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DEMNAS: A Recently Released Nation-Wide Digital Elevation Model from the Indonesian Government and its Implication for Geothermal Exploration – Study Case of Gunung Endut Geothermal Prospect, Banten Province, Indonesia

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ABSTRACT

Digital elevation model (DEM) is very useful for geothermal exploration in Indonesia. It is very useful when the ground geodetic survey is not available or hard to implement in dense forests. However, Airborne LiDar survey might be too expensive for the initial exploration stage. The most common DEM used for geothermal exploration in Indonesia is DEM Shuttle Radar Topographic Mission (SRTM) that has spatial resolution 3 arc second (±90m). Recently, Indonesian Geospatial Information Agency has released DEM Nasional (DEMNAS), an open-access DEM with a spatial resolution of ±8.25 meter. Similar to SRTM, the DEMNAS could be implemented in various applications, including geothermal exploration.

In this study, we implemented DEMNAS in our scientific exploration work in Gunung Pancar Geothermal Prospect, Banten Province, Indonesia. Previously, we use SRTM to guide our geological interpretation, particularly when interpreting lithological boundaries and geological structures. We re-interpreted the geological structures and lithologies using DEMNAS as digital elevation model and compare the result with the previous interpretation.

For the lithological interpretation, DEMNAS showed better result compared to DEM SRTM due to the textural variations that can be better observed in higher spatial resolution. Smaller geological structures can be interpreted with more confidence compared to when using SRTM. However, we also find that SRTM is still useful when interpreting major geological structures. From this comparison, we believe that DEMNAS could be a useful tool for geothermal exploration in Indonesia. DEMNAS could replace SRTM for general purpose, although SRTM still needed to complement DEMNAS for specific tasks.

1. INTRODUCTION

Gunung Endut Geothermal Prospect Area (GPA) is a geothermal prospect in Banten Province, Java Island, Indonesia (Figure 1). The name of this GPA derived from the occurrence of Endut Mountain that positioned in the southeast part of GPA. This prospect is known to have the geothermal potential of 100Mwe speculative resource and 80Mwe indicated reserve (Ditjen EBTKE, 2017). Only a small amount of data has been acquired in the study area (Ditjen EBTKE, 2017) and the estimated resource has big potential to be increased along with increasing exploration activities in the area.

Previous geological studies have been carried out in the area, with the most widely available geological data derived from the regional geological map (Sujatmiko and Santosa, 1992). Later in 2006, Center for Geological Resource - PSDG (now PSDMBP) carried out a geological survey for the geothermal exploration. Recently in 2018, we carried out a geological survey in half western part of the Gunung Endut GPA, particularly near its geothermal manifestations. Except for the 1992 geological survey, other geological surveys also accompanied with the geophysical and geochemical surveys.

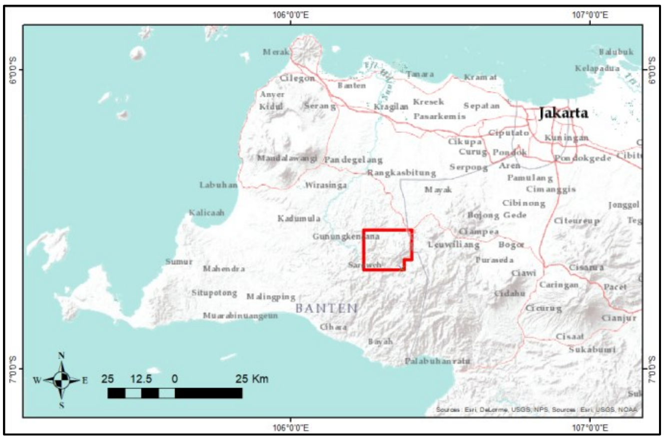

Figure 1: Gunung Endut Geothermal Working Area (red polyline) situated in Java Island, Indonesia.

Recently, Indonesian Geospatial Information Agency (Badan Informasi Geospasial - BIG) has released DEM Nasional (DEMNAS). DEMNAS is an open-access digital elevation model that can be downloaded with a spatial resolution of ±8.25 meter (big.go.id). Similar to SRTM, the DEMNAS could be implemented in various applications, including geothermal exploration. In this study, DEMNAS was implemented to interpret lithologies and geological structures the Gunung Endut GPA. We also compare the interpretation result from DEMNAS and from SRTM.

Before the DEMNAS released to the public, other DEM maps have been released by JAXA, namely ALOS PALSAR with a spatial resolution of 10m (www.eorc.jaxa.jp) and the latest SRTM with 1 arc second spatial resolution (±30m) (https://search.earthdata.nasa.gov/). However, since all geological map mentioned before were produced possibly using the aid of SRTM map with 3 arc second (±90m) spatial resolution, it is worth comparing DEMNAS with SRTM rather than comparing with other DEM maps.

2. GEOLOGICAL BACKGROUND

Gunung Endut GPA situated in quaternary volcanic rocks that sit on top of the Tertiary sedimentary rocks (Sujatmiko and Santosa, 1992). According to the physiographic zone by Van Bemmelen (1949) the study area located in Central Depression Zone and Quaternary Volcanic Zone, an important zone for geothermal potential in Java Island. There are four hot springs observed in the study area, namely Cikawah-1 (CKW-1), Cikawah-2 (CKW-2), Handeuleum (HDL), and Gajrug (GJR) (Supriyanto et al., 2018) where the manifestation located around 6-8 km from the summit of Endut Mountain. The quaternary volcanic rocks comprised of pyroclastic and igneous rocks that derived mainly from the Endut Mountain and the adjacent volcanoes. In some area, the volcanic rocks have been altered to clay, indicating geothermal activities. The location of altered volcanic rocks is also adjacent to the hot springs, that possibly indicating some correlation. Several faults have been interpreted by previous workers. However, in our study, the faults are not well studied, and no significant fault data was collected.

In most of the case, the location of the fault and lithological distribution are different from one map to other. This is possibly due to data scarcity, subjectivity, and different research objectives of each previous workers. For instance, the 1992 map did not separate volcanic rocks in the study area and only considered as one undifferentiated volcanic unit. Meanwhile, the geological maps of 2005 separate them into ten different units, where there are four units associated with volcanism in Endut Mountain. In addition, there is no fault identified in the quaternary volcanic rocks in the 1992 map, while there are several faults identified in the 2005 map with different degree of certainty. The 2005 maps still leave ambiguity for its faults because the faults identified did not really show relative movement pattern. Hence it is unclear whether the identified faults are faults observed in the geological survey or only as lineament identified in the remote sensing data. With this various issue, it is worth to revisit both the geological maps and aid the interpretation using DEM data.

The incorporation of DEM data can be useful to assist in the interpretation of lithology and structural geology before the geological survey begin. In addition, even after the geological survey have been completed and the map has been drafted, reevaluating the DEM map for assisting the interpretation could bring addition value to the interpretation activities. It is expected that more interpretation can be concluded if the data supported by DEMNAS which has better quality than SRTM.

3. ACQUIRING DATASET

DEM SRTM data used in this study (Figure 2) derived from SRTM CGIAR that can be downloaded from http://srtm.csi.cgiar.org/. We use this modified version of SRTM because this is the most widely used SRTM in Indonesia due to its easy access. The data can be access easily and have been processed to improve quality. This DEM data has a spatial resolution of 3arc second (±90m).

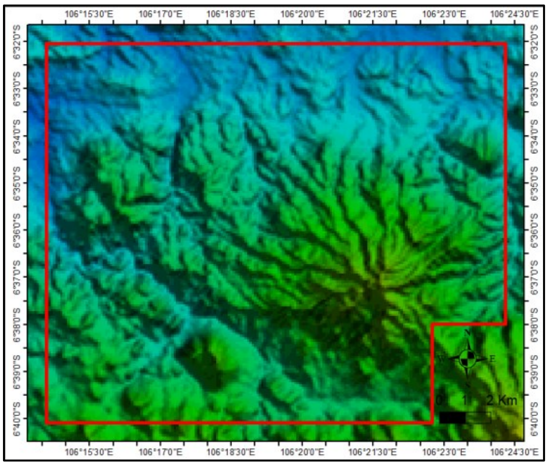

Figure 2: DEM SRTM. The red polyline is the boundary of Gunung Endut GPA.

DEMNAS can be downloaded from http://tides.big.go.id/DEMNAS/#. The study area was mainly covered by the DEMNAS of sheet number 1109-34 version 1.0. There is a small portion of the study area that is part of DEMNAS sheet 1109-34 version 1.0. However, by the time this paper is written the dataset has a problem and cannot be accessed properly. The sheet will not be used, considering only a small amount of area covered by it and will only give minor impact to this study. This DEM data has a spatial resolution of ±8.25m

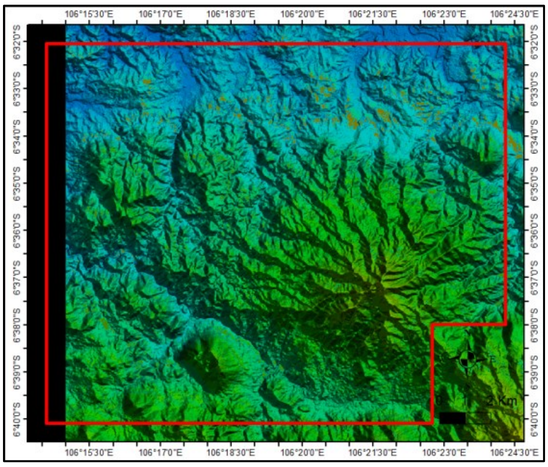

Figure 3: DEMNAS data. The red polyline is the boundary of Gunung Endut GPA. Black area means no data available.

After two DEM data imported, various version of geological maps collected as reference for interpreting lithology and structural geology in this study. The geological maps derived from three different geological surveys that have been mentioned before. For the practicality, the various versions of geological maps will be referred here according to their publication date, where 1992 map refer to general regional geology (Figure 4) (Sujatmiko and Santosa, 1992), 2006 map refer to geological map after PSDMBP for geothermal survey (Figure 5) (PSDG, 2006), and 2018 map after the geological survey by Geoscience Department, University of Indonesia (Figure 6). After all, data was collected, the lithology and geological structure are reinterpreted with the assistance of the DEM data. The result will be explained in the preceding chapter.

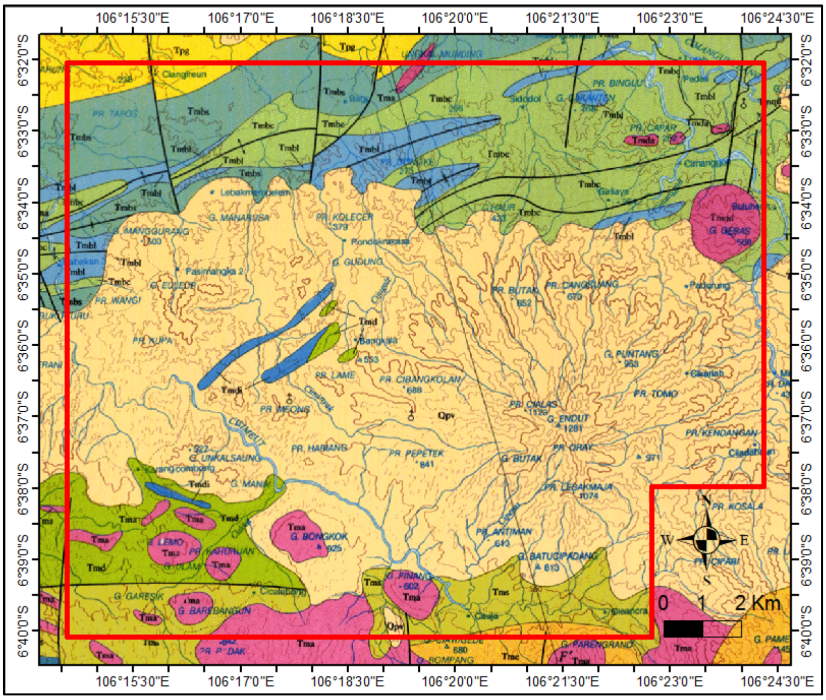

Figure 4: Geological Map of Gunung Endut Gunung Endut GPA (Sujatmiko and Santosa, 1992). The red polyline is the boundary of Gunung Endut GPA. (Pink: Quaternary Andesite Intrusion; Tan: Undifferentiated Quaternary Volcanic rocks; Green, teal, and yellow: Terrigenous Clastic Strata; Blue: Carbonate Rocks).

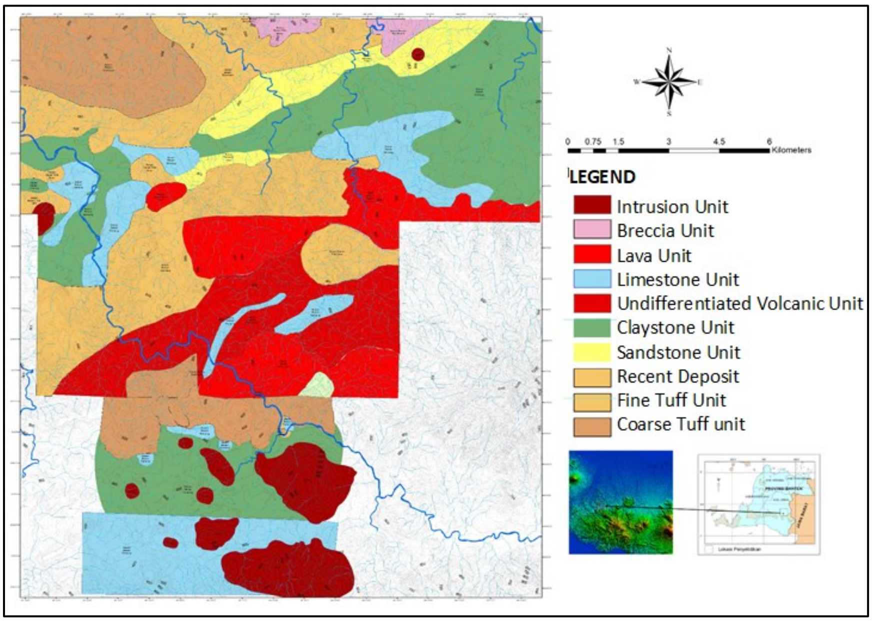

Figure 5: Geological Map of Gunung Endut from 2018 geological survey.

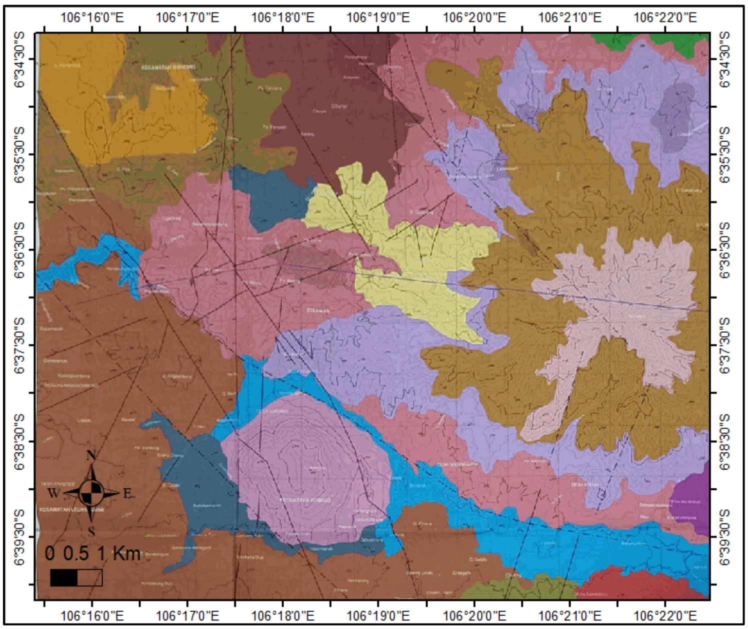

Figure 6: Geological Map of Gunung Endut from PSDMBP (modified from PSDG, 2006).

4. LITHOLOGICAL AND STRUCTURAL INTERPRETATION

The preceding subchapter will discuss the result of lithological interpretation using DEMNAS and its comparison with SRTM, followed by the geological structure interpretation.

4.1 Comparison of Lithological Interpretation.

After the DEMNAS and SRTM data were downloaded, slope illumination was implemented using software Global Mapper and ArcMap. Other datasets were imported to the software for analysis purposes, including Boundary for Gunung Endut GPA, various versions of geological maps, and location of hot spring manifestations. The results of slope illumination are shown in Figure 7.

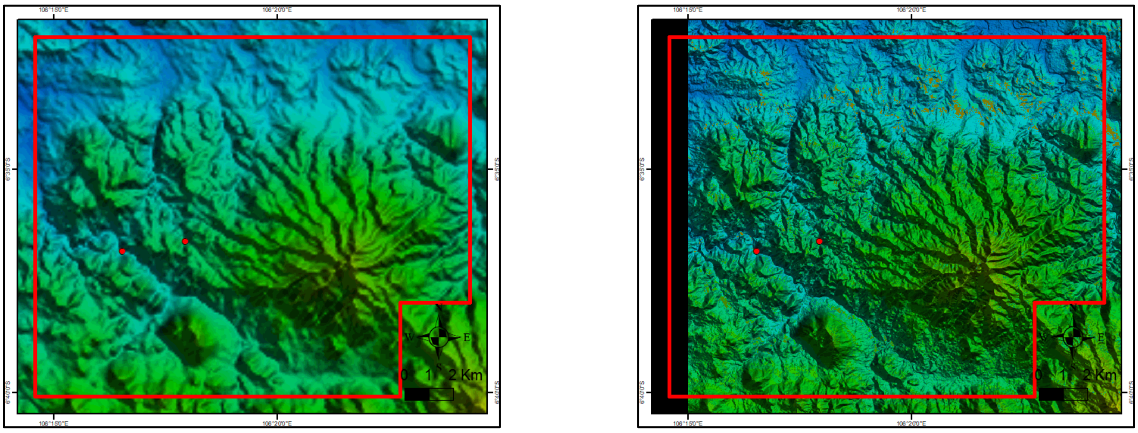

Figure 7: Undifferentiated volcanic rocks unit in 1992 map (left) and differentiated volcanic units in the 2006 map (right). Red polyline indicates textural different within the undifferentiated volcanic unit.

4.1.1 Case 1: Identifying different volcanic rocks in quaternary deposits.

The first case for discussion is the lithological variation in the Quaternary volcanic rocks, the southern part of Endut Mountain (Figure 8, left). The 1992 map did not separate the rocks. However, in the 2006 map (Figure 8, right), the volcanic rocks area is separated into different units. Interestingly, these lithological variations are reflected by the texture difference in DEMNAS map (Figure 9, left). In the DEMNAS map, smoother texture associated with the lithological unit 'Lava Endut', while the coarser texture associated with units 'Lava Endut 2', 'Breksi Lava Endut', and 'Lava Endut 3'. In the SRTM map the texture difference is not observed in the SRTM map (Figure 9, right). The slope variation between these zones can be identified, although relatively harder to interpret. Using this information, the accuracy for the extent of volcanic rocks in the study area can be improved.

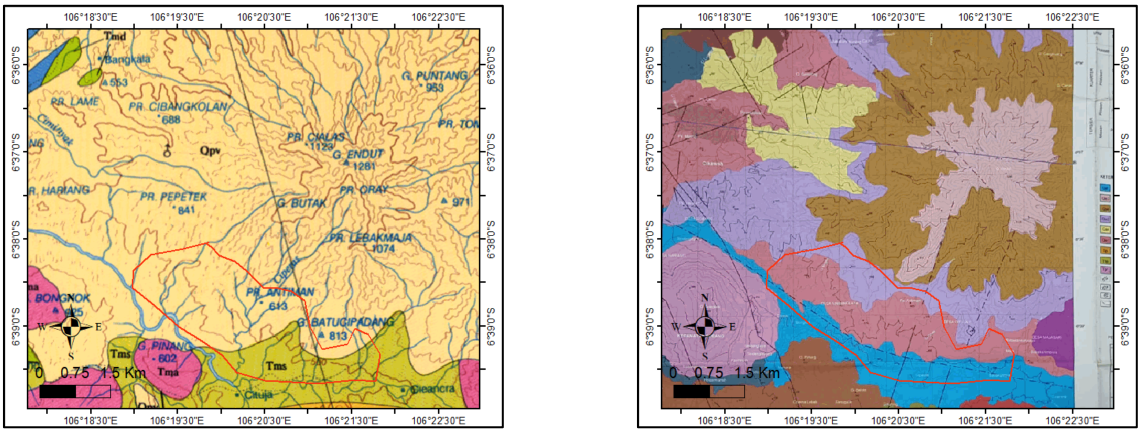

Figure 8: Undifferentiated volcanic rocks unit in 1992 map (left) and differentiated volcanic units in the 2006 map (right). Red polyline indicates textural different within the undifferentiated volcanic unit that observed in DEMNAS.

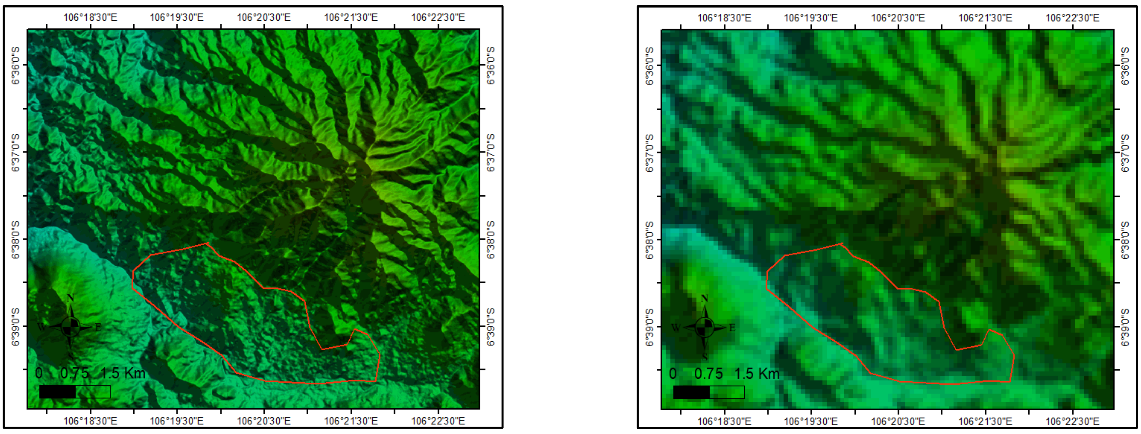

Figure 9: Textural different within the undifferentiated volcanic unit (red polylines) overlain DEMNAS map (left) and SRTM map (right).

4.1.2 Case 2: Identifying Carbonate Mounds and Igneous Intrusion Bodies

The second case for the discussion is the occurrence of carbonate mounds and igneous intrusion bodies. Both rocks commonly form vertical bodies due to their initial vertical formation and their resistance to weathering processes. In both 1992 map and 2018 map, there are several of such vertical bodies observed, which in this case is hosted by claystone-dominated unit, shown as the green area in Figure 10.

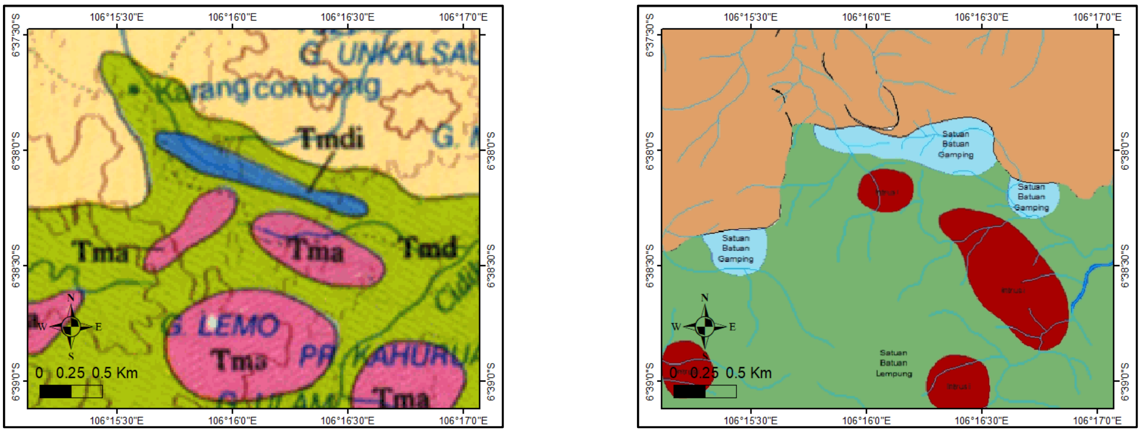

Figure 10: Carbonate mounds and intrusion mounds from the 1992 map (left) and 2018 map (right). Intrusion mounds are shown in red color, while carbonate mounds are shown in blue color.

After comparing the geological map and DEM map, we can see there is mound morphology observed in either SRTM and DEMNAS (Figure 11). This information can be used to review the extent of carbonate mounts and igneous bodies. One advantage of using DEMNAS is it can capture the textural difference between the vertical bodies and the host due to its higher spatial resolution, (Figure 11, right). In this example case, the claystone dominated unit as the host has smother texture with smaller elevation variation. This might represent the rock unit that area easier to experienced weathering and erosion. SRTM data can only capture the elevation and slope difference between these rock units.

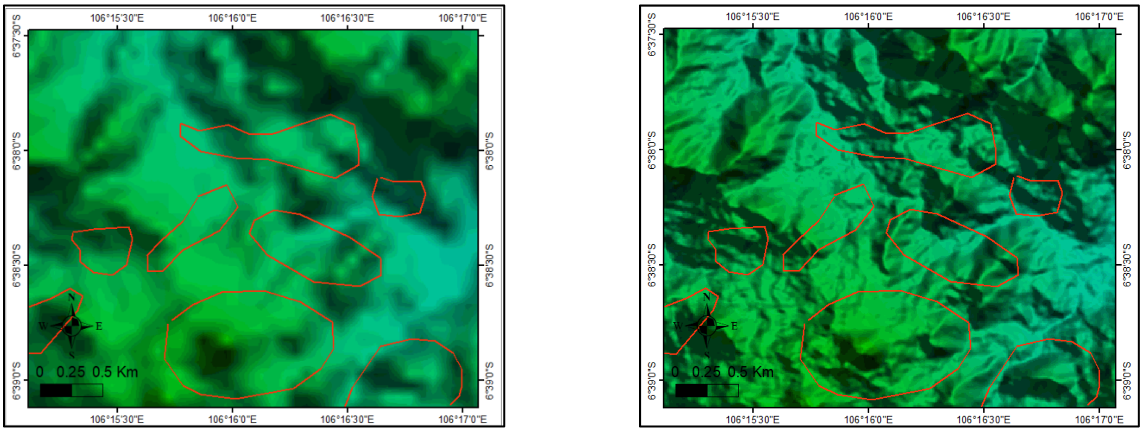

Figure 11: Traces of carbonate mounds and intrusion bodies from Figure 10 (shown in red polylines) overlain SRTM map (left) and DEMNAS map (right).

4.1.3 Case 3: Unclear correlation between rock distribution and DEM.

Not every rock variation can be observed in DEMNAS map. Rocks with similar physical characteristic might not show the significant variation that can be identified with either SRTM or DEMNAS. The example case can be seen the Figure 12 below where there are carbonate rocks (blue color) that surrounded with volcanic rocks (yellow brown and red color). When compared, these different rock types cannot be interpreted separately when using SRTM (Figure 13, left). The DEMNAS also could not show significant variation to identify this rock unit (Figure 13, right).

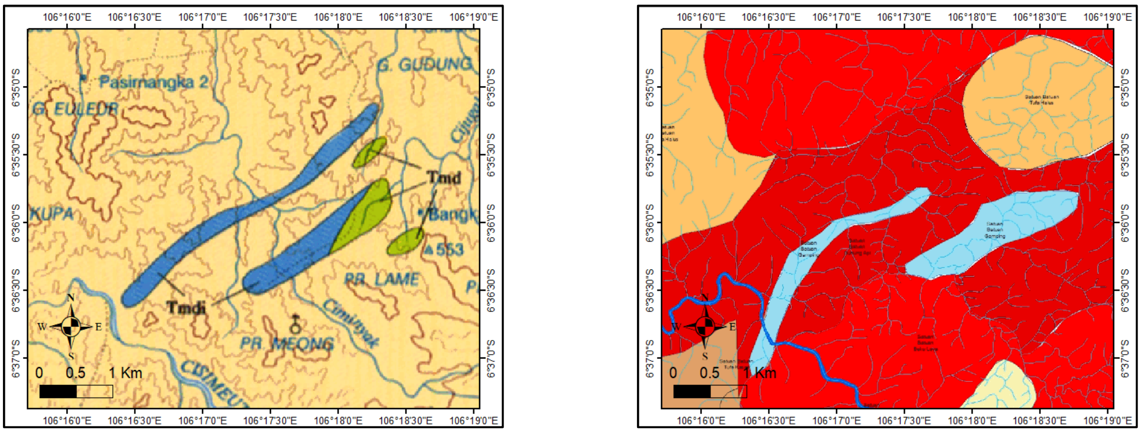

Figure 12: Distribution of carbonate rocks (blue color) within the volcanic rock (light brown) in the 1992 map (left) and 2018 map. In the 1992 map, volcanic rocks are shown in light brown color, while in the 2018 map the volcanic rocks are shown in red color.

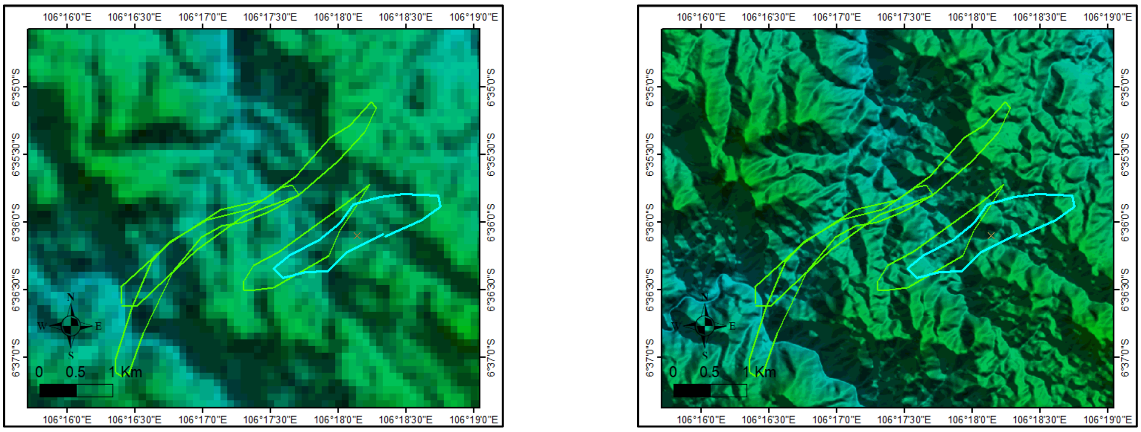

Figure 13: SRTM map (left) and DEMNAS map (right) overlain by traces of carbonate rocks lithology interpretation from Figure 10.

4.2 Comparison of Geological Structure Interpretation

<u>4.2.1 Case 4: Drainage as Indicator of Structural Lineament</u>

Since the occurrence of geological structures could enhance the weathering processes, in many cases the drainage pattern could reflect the structural condition in that area. Therefore, the drainage pattern could be beneficial for structural interpretation. In this case, we calculate the drainage pattern using both the DEMNAS map and SRTM map to analyze its association with geological structures (Figure 14).

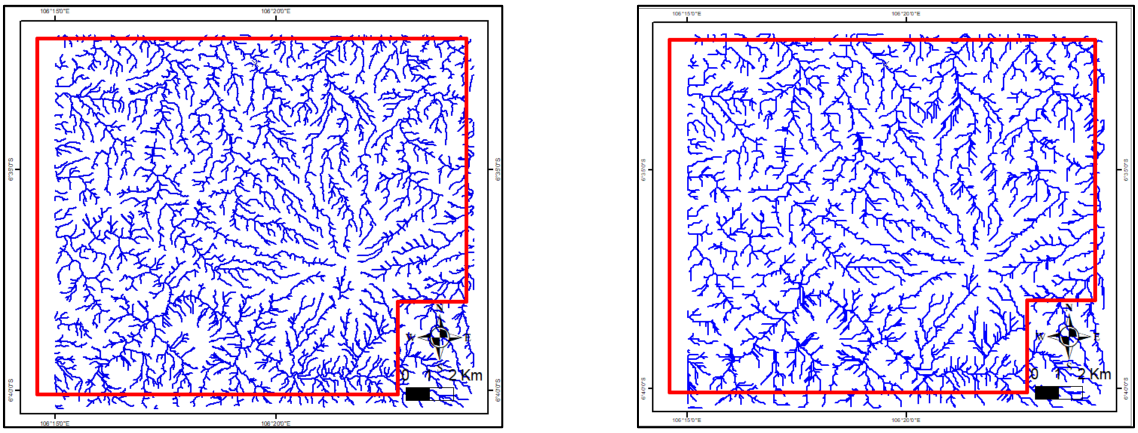

Figure 14: Drainage Pattern calculated from DEMNAS map (left) and SRTM map (right).

Drainage pattern was generated using Global Mapper software. Both DEM maps can produce the drainage map without error. However, the drainage pattern from the SRTM map suffers from its lower spatial resolution, particularly when observed in zoom smaller scale (Figure 15). The drainage pattern looks unnatural, with strong occurrence for orientation of 0°, 45°, 90° and 135° (Figure 15, right). The drainage pattern derived from DEMNAS map does not experience the same problem and show a more natural pattern (Figure 15, left).

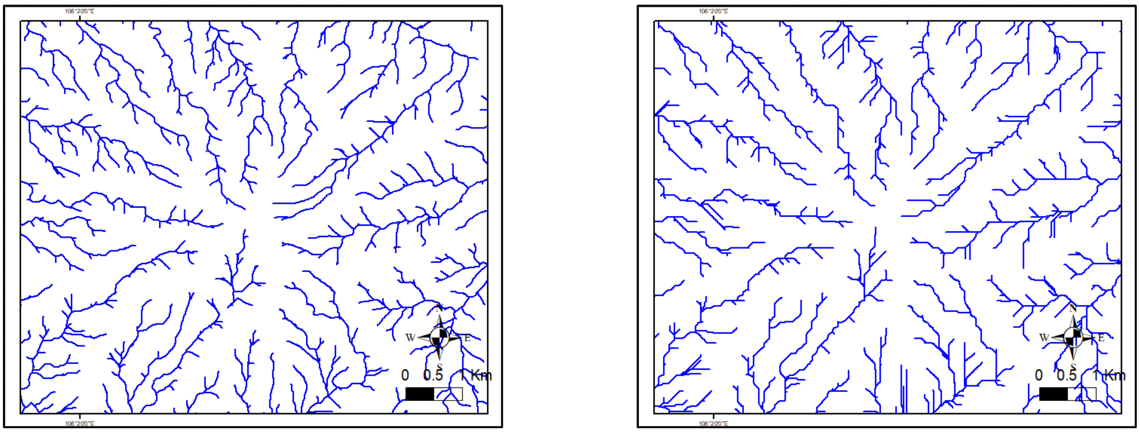

Figure 15: Zoom of drainage pattern calculated from DEMNAS map (left) and SRTM map (right). The map zoomed to the Mount Endut Summit in the southeast of the study area.

For each map, the orientation and length for each segment of the rivers are collected and plotted into the rosette. When plotted to the stereo net, each river segment is weighted using its length (Figure 16). The problem that occurred in the drainage pattern can be clearly seen in the rosette from SRTM data (Figure 16, right) and causing the data hard to interpret. Meanwhile, rosette from DEMNAS has better orientation result where it shows almost uniform orientation (Figure 16, left). This is probably due to the study area positioned in the volcanic area, where the river tends to form a radial drainage pattern, particularly young volcanic area. However, there are slight orientation trends can be observed in NW-SW and SE-NW orientation. This would be related to the faults interpretation discussed in subsection 4.2.3.

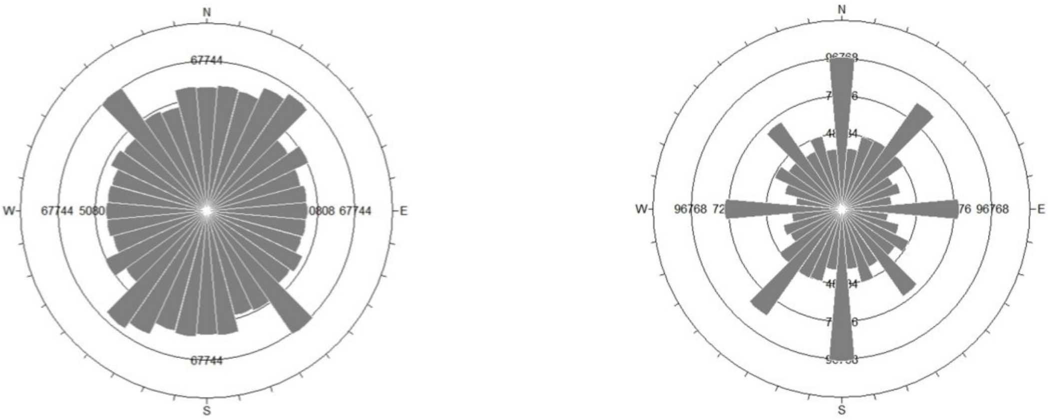

Figure 16: Rosette diagram of river orientation that calculated from DEMNAS map (left) and SRTM map (right).

<u>4.2.2 Case 5: Qualitative Interpretation of Faults</u>

From the previous studies, there are major differences in the fault interpretation. The 1992 map shows that in the study area faults only occurred in the tertiary sedimentary rocks (Figure 17, left). Possibly this is assuming that in quaternary periods there is no significant deformation have occurred yet. However, the 2006 map (Figure 17, right) shows a large number of faults, with different degree of certainty.

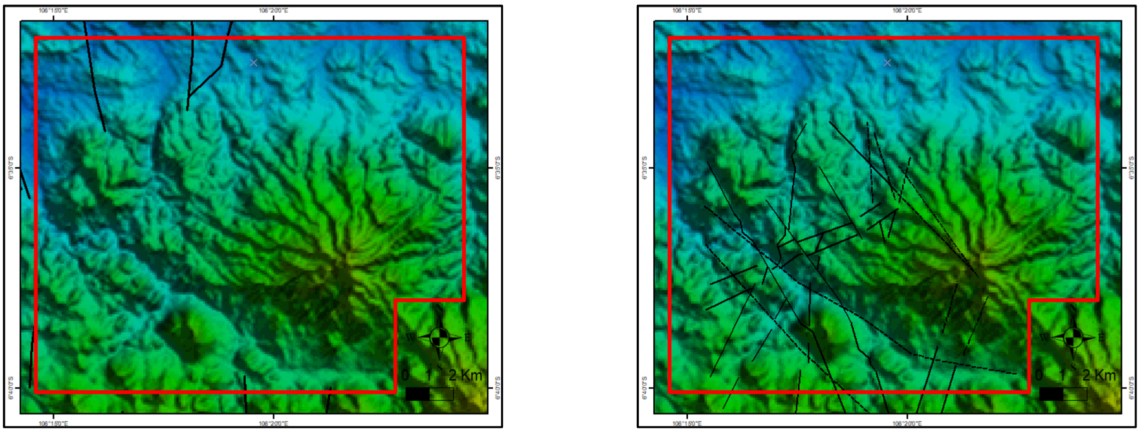

Figure 17: Geological Structures from 2006 geological map (left) and 1992 geological map (right) overlain the SRTM map.

Our interpretation of faults based on DEMNAS and SRTM can be seen in Figure 18. There are similarities and differences with both geological maps from 2006 and 1992. When compared with the 1992 map, the faults that cut the tertiary units can be observed in a similar location, although with different orientation. The similarity also applies when compared with the 2006 map where faults in quaternary rocks mostly have NW-SW and SE-NW orientation. These orientations also fit with the rosette of river orientation that derived from DEMNAS map (Figure 16, left). We also notice that when using DEMNAS map smaller faults can be interpreted with higher confidence (Figure 18, right).

The process of interpreting major faults within the GPA using the SRTM map is arguably easier to do. This is most likely because SRTM has a lower spatial resolution, hence reducing the minute textural variation that could hinder the detection of the fault. Also note that the hot spring manifestation sits on the top of major faults which can be interpreted even when using the SRTM (Figure 18, left). Therefore, in the initial stage when major faults are the main concern, SRTM is sufficient for fault interpretation. However, when advanced exploration commenced and smaller faults become concern as well, using both DEMNAS and SRTM is recommended.

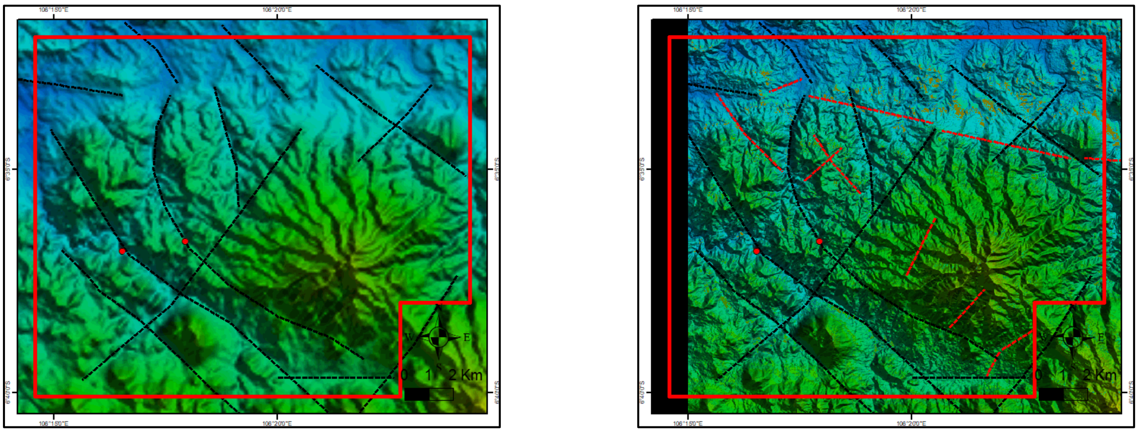

Figure 18: Faults interpreted from SRTM map as black dashed lines (left). Additional faults can be inferred using the DEMNAS map shown as red dashed lines (right). Hot spring manifestation is shown as red dots.

<u>4.2.3 Case 5: Lineament Extraction</u>

Automatic lineament extraction was done using LINE algorithm in PCI Geomatica 2018 version. When using LINE algorithm, there are a set of parameters need to be provided so the algorithm can produce meaningful lineament, namely RADI, GTHR, LTHR, FTHR, ATHR, and DTHR (PCI Geomatics, 2018). The parameters for processing the SRTM and DEMNAS map used in this study are listed in table 1. These parameters produced a fair result for geological interpretation, although further improvement for each parameter is very possible. All lineament extraction was done using shaded relief of SRTM and DEMNAS, with illumination azimuth 0°. After extracted, the lineament orientations are presented as rosette diagram. To reduce bias, each lineament is weighted by its length.

Table 1. Parameters for Lineament Extraction

Parameter	Value for SRTM Map	Value for DEMNAS Map
RADI – Filter Radius	500	100
GTHR – Edge Gradient Threshold	90	45
LTHR – Curve Length Threshold	10	30
FTHR – Line Fitting Error Threshold	10	5
ATHR – Angular Difference	15	15
DTHR – Linking Distance Threshold	20	20

When using the SRTM, the LINE algorithm can extract 263 lineaments (Figure 19, left). The average length for lineaments is 2492 meters. Meanwhile, there are 1568 lineaments can be extracted from DEMNAS map (Figure 19, right) with an average length of 448 meters. From the rosette, the lineament extracted from SRTM show dominant trend of NE-SW with the minor trend of NW-SE (Figure 20, left). These orientation trends are slightly similar to the river orientation from DEMNAS map (Figure 16, left), where there is a slight increase in the trend in such orientation. The lineament extraction in this area using SRTM probably represent a more regional trend of fractures with NE-SW and NW-SE.

The lineament extraction from DEMNAS map shows different result from SRTM map. From the rosette, lineaments from DEMNAS show dominant N-S and E-W trend, with the minor trend of NE-SW and NW-SE (Figure 20, right). The major difference between lineament trends from DEMNAS and SRTM possibly caused by the lineament that is able to be extracted using the implemented parameter. The extracted lineaments from DEMNAS show more local trend compared to the extraction result from SRTM data. In some cases, the lineaments from DEMNAS can capture features that might not related to geological structures. For instance, some group of lineaments form the circular pattern in the southwest part (Figure 19, right) that are most likely reflecting intrusion body or carbonate mounds as shown in Figure 4. There are also anomalous north-south lineaments in the east border of Gunung Endut GPA that possibly only caused by the lack of data in the east border (Figure 19, right). These anomalous data have been omitted when constructing the rosette diagram.

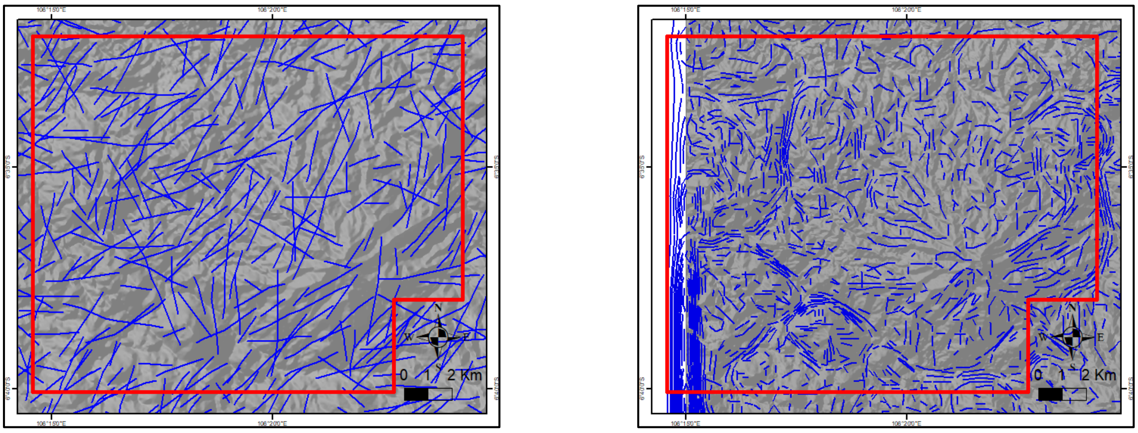

Figure 19: Lineaments extracted from SRTM map (left) and DEMNAS map (right).

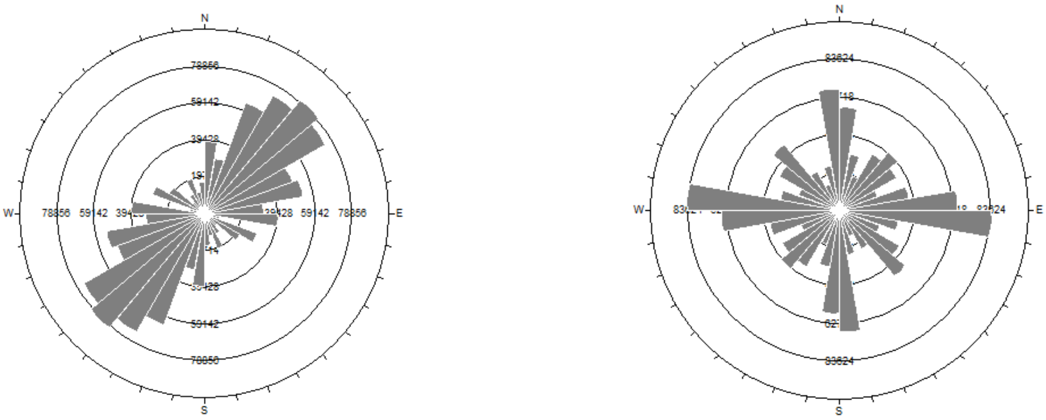

Figure 20: Rosette diagram of extracted lineaments from SRTM map (left) and DEMNAS map (right). The anomalous north-south lineaments in the east part of extracted DEMNAS lineaments have been omitted when constructing the rosette diagram.

5. Conclusion

This study demonstrates that DEMNAS can be useful for interpreting lithology and geological structures. It is recommended for every geologist who works in geothermal exploration in Indonesia to use DEMNAS as a substitute for SRTM map for their geological works. We also suggest that geological maps that used SRTM for the interpretation should be reinterpreted using DEMNAS to give a better and more confidence interpretation. It is important to note that there is a condition where SRTM or other DEM with lower spatial resolution still can be useful. Therefore, SRTM still needed to complement the implementation.

6. Acknowledgement

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