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AIRPORT PLAN TOPOGRAPHIC EXAMINATION: ACCURACY ANALYSIS BY DEMNAS AND ASTER GDEM METHOD IN TERRESTRIAL SURVEYS

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Abstract

An airport feasibility study is an important thing that must be completed to propose a new airport as a condition for issuing an airport location determination. The most critical indicator is the technical construction, which examines the topographic conditions of the new airport location. The topographic conditions using a terrestrial survey are highly accurate because they are carried out directly on the analyzed object. However, terrestrial surveys require time, energy, and money. This study aims to examine the topographic conditions using DEMNAS and ASTER GDEM, which can provide the same data as terrestrial surveys with a spatial resolution of 8 meters and 30 meters for free. The results of the comparative analysis show that the average elevation difference between DEMNAS and ASTER GDEM against terrestrial survey in the new airport location plan in Mahakam Ulu Regency is 2.04 meters and 8.89 meters, respectively. The validity and accuracy test of DEMNAS against terrestrial survey resulted in R^2 0.963, RMSE 2.417 meters, NSE 0.941, and LE90 3.897 meters. ASTER GDEM against terrestrial survey resulted in R^2 0.674, RMSE 6.244 meters, NSE -0.666 and LE90 10.3 meters. The analysis results show that DEMNAS data is better than ASTER GDEM. The conclusion is that DEMNAS data has a good level of accuracy that can be used to determine and analyze the topographic conditions of the new airport land plan so that it can be an alternative for the initiator in preparing the airport feasibility study.

Keywords: *Airport Plan, Topographic, Terrestrial Survey, DEMNAS, ASTER GDEM*

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Introduction

In determining the location of airport coordinate points, some procedures are required and regulated in Ministerial Regulation Number 20 of 2014 on Procedures for Determining Airport Location (Subagiyo 2017). The coordinate point is obtained through an airport feasibility study with seven feasibility indicators. One of the feasibility indicators critical to determining the coordinate point is the technical feasibility of construction. Technical feasibility examines the topographic condition of the new airport, especially the surface elevation. Currently, the applicant must conduct a terrestrial survey to find out the topographic condition of the new airport location. Terrestrial surveys are considered highly accurate because they are carried out directly on the Earth's surface. However, terrestrial surveys require a long time and high cost, and the operation of the tools (total station) must be recalibrated to ensure accurate data.

The Digital Elevation Model (DEM) is a digital model capable of presenting topographic data such as slope and elevation of a earth surface. DEMs that are commonly used in Indonesia nowadays are Seamless Digital Elevation Model and National Bathymetry (DEMNAS) issued by the Geospatial Information Agency in 2018 and Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) GDEM issued by NASA in 2009. The data sources used to form both DEMNAS and ASTER GDEM are different.

DEMNAS is formed by assimilation of IFSAR, TERRASAR-X, ALOS PALSAR and masspoint data used in the creation of Indonesia Rupabumi Map (RBI) and produced final spatial resolution by 0,27 arcsecond (8 meter) (Badan Informasi Geospasial 2018). ASTER GDEM was generated using stereo-pair images collected by the ASTER instrument onboard Terra and produces a spatial resolution by 1 arcsecond (30 meter) (NASA 2019). DEMNAS data is considered detailed for the coverage of Indonesia region while ASTER GDEM covaerage is a 99% of the Earth's surface (Marindah et.al.,2018).

The spatial resolution and the absolute vertical error of the DEM data are important to analyzed its level of elevation accuracy (Schumann et al.,2018). As shown by (Daniel et al.,2019) that have carried out a study that shows the level of accuracy of DEMNAS compared with the elevation of ground test point in Medan. Based on 209 test points, the average of difference between DEMNAS and ground test point is -0.637 meter and RMSE value is 1.105 meter with vertical accuracy at 90% confidence level is 1.818 meter. Comparison of DEMNAS with global DEM such as ASTER GDEM, has also carried out in land planning in the West Bogor Agrohills Leuwiliang area in Bogor Regency.

