UTILIZATION OF SAR AND EARTH GRAVITY DATA FOR SUB BITUMINOUS COAL DETECTION

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Received: 22 July 2014; Revised: 28 August 2014; Approved: 12 November 2014

Abstract. Remote sensing data can be used for geological and mining applications, such as coal detection. Coal consists of five classes of Anthracite, Bituminous, Sub-Bituminous, Lignite coal and Peat coal. In this study, the type of coal that is discussed is Sub bituminous, Lignite coal, and peat coal. This study aims to detect potential sub bituminous using Synthetic Aperture Radar (SAR) data, and earth gravity. One type of remote sensing data to detect potential sub bituminous, lignite coal and peat coal are SAR data and satellite data Geodesy. SAR data used in this study is ALOS PALSAR. SAR data is used to predict the boundary between Lignite coal with Peat coal. The method used is backscattering. In addition to the SAR data is also used to make height model. The method used is interferometry. Geodetic satellite data is used to extract the value of the earth gravity and geodynamics. The method used is physical geodesy. Potential sub-bituminous coal can be known after the correlation between the predicted limits lignite coal-peat coal by the earth gravity, geodynamics, and height model. Volume predictions of potential sub bituminous can be known by calculating the volume using height model and transverse profile test. The results of this study useful for preliminary survey of geological in mining exploration activities.

Keywords: *SAR and Earth Gravity Data, sub bituminous, lignite coal and peat coal, height model*

1 INTRODUCTION

Indonesia is one of the largest coal producers and exporters in the world. Since 2005, when production exceeded Australia, Indonesia became the leading exporter of thermal coal. A significant portion of export thermal coal consists of the type of medium quality (between 5100 and 6100 cal/gram) and the kind of quality is low (below 5100 cal/gram) which is largely demand from China and India (Srivastava, 1998). Indonesia coal reserves expected to be exhausted in about 83 years if the current production rate is passed. In connection with the global coal reserves, Indonesia is now ranked 10th with about 3.1 percent of total global coal reserves. About 60 percent of Indonesia's total coal reserves consist of low quality coal that is cheaper (sub-bituminous) which contains less than 6100 cal/gram. (Hamilton, 2005)

Some bags smaller coal reserves found in the islands of Sumatra, Java, Kalimantan, Sulawesi and Papua, however, the three regions with the largest coal reserves in Indonesia are: South Sumatra, South Kalimantan, East Kalimantan.

One of the geology and mining problems in Indonesia is in the exploration of energy mineral potential. Remote sensing data can be used to assist in the preliminary survey phase of this exploration. This will save time and costs in exploration. Besides the remote sensing data will be generating more precise spatial information (van der Meer *et al.*, 2012). This level of accuracy can be improved by conducting exploration in the field (Ramachandran *et al.*, 2011).

Coal is one of the fossil fuels. General sense is a sedimentary rock that can be burned, formed from organic sediment, primarily plant debris and formed through a process coal. The main elements consist of carbon, hydrogen and oxygen. Coal is also an organic rock that has physical properties and chemical complex that can be found in various forms. The elemental analysis gave the empirical formula as $C_{137}H_{97}O_9NS$ for $C_{240}H_{90}O_4NS$ for bituminous and anthracite. Coal formation requires certain conditions and only occurs in certain eras in the history of geology. Carboniferous period, about 340 million years ago (Mya), is the formation of the most productive coal deposits which almost all coal (black coal) are economical in the northern hemisphere is formed. In the Permian Period, about 270 Mya, also formed the coal deposits that are economical in the southern hemisphere, such as Australia, and continue up to the Tertiary Period (70-13 Mya) in various other parts of the world.

Almost all the coal-forming plants. The types of plants and coal-forming age by (Diessel, 1982) are as follows Algae, Silofita, Pteridofita, Gimnospermae, and Angiospermae.

Based on the rate of formation process is controlled by pressure, heat and time, coal is generally divided into five classes: anthracite coal, bituminous coal, sub-bituminous coal, lignite coal and peat coal.

a. Anthracite coal is the highest grade, with sparkling black color (luster) metallic, containing between 86% - 98% of the elements carbon (C) with a water content of less than 8%.
b. Bituminous contains 68-86% elemental carbon (C) and the water level of 8-10% by weight. Class most coal mined in Australia.
c. Sub-bituminous coal contains less carbon and more water, and therefore a source of heat is less efficient compared to bituminous.
d. Lignite or brown coal is very soft coal containing 35-75% water by weight.
e. Peat coal, porous and has a moisture content above 75% and the low calorific value (Konecny *et al.*, 2015). The process changes the remains of plants into peat to coal termed coalification (Posa *et al.*, 2011). In summary there are two stages of the process phase diagenetic (biochemistry) and phase metamorphic (geochemistry), covering the process of change from lignite to bituminous and anthracite eventually (Poggio *et al.*, 2013).

In Indonesia, economically valuable coal deposits are in the Tertiary basin, which is located in the western part of the Lesser Sunda (including Sumatera and Kalimantan), in general, the economic coal deposits can be classified as Eocene coal or around the Lower Tertiary, about 45 million years ago, or about the Tertiary and Upper Miocene, about 20 million years ago according to Geological Timescales. Coal is formed from peat deposits in ancient climates around the equator is similar to current conditions (Hoscilo *et al.*, 2011). Some of them classified to peat dome that formed above the water table at an average wet climate throughout the year. In other words, the peat dome formed under conditions where inorganic minerals carried by water can get into the system and form a layer of coal ash and low sulfur levels and locally thickened. It is very common in Miocene coal. In contrast, the Eocene coal deposits are generally thinner, high-yield ash and sulfur. Both age coal deposits are formed in lacustrine environments, the coastal plain or delta, similar to peat formation region is happening right now in the area of eastern Sumatra and Kalimantan mostly.

The precipitate was formed in extensional tectonic fabric that starts around the Lower Tertiary or Paleogene sediments in basins in Sumatra and Kalimantan. The Eocene extension occurred along the Sunda Shelf, west of Sulawesi, eastern Borneo, Java Sea to

Sumatera. Of sedimentary rocks ever found it can be seen that the deposition took place began in the Middle Eocene. Redistricting happens to Lower Tertiary Sundaland is interpreted to be the order of the arc, which is caused mainly by the motion of the Indo-Australian Plate subduction. Original depositional environment during the Paleogene non-marine, mainly fluviatil, alluvial fan and shallow lake sediments. In southeastern Kalimantan, coal deposition occurred around the Middle Eocene - Upper but in Sumatra younger age, the Upper Eocene to Lower Oligocene.

In central Sumatera, fluvial sediment that occurs in the early phase and then covered by lake sediments (non-marine). Different from what happened in the southeastern part of Borneo where fluvial sediments then covered by a layer of coal that occur on the coastal plain is covered later on it is transgressive by Upper Eocene marine sediments. Eocene coal deposits that have been commonly known to occur in the following basins: Paser and acids (South and East), Barito (South Kalimantan), Upper Kutai (East and Central Kalimantan), Melawi and Ketungau (West Kalimantan), Tarakan (Borneo east), Ombilin (West Sumatera) and Central Sumatera (Riau). Below are average quality of some Eocene coal deposits in Indonesia.

Figure 1-1: Coal mining in the Eocene coal deposits

In the Early Miocene, Lower Tertiary regional division - Central at Sunda Shelf has ended. At Kala Oligocene to Early Miocene marine transgression is the case of a large region in which sedimented marine clastic sediments and adjacent thick limestone sequences. Appointment and compression is a common appearance on Neogene tectonics in Borneo and Sumatera. Miocene coal deposits that are economical, especially in the bottom of the Kutai Basin (East Kalimantan), Barito Basin (South Kalimantan) and southern Sumatera Basin. Miocene coal also economically mined in Bengkulu Basin. Coal is generally deposited in fluvial environments, delta and coastal regions that are similar to the current peat formation in eastern Sumatera. The other main characteristic is the ash content and low sulfur.

But mostly Miocene coal resources are classified as sub-bituminous or lignite making it less economical unless it is very thick (PT Adaro and Kideco) or favorable geographical location. However Miocene coal in some locations is also quite high grade deposits such as Penang and Kaltim Prima Coal (KPC), coal deposits around downstream Mahakam River, East Kalimantan and several locations near Tanjung Enim, southern Sumatra Basin.

Figure 1-2: Coal mining in the Miocene coal deposits

Undulation is the value of the distance between the geoid to the reference ellipsoid measured along the ellipsoid normal (Mc. Donald, 2004). The relationship between the geoid, ellipsoid, and undulation can be seen in Figure 1-3.

Geoid undulation or geoid height is the distance from the reference ellipsoid to the geoid surface is measured along the normal ellipsoid. Methods of undulation determination, there are two kinds of methods of gravimetric and geometric methods. Geoid undulation determination with geometric methods (Vaníček, 1976).

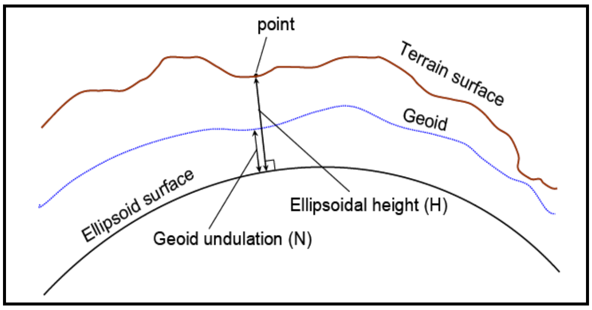

Figure 1-3: The relationship between the geoid, ellipsoid, and undulation (Ziebart *et al*, 2008)

Geometric geoid undulation is obtained from a count of geometric height (ellipsoid) and orthometric height (equation 1).

$$N = h - H \tag{1-1}$$

In this case,
H : orthometric height
H : normal height
N : undulation

Geometric geoid undulation can be computed when at one point the same geometric height and orthometric height. Geometric geoid undulation value can be calculated by two methods is the absolute and relative methods. Absolute method is counting undulation only at one point. Calculation of absolute undulation can abbreviated as in equation (2). While the method of calculating relative is a relative inter-point undulation (dN). Equation counting relative undulation can be derived from equation (3) the following:

$$N_B = N_A + (h_B - h_A) - (H_B - H_A) \tag{1-2}$$

can be reduced to

$$\Delta N_{AB} = \Delta h_{AB} - \Delta H_{AB} \tag{1-3}$$

Undulation calculation methods provide information about the range of relative undulation that happened between the point so that information gained wider undulation territory not only at one point undulation well as to check consistency between a given point in (Figure 1-4)(a) (b).

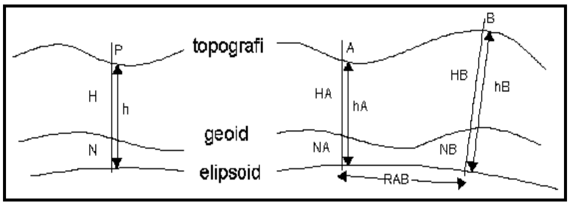

Figure 1-1: (a) Absolute undulation ; (b) Relative undulation

Geoid undulation determination with gravimetric method. Gravimetric method obtained by measurements of terrestrial gravity or microgravity with satellite gravity measurements (Li *et al.*, 2005). Gravimetric of geoid undulation determination requires gravity anomaly data are distributed evenly across the surface of the earth. It is very difficult to realize in practice. At a certain level of accuracy geoid model can be derived from global geopotential coefficients obtained from gravity measurements with satellite gravity. Potential at a point P with coordinates geocentric radius r, the geocentric latitude and longitude of each φ, λ can be presented as follows (Heiskanen and Moritz, 1967) and (Wellenhof, B.H., and Moritz, H., 2006).

$$V(r,\varphi,\lambda) = \frac{GM}{r}\left[1 + \sum_{n=2}^{\infty}\left(\frac{a}{r}\right)^n \sum_{m=0}^{n} \left(C_{nm}\cos m\lambda + S_{nm}\sin m\lambda\right) P_{nm}(\sin\varphi)\right] \tag{1-4}$$

in this case,

GM : Earth's gravitational constant
A : half the long axis of the ellipsoid
R : distance to the center of the earth
Φ : latitude geocentric spherical coordinates

Λ : longitude geocentric spherical coordinates
n, m : degree and order spherical harmonic
CNM,: coefficient of fully normalized
SNM spherical geo potential
Pnm : the first kind associated Legendre functions and fully normalized

Long-wave components can not be obtained from terrestrial gravity measurements in the field because it has a wavelength of 800 km (Khafid, 1999). Along with advances in satellite technology, the current long-wave components can be obtained from satellite gravity that have a level of order and degree harmonics ball reaches 2190. With a wavelength equation as in equation (5), the wavelength for satellite gravity that has the degree and order 2190 is 18 km (Li *et al.*, 2001).

$$\lambda = \frac{2\pi R}{n} \approx \frac{40.000.000}{n} \qquad (1\text{-}5)$$

in this case, R = radius of the earth's average of 6.371.000 m

This research aims to perform the detection potential of sub bituminous coal using SAR and earth gravity data.

2 MATERIAL AND METHOD

The research location is the border of South Kalimantan and East Kalimantan, precisely in Tabalong and Paser (Figure 2-1).

This study used ALOS PALSAR satellite image data and satellite geodesy. SAR data is used to detect the boundary between Lignite coal with peat coal. Geodesy satellite data in the form of GRACE, GOCE and CHAMP used for extraction of earth gravity and geodynamics. In addition to the SAR data is also used to make height model. The method used is interferometry (Knopfle *et al.,* 1998).

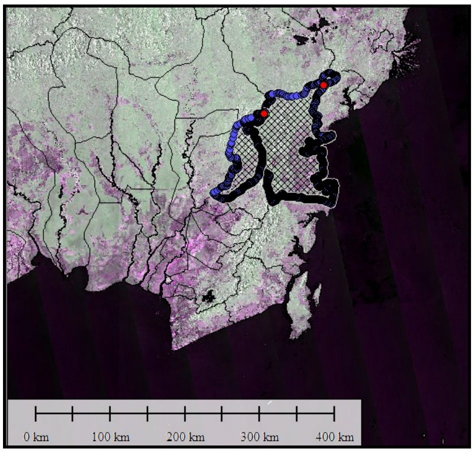

Figure 2-1: Research study area

The method used for the detection limit of lignite and peat is backscattering. Earth gravity and geodynamics extracted using physical geodesy methods (Vanicek and Krakiwsky, 1987; Seigel, 1995; Freeden *et al.*, 2010). Then do the correlation between the limits obtained from the backscattering by the earth gravity and geodynamics.

Gravity Recovery And Climate Experiment (GRACE) satellite gravimetry system is a result of cooperation between National Aeronautics and Space Administration NASA) with Deutsches Zentrum fur Luft und Raumfahrt (DLR). The main goal of the GRACE mission is to provide accurate enough information from the Earth gravity field model for the project for a period of 5 years. Temporally periodic estimation of Earth gravity field can be obtained following the variations occur. Other purposes (secondary mission) of the GRACE mission is to provide information about the amount of ionospheric and tropospheric refraction that can slow down and signal measurement arching Global Navigation Satellite System (GNSS). Device mounted in the GRACE satellites for the provision of this information in the form Lim Sounding. This tool can provide the amount of Total Electron Content (TEC) and or refractivity in the ionosphere and troposphere.

GRACE is the technique of detecting changes in the Earth gravity field changes by monitoring the distance between pairs of two GRACE satellites in orbit.

Gravity field and steady state Ocean Circulation Explorer (GOCE) satellite is the mission of the European Space Agency (ESA) in the field of geodesy and geodynamic combination of Satellite Gravity Gradiometry (SGG) and Satellite to Satellite Tracking (SST). Objective of the mission is to determine the GOCE gravity field and geoid anomaly static form of the earth's gravity with an accuracy of 1 cm for the geoid height, and 1 miligal to earth gravity anomaly, the spatial grid 100 km on the surface of the earth even less than 1 miligal. Data from GOCE provides a unique model of the Earth gravity field and also in terms of representation of equipotential field, represented by the geoid. GOCE mission of providing support to the various interests of multi disciplinary applications. GOCE mission conducted a mission that complements other satellite missions in the same field, namely CHAMP.

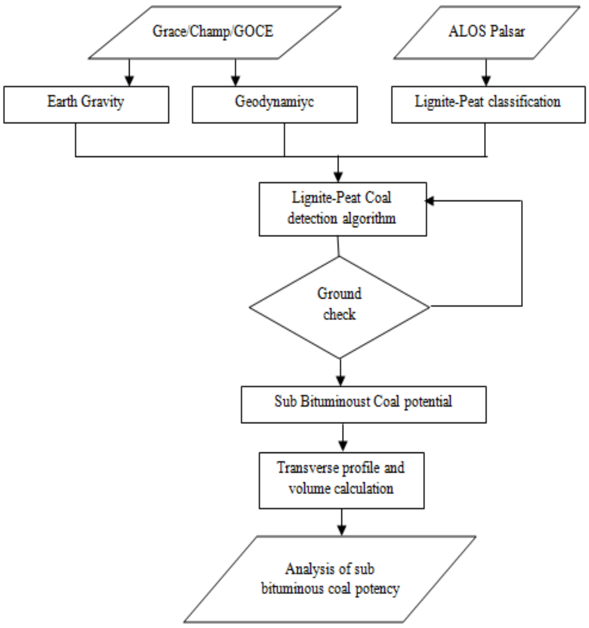

Figure 2-2: Research flow chart

Potential Sub Bituminous be known after the correlation between the predicted limits lignite coal and peat coal by the earth gravity, geodynamics, and height models. The results predicted potential of sub-bituminous is necessary to do a field survey. If they meet the specified tolerances then it could be used to predict the volume calculation by the cut and fill method and with transverse profile test (Dill, 2010).

3 RESULT AND DISCUSSION

A simple way mine detection of potential carbon (coal). There are simple way to detect potential sub bituminous coal mine. Required data in the form of earth gravity and geodynamic (xi and eta components), SAR image (ALOS PALSAR), HV composition preferably more dominant, Classification of Lignite coal and Peat coal. Xi component is the vertical deformation along north-south. Eta component is the vertical deformation along west-east. If the Eocene sediments, peat coal will be bordered by the Bituminous and Anthracite continued to type. If the Miocene sediments, peat coal and lignite coal will be adjacent to proceed to the sub-bituminous type.

We must have knowledge of the Eocene and Miocene sediments location. Anthracite and Bituminous lies in Eocene sediments, while the sub-bituminous and lignite located in Eocene sediments.

Parameter extraction of vertical deformation components xi, then made interval gravity values as needed. It should be adjusted to the results of a calculation geomathemathic algorithm. There is a prediction of sub bituminous coal limits if only using xi components.

Parameter extraction of vertical deformation components eta, then made interval gravity values as needed. It should be adjusted to the results of a calculation geomathemathic algorithm). There is a prediction of sub bituminous coal limits if only using component eta.

Then combined these two geodynamic parameters, so that more accurate detection of sub bituminous coal mines.

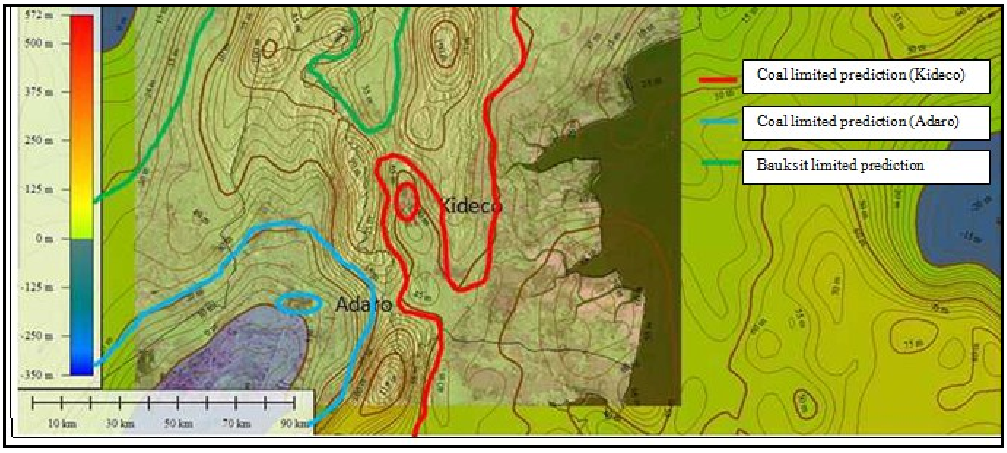

Figure 3-1: Boundary limits prediction of sub bituminous coal by Xi component

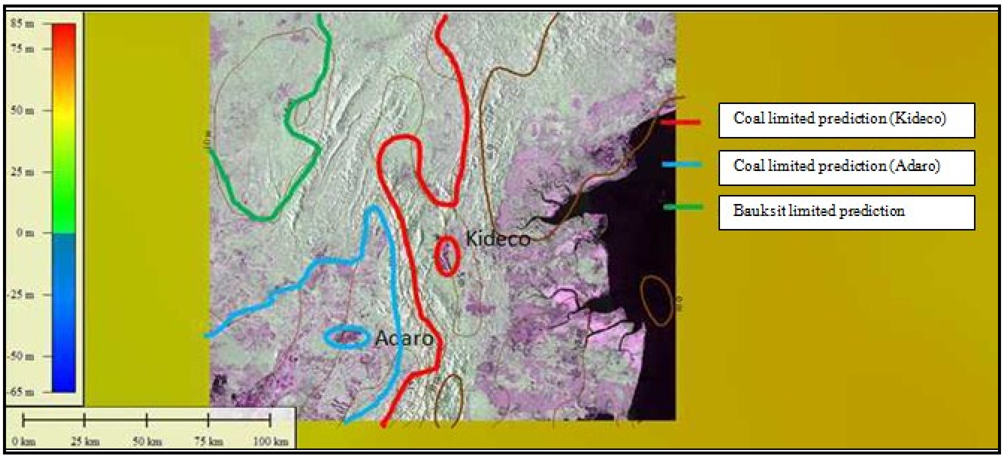

Figure 3-2: Boundary limits prediction of sub bituminous coal by Eta component

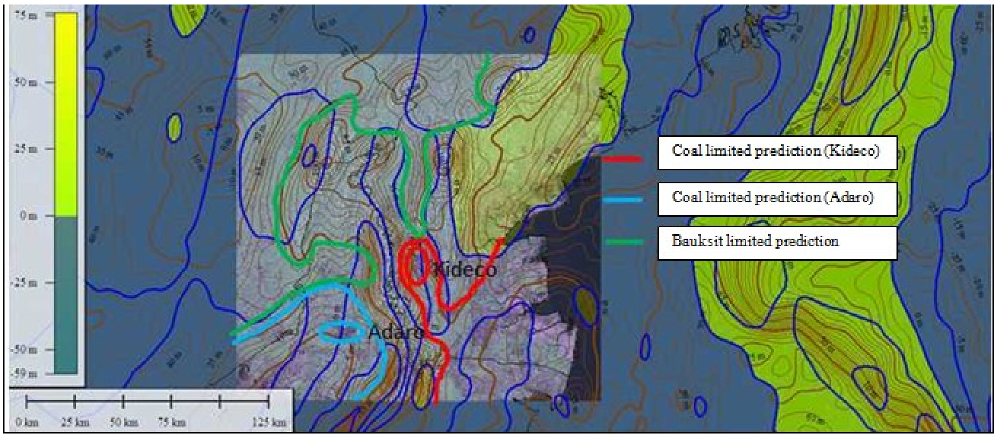

Figure 3-3: Boundary limits prediction of sub bituminous coal by Xi and Eta component

After that, checks boundary limit of Lignite coal and Peat coal from the SAR data classification using backscattering. SAR data for this research using HV polarization.

HV polarization is better for geology application. Then the result of this boundary will overlay with geodynamic and earth gravity then we will know where the sub bituminous coal limited prediction.

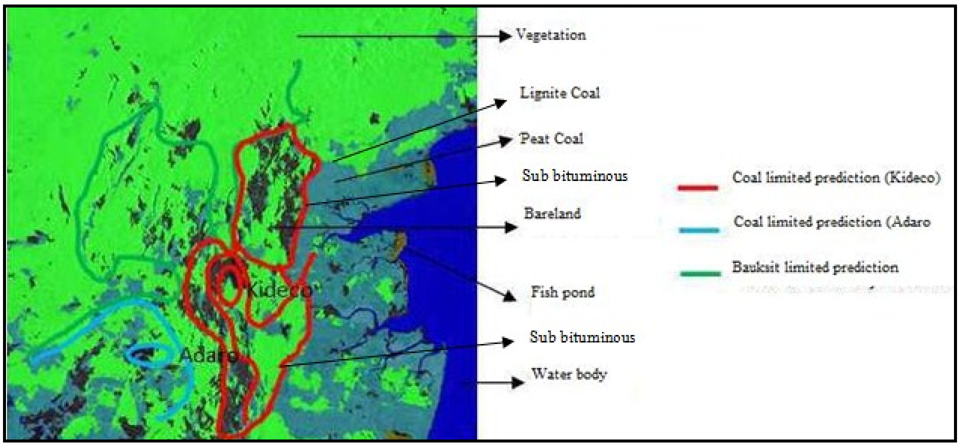

Figure 2: Boundary limits prediction of sub bituminous coal by gravity, geodynamic, lignite coal, and peat coal

This research location is in coal mining site of Kideco and Adaro. We will know the volume prediction using height model that created from interferometry using ALOS PALSAR. Prediction analysis using cut and fill methods for transverse profile and volume calculation.

Transverse profile is intended to see the appearance of 3D by making transverse incision in the study area. One of the benefits is the transverse profile can determine the volume of the study area. The method used for calculating the volume of cut and fill is to set a specific reference plane height.

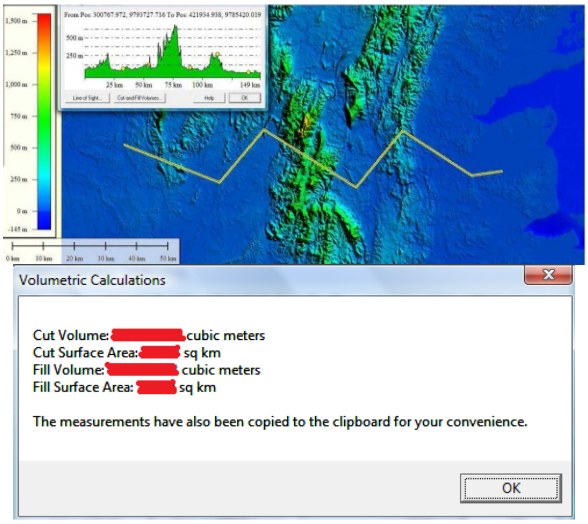

Figure 3: Transverse profile and volume calculation in Tabalong-Paser

The Figure 3-6 display the predicted transverse profile and volume calculation (Adaro mine site) with cut and fill method.

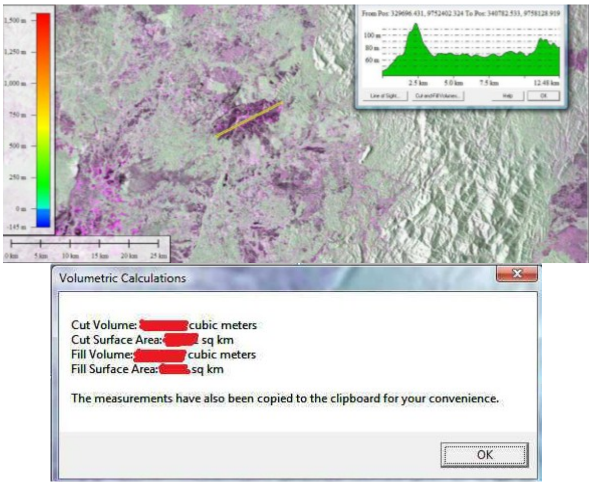

Figure 4: Transverse profile and volume calculation in Adaro mine site

The Figure 3-7 display the predicted transverse profile and volume calculation (Kideco mine site) with cut and fill method.

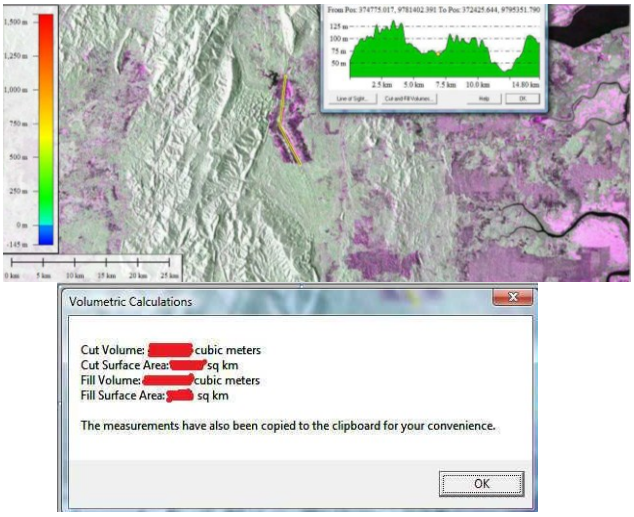

Figure 5-7: Transverse profile and volume calculation in Kideco mine site

SAR and earth gravity data are also useful for the detection volume of mining land, tectonic deformation, detection of mineral materials, and others. Based on the results of making the transverse profile of the volume are used to determine the mine area. The calculations are divided into four types of matter, ie the volume of the region that is cut by cut volume, wide area 3D by cut surface area, the stockpiled area by fill volume, 3D wide area stockpiled by fill surface area. Cut and fill the reference refers to a specific field, such as the reference plane 80 m above sea level (asl). The volume value indicates the total volume of coal that exist in the region. Economic value will only be known after the multiplication of the volume of coal mines with total sales per unit amount of weight (tons).

4 CONCLUSION

SAR and Earth Gravity from Geodesy satellite can be used for sub bituminous coal detection. There are several parameters that can be derived from remote sensing data for sub bituminous coal detection, of which the earth gravity, geodynamic (xi and eta components), lignite coal and peat coal. In addition to detect the sub bituminous coal can be done, remote sensing data can also be used to predict the transverse profile test and count the volume of sub bituminous coal. Remote sensing data can be used to assist in the preliminary survey phase of this exploration. This will save time and costs in exploration.

ACKNOWLEDGEMENT

Thank you very much for Geodesy satellite data from ESA, DLR, NASA, ALOS data from Alaska University and JAXA.

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