available in free, you can also extract the shapes and the change of the system of water streams that can be overlain with satellite and other GIS data.

Discussion and conclusion

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All data can currently be available from LANDSAT series and EO-1(Hyperion) in free in charge. Applications are free, too, so that you can minimize the cost to monitor the surface. Google map (image) may provides more detailed image of higher resolution than TM, but the data are mostly recent conditions and the usage might be traced and shared to commercial companies that some people do not want. In turn, LANDSAT provides more than 40 years changing history, even the first decade provides relatively low in resolution, 79 meters of pixels, though the data since 1982 provided 30 meters resolution of TM and since 1999 it has provided 15 meters resolution for a spectral band.

Even if you have enough budget to buy charged data of higher resolution like as those of Digital Globe's products, you might use the intermediate resolution to recognize the wider area like as the water stream system, because the area of distribution can be fit to the scale. They are open data downloadable and in free in charge, so that you can minimize the cost.

The government activity to monitor and clarify the area of artisanal small scale mining can use all the data available using the modern techniques of remote sensing. In addition, the recent trend of open government policy in worldwide enables that more and more free and open data can be available and shared with free and open source system environment.

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Glossary

ASTER [Advanced Spaceborne Thermal Emission and Reflection Radiometer]: ASTER is a cooperative effort between NASA and Japan's Ministry of Economy Trade and Industry (METI), with the collaboration of scientific and industry organizations in both countries. The ASTER instrument provides the next generation in remote sensing imaging capabilities when compared to the older Landsat Thematic Mapper and Japan's JERS-1 OPS scanner. ASTER captures high spatial resolution data in 14 bands, from the visible to the thermal infrared wavelengths, and provides stereo viewing capability for digital elevation model creation. The swath width (ground footprint) is 30 km long. (https://asterweb.jpl.nasa.gov)

Digital Globe: Digital Globe is a global provider of high-resolution Earth-imagery products and services. Sourced from Digital Globe's own advanced satellite constellation including Word View series, the imagery solutions support a wide variety of uses within defense and intelligence, civil agencies, mapping and analysis, environmental monitoring, oil and gas exploration, infrastructure management, Internet portals, and navigation technology. With the collection sources and comprehensive image library Digital Globe offer a range of on- and offline products and services designed to enable customers to easily access and integrate our imagery into their business operations and applications. (https://www.digitalglobe.com/about/overview)

Hyperion: One of main sensor systems of EO-1 satellite to provides 242 spectral bands which is called hyperspectral ranging from visible to short wavelength infrared. Spatial resolution is 30 in meters but swath width of ground surface is only 7 km.

LANDSAT: The Landsat Program is a series of Earth-observing satellite missions jointly managed by NASA and the U.S. Geological Survey. The swath width (ground footprint) is 185 km long. In 1972, the launch of ERTS-1 (Earth Resources Technology Satellite, later renamed Landsat 1) started the era of a series of satellites that have since continuously acquired space-based land remote sensing data. The latest satellite in the Landsat series is Landsat 8 since 2013. Next Landsat 9 will be launched in 2023. (http://landsat.usgs.gov/what_is_landsat.php)

RADARSAT: Launched in November 1995, RADARSAT-1 provided Canada and the world with an operational radar satellite system capable of timely delivery of large amounts of data. Equipped with a powerful synthetic aperture radar (SAR) instrument, it acquired images of the Earth day or night, in all weather and through cloud cover, smoke and haze. (http://www.asc-csa.gc.ca/eng/satellites/radarsat1/)

SAR: Synthetic Aperture Radar.

SARSAT: The SARSAT system uses NOAA satellites in low-earth and geostationary orbits to detect and locate aviators, mariners, and land-based users in distress. The satellites relay distress signals from emergency beacons to a network of ground stations and ultimately to the U.S. Mission Control Center (USMCC) in Suitland, Maryland. The USMCC processes the distress signal and alerts the appropriate search and rescue authorities to who is in distress and, more importantly, where they are located. Truly, SARSAT takes the "search" out of search and rescue. (http://www.sarsat.noaa.gov)

SPOT: SPOT (French: Satellite Pour l'Observation de la Terre, "Satellite for observation of Earth") is a commercial high-resolution optical imaging Earth observation satellite system operating from space. It is run by Spot Image, based in Toulouse, France. Earlier satellites were launched using the European Space Agency's Ariane 2, 3, and 4 rockets, while SPOT 6 and SPOT 7 were launched by the Indian PSLV. Image product resolution is composed of Panchromatic: 1.5 m, Colour merge: 1.5 m and Multispectral: 6 m. The swath width(ground footprint) is 60 km long. (https://en.wikipedia.org/wiki/SPOT_(satellite))

TERRA: A platform satellite launched by NASA to provide ASTER and MODIS sensors.

TM: Thematic Mapper, the main sensor system of LANDSAT that provides 15 and 30 meters resolution and 11 spectral bands covering from visible to thermal infrared.