In this study, GPS RTK is used as a reference data, the result of the study DEMNAS shows a higher level of correlation with GPS RTK tha ASTER GDEM (Afifi, et.al., 2022). ASTER GDEM has varying accuracy depending on the location and ground conditions (Yao et al., 2020). Based on the references, the accuracy analysis of DEMNAS and ASTER GDEM on topographic examination of new airport can be identified by comparing DEMNAS and ASTER GDEM with reference data that carried out by terrestrial surveys. The purpose of this study is to determine the accuracy of DEMNAS and ASTER GDEM data used for topographic examination of new airport.

Methods

The method of this study is quantitative. It is about processing data and analyzing the problems with Geographic Information System (GIS) software such as, ArcMap 10.4.1 and Global Mapper and examining validity and accuracy of DEMNAS and ASTER GDEM against terrestrial surveys with statistic models. The location of this study is on island of Kalimantan, precisely on the new airport location plan in Mahakam Ulu Regency, East Kalimantan Province. The reference coordinate point of the airport runway direction TH. 19 is located at geographical coordinate 00º 30' 10.73" North 115º 14' 53.85" East (Kementerian Perhubungan Republik

Indonesia 2019). The study location can be seen in Figure 1.

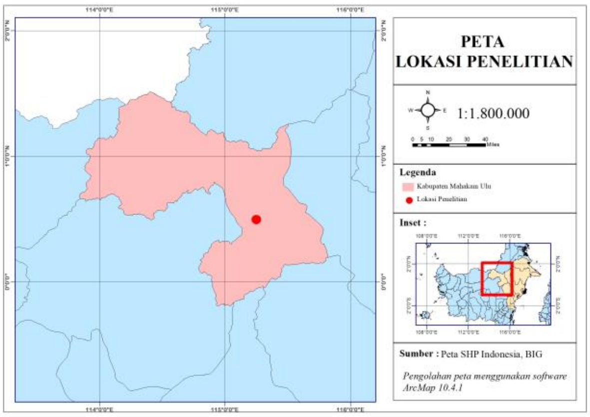


Figure 1. Study Location

This study will focus on examining the topographic conditions on the new airport location that is dedicated for airside facilities. Airport facilities generally consist of two main componens, airside facilities and landside facilities. Runway, runways strip, RESA, taxiway and apron will be built on the airside facilities (Amadou et al. 2021; Ramadhani et al. 2022). The data that required in this study are the x, y, and z points. The x and y points are coordinates and the z point is the elevation or height of the point. Terrestrial survey gains the x, y and z points directly through measurements on the Earth's surface of the new airport location plan. Meanwhile, DEMNAS and ASTER GDEM must be done by georeferencing or giving coordinate points from raster data. Georeferencing is done with Global Mapper software by exporting xyz grid. It is necessary to project the coordinate system from geographic coordinate system to Universal Transfer Mecator (UTM) coordinate system. DEM data must have projection system and it must be in UTM (Badan Informasi Geospasial 2012). This process is done by entering all x, y and z data into ArcMap 10.4.1 then utilizing arctoolbox and feature transformation and projection.

After being in the same coordinate system, the next data processing is to superimpose the coordinate points on ArcMap 10.4.1. this superimposed is intended to get the same point or overlapping points which are assumed to have same coordinates between terrestrial survey points and DEMNAS also terrestrial survey and ASTER GDEM. These test points are scattered on the airside facility of new airport. Based on each superimposed, the z point (elevation) of each terrestrial survey, DEMNAS and ASTER GDEM will be taken and then a comparison analysis will be conducted between terrestrial survey, DEMNAS and ASTER GDEM. Comparative analysis is needed to compare the data that has been collected in order to generate new conclusions (Hernanda et al. 2022). Comparative analysis is carried out by comparing the z point (elevation) and then start to calculating the difference. The next comparison is to compare the DEM of each data to see the difference visually.

The validity and accuracy assessment of DEMNAS and ASTER GDEM against terrestrial survey in this study utilizes statistical models. The three statistical models used include the coefficient of determination (R^2), root mean square error (RMSE) and Nash-Sutcliffe (NSE) measurements, were accurately evaluated to specify the most impressive approach (Band et al. 2020). In addition, LE90 or Linear Error 90% is also calculated in this study. LE90 is commonly used to evaluate the accuracy of remote sensing data, such as DEMs (Dolloff, et.al 2016).

The coefficient of determination (R^2) is able to show the extent to which the estimated regression line reflects or approaches the actual data (Afifi et al. 2022). The value of R^2 which is getting closer to 1, means that the estimated regression line is able to represent almost all of the actual data (Ghozali,2011). Interpretation of the R^2 value described in Table 1. Equation 1 is used to calculate the coefficient of determination (R^2). Root Mean Square Error or RMSE is a parameter to measure the error rate of prediction results in the context of predictive analysis. The smaller the RMSE value, the higher the prediction accuracy. RMSE can be calculated with Equation 2. The resulting Nash-Sutcliffe efficiency (NSE) value can indicate whether or not the observed data describes the simulated data exactly on the 1:1 line (Akhmat 2019). The NSE coefficient is between the range $-\infty$ to 1.0. NSE can be interpreted in Table 2. Where the value of 1 in

NSE is the optimal value (Band et al. 2020). NSE can be calculated with Equation 3. Linear Error 90% (LE90) is the vertical (height) geometric error rate. Where 90% of the difference or error in the height value between the object on the map and the actual height value does not exceed that distance (Geospatial Information Agency 2014). From the LE90 results, we can determine the accuracy of RBI maps with particular scale as defined by the Geospatial Information Agency.

$$R^2 = \left[\frac{n(\sum N_o N_p) - (\sum N_o)(\sum N_p)}{\sqrt{\left[n\sum N_o{}^2 - (\sum N_o)^2\right]\left[n\sum N_p{}^2 - (\sum N_p)^2\right]}}\right]^2 \quad (1)$$

$$RMSE = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(N_o i - N_p i)^2} \quad (2)$$

$$NSE = 1 - \frac{\sum_{i=1}^{n}(N_o i - N_p i)^2}{\sum_{i=1}^{n}(N_o i - \overline{N_o} i)^2} \quad (3)$$

$$LE90 = 1{,}6499 \times RMSE_Z \quad (4)$$

Where N_o is the observed value of dependent variables, N_p is the estimated value of dependent variables, and $\overline{N_o}$ is the observed mean value of dependent variables.

Table 1. R^2 Interpretation

R^2 Value	Interpretation
R^2 > 0,67	Strong
0,33 > R^2 > 0,67	Moderate
0,19 > R^2 > 0,33	Low

Table 2. NSE Interpretation

NSE Value	Interpretation
NSE > 0,75	Good
0,36 > NSE > 0,75	Qualified
NSE < 0,36	Not Qualified

Results And Discussions

Topographic conditions of Mahakam Ulu Regency were dominated by altitudes ranging from 0-1,500 meters above sea level) with slopes between 0-60%. At the same time, the topographic conditions of the new airport are in the form of undulating flat land and hills with slopes ranging from 0-15%. The number of test points was obtained by the superimposed result between terrestrial survey and DEMNAS (57 test points) also terrestrial survey and ASTER GDEM (30 test points). The distribution of test points for terrestrial survey and DEMNAS can be seen in Figure 1 and Figure 2 is for terrestrial survey and ASTER GDEM.

Figure 2. The Distribution of Terrestrial Survey and DEMNAS Test Points

Figure 3. The Distribution of Terrestrial Survey and ASTER GDEM Test Points

Comparison Analysis

Based on the test points obtained, each test point has x and y as coordinates, indicating the position of the point and z as the elevation. Each point of DEMNAS and ASTER GDEM was compared with the terrestrial survey. The error of DEMNAS and ASTER GDEM against the terrestrial survey is determined by the differences in the value of z (elevation). As shown in Table 3, from 57 test points shows that the average elevation difference between terrestrial survey and DEMNAS is 2.04 meters. The elevations generated by the terrestrial survey and DEMNAS from 57 test points have almost the same trend. The graph in Figure 3 shows how the elevation pattern generated by the terrestrial survey and DEMNAS. It shows that DEMNAS tends to follow the ups and downs of elevation generated by terrestrial surveys.

Table 3. Coordinates and error DEMNAS to terrestrial surveys

Point	UTM Coordinates x	y	z terrestrial survey (m)	z DEMNAS (m)	Error in DEMNAS (m)
1	304726	53924,99	41,491	40,212	1,279
2	304734,8	53923,71	41,626	40,18	1,446
3	304803,7	53924,78	40,065	42,935	2,87
4	304844,9	53907,25	42,022	44,734	2,712
5	304809,8	53964,86	37,244	36,442	0,802
6	304861,1	53957,68	36,561	36,926	0,365
7	304902,4	54089,99	36,169	39,88	3,711
8	304919,4	54239,38	38,485	39,151	0,666
9	304918,6	54231,28	40,025	39,288	0,737
10	304778,3	54240,92	47,005	49,09	2,085
11	304801,5	54364,07	61,797	62,639	0,842
12	304844,6	54331,18	56,062	56,905	0,843
13	304811,2	54472,11	60,924	61,936	1,012
14	304776,5	54496,81	59,467	60,362	0,895
15	304810,6	54489,74	60,383	61,316	0,933
16	304851,5	54481,17	61,36	61,786	0,426
17	304886	54489,91	60,307	62,337	2,03
18	304978,5	54471,56	60,879	64,859	3,98
19	304928,5	54511,47	48,583	48,583	0
20	304827,2	54630,23	59,066	62,672	3,606
21	304803,2	54589,23	53,322	53,509	0,187
22	304900,4	54752,3	57,42	61,308	3,888
23	304892	54753,71	56,272	59,627	3,355
24	304895,9	54779,56	58,67	62,349	3,679
25	304911,6	54777,66	61,529	64,808	3,279
26	304860,7	54830,14	55,316	59,283	3,967
27	304951,8	54886,58	45,515	49,37	3,855
28	304875,8	54943,43	60,613	60,576	0,037
29	304877,2	54979,26	46,265	49,385	3,12
30	304926,7	54971,03	59,217	58,019	1,198
31	305000,5	54986,39	52,77	54,753	1,983
32	304953,6	54993,44	59,275	62,312	3,037
33	304894,1	55171,13	45,169	47,393	2,224
34	305002,4	55350,4	48,868	52,313	3,445
35	305111,2	55484,67	38,255	41,128	2,873
36	305010,9	55509,67	37,515	40,101	2,586
37	305070,6	55558,35	38,42	41,24	2,82
38	305069,3	55566,34	39,801	41,044	1,243
39	305062	55575,67	35,024	39,002	3,978
40	305027,8	55550,95	40,288	36,668	3,62
41	305075,9	55773,07	36,654	39,184	2,53
42	305144,3	55633,02	40,365	42,708	2,343
43	305036,1	55549,74	40,194	37,127	3,067
44	305007,7	55508,85	37,515	40,101	2,586
45	305026,6	55498,96	37,515	40,633	3,118
46	304903,4	55001,43	46,729	49,527	2,798
47	304702,3	54514,46	60,928	59,315	1,613
48	304776,6	54439,94	60,219	60,5	0,281

Point	UTM Coordinates x	UTM Coordinates y	z terrestrial survey (m)	z DEMNAS (m)	Error in DEMNAS (m)
49	304752,7	54397,05	60,79	60,169	0,621
50	304794,1	54388,78	61,421	61,76	0,339
51	304866,7	54146,94	37,203	36,867	0,336
52	304828,4	54132,23	36,928	38,31	1,382
53	304825,8	54107,87	36,795	40,435	3,64
54	304796,3	53874,18	42,304	42,134	0,17
55	304800,2	53900,61	41,802	43,019	1,217
56	304877,8	53992,5	36,524	36,997	0,473
57	304842,6	54064,26	37,112	41,009	3,897

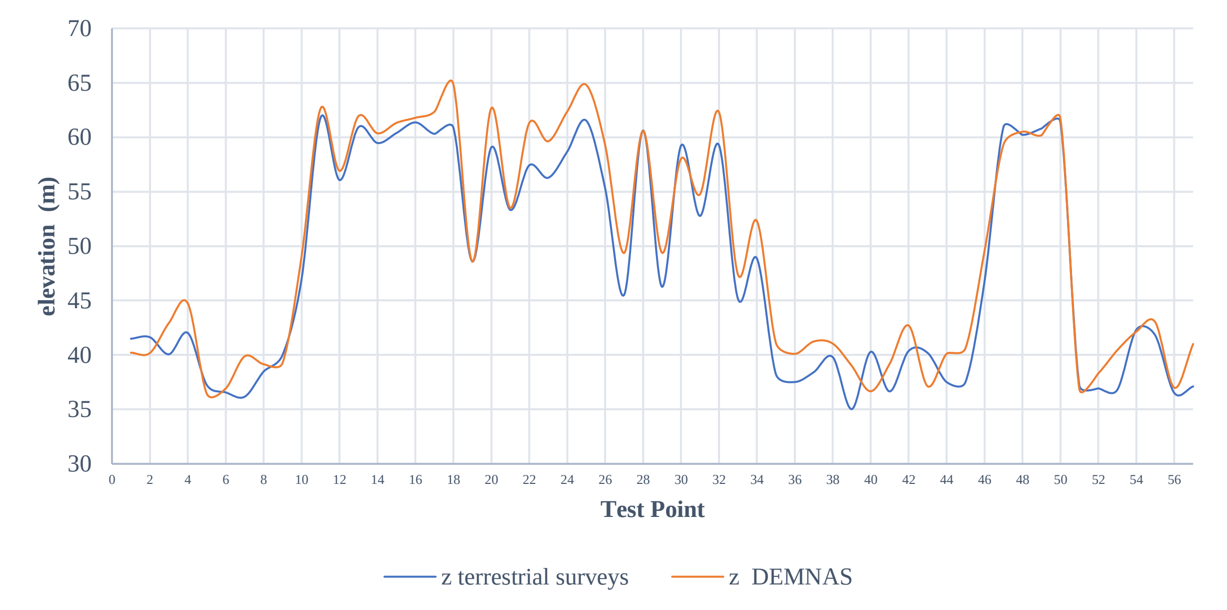


Figure 4. Elevation Difference Patterns of DEMNAS and terrestrial surveys

ASTER GDEM and terrestrial survey from 30 test points that shown in Table 4, have the average elevation difference at 8.89 meters. The pattern of elevations produced by the terrestrial survey and ASTER GDEM can be seen in Figure 4. ASTER GDEM tends to produce lower elevations than terrestrial survey. Elevation differences are fundamentally caused by different topographic data methods.

Where terrestrial surveys are carried out by directly measuring in the field, DEMNAS is obtained through a data assimilation process (masspoint, IFSAR, TERRASAR-X and ALOS PALSAR) and ASTER GDEM is obtained using the TERRA satellite sensor, which utilizes 14 bands to compile the earth surface image data, ranging from the visible wavelength region (optical) to the thermal infrared region.

Table 4. Coordinates of Terestrial Survey and ASTER GDEM test points

Point	UTM Coordinates x	UTM Coordinates y	z terrestrial survey (m)	z ASTER GDEM (m)	Error in ASTER GDEM (m)
1	304851,481	54481,165	52,025	44,457	7,568
2	304931,252	54933,197	61,36	51,886	9,474
3	305009,826	55428,767	54,454	49,99	4,464
4	305009,119	55500,808	47,368	52,31	4,942
5	305048,587	55693,689	48,863	46,246	2,617

Point	UTM Coordinates x	y	z terrestrial survey (m)	z ASTER GDEM (m)	Error in ASTER GDEM (m)
6	305083,32	55732,549	57,97	49,173	8,797
7	304895,777	54512,633	49,497	39,335	10,162
8	304896,587	54557,947	48,338	49,595	1,257
9	304781,97	54596,053	48,192	56,913	8,721
10	304813,903	54634,237	55,069	55,777	0,708
11	304972,526	54631,793	60,944	67,701	6,757
12	304933,516	54669,308	58,67	63,753	5,083
13	304931,389	54707,843	51,829	61,554	9,725
14	304894,322	54708,475	53,713	63,518	9,805
15	304934,526	54747,068	49,497	48,794	0,703
16	304895,875	54779,561	38,945	42,627	3,682
17	304896,305	54820,718	37,524	25,862	11,662
18	304856,974	54857,646	39,059	31,763	7,296
19	305047,144	55541,87	37,025	35,552	1,473
20	305047,904	55730,61	53,022	42,975	10,047
21	305042,749	55769,758	36,587	34,208	2,379
22	305047,669	55466,132	40,081	34,023	6,058
23	304856,354	54402,461	36,654	26,569	10,085
24	304856,234	54100,941	36,647	18,8	17,847
25	304853,488	53905,933	42,113	25,356	16,757
26	304856,903	53988,222	36,524	14,983	21,541
27	304857,536	54061,798	37,06	14,258	22,802
28	304892,126	54214,331	38,154	24,204	13,95
29	304778,409	54285,797	56,249	42,918	13,331
30	304931,67	54821,491	52,907	69,677	16,77

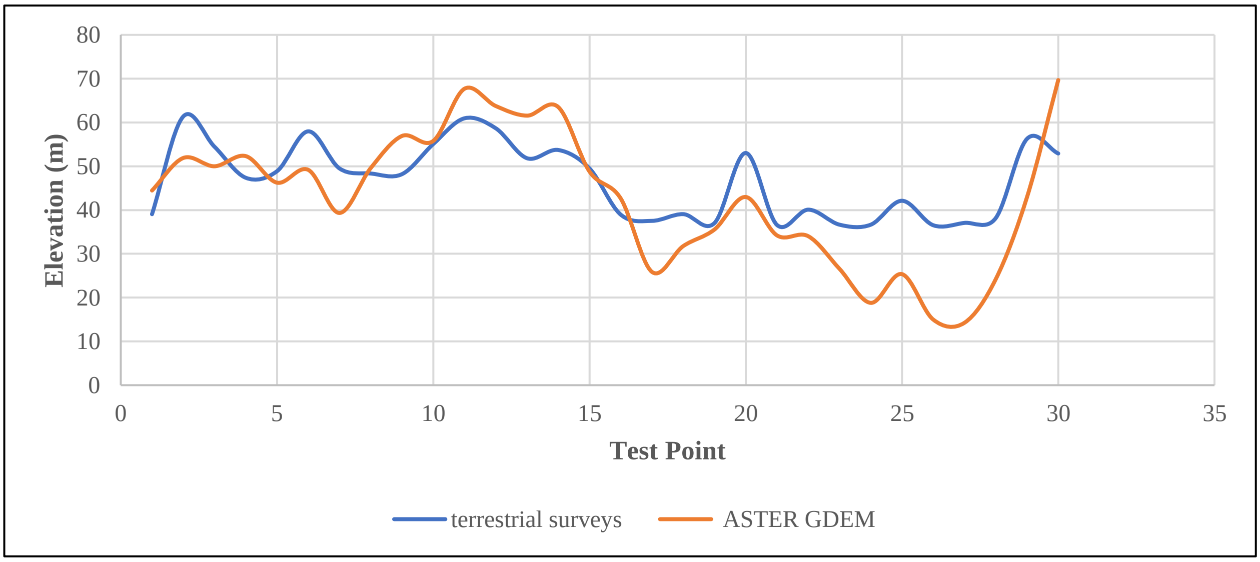
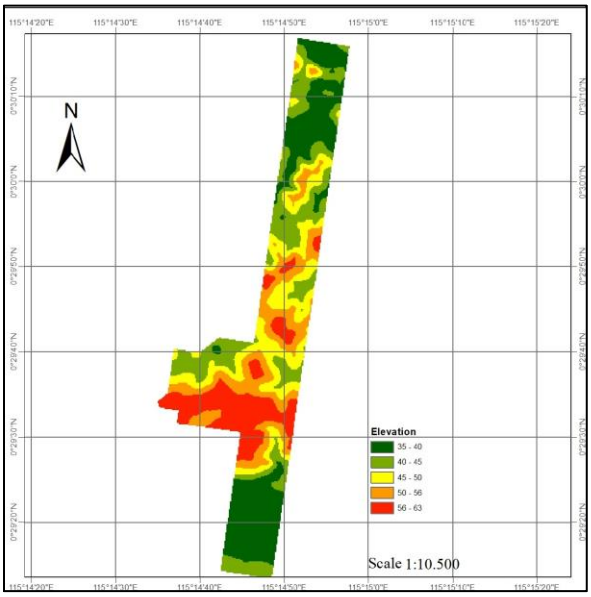


Figure 5. Elevation Difference Graph of ASTER GDEM and Terrestrial Surveys

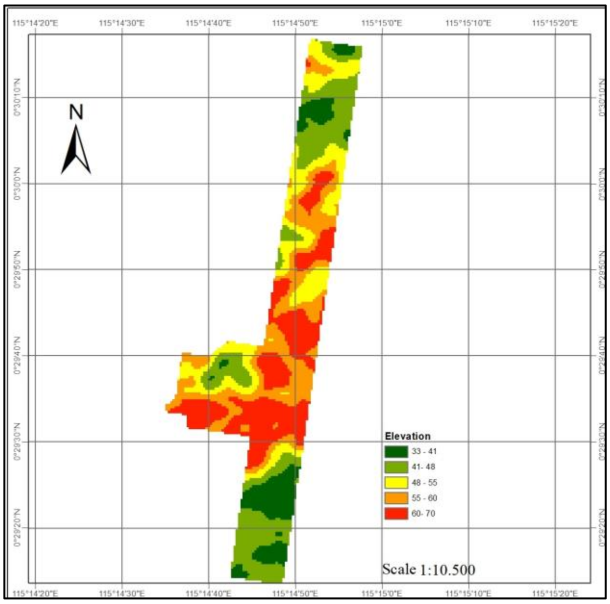
The new airport land in Mahakam Ulu Regency is plantation land. Where on the land there is a lot of vegetation in the form of tall trees so that DEMNAS data errors can occur during data assimilation which can be cause by human error (operator) when putting floating mark during the stereo plotting process. Meanwhile, ASTER GDEM data errors can be caused by errors during measurement, which is an error in the DEM measuring device (sensor) used or can be caused by disturbances that occur during DEM measurements, such as weather factors and human error (Purwadi, S., 2001 in Usud and Sukojo 2014).

Figure 6. DEM produced



by Terrestrial Survey

Figure 7. DEM produced by DEMNAS



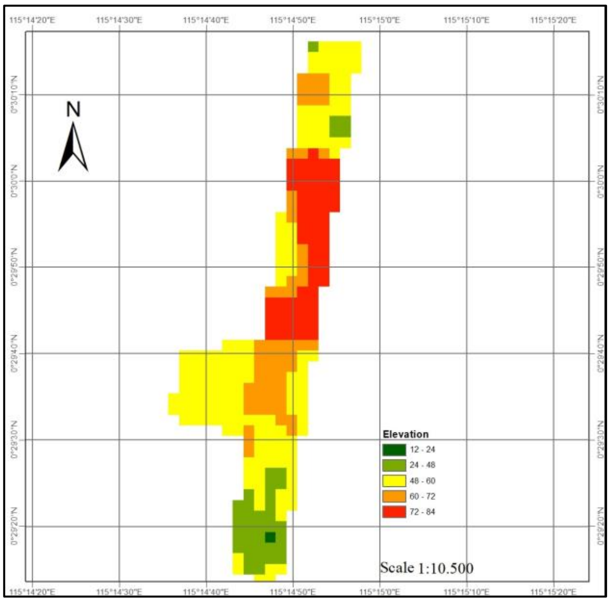


Figure 8. DEM produced by ASTER GDEM

The next comparative analysis is to compare the DEMs that produced by terrestrial survey, DEMNAS and ASTER GDEM visually. The purpose of this section is to see how similar the DEMs of the three data sources. DEM comparison of terrestrial survey, DEMNAS, and ASTER GDEM can be seen in Figure 5, Figure 6 and Figure 7.

Validity and Accucary Assesement

The validity and accuracy assessment in this study will show how valid and accurate the data generated by DEMNAS and ASTER GDEM. The expected result is the data that has high similarity with the actual data (terrestrial survey). The coefficient of determination (R^2), root mean square error (RMSE) and Nash-Sutcliffe (NSE) measurements for DEMNAS and ASTER GDEM against terrestrial survey have been summarized in Table 5.

Table 5. R^2, RMSE, and NSE Results

Parameters	DEMNAS	ASTER GDEM
R^2	0,963	0,674
RMSE	2,417	6,244
NSE	0,941	-0,666

The assessment result indicated that the DEMNAS has a better performance in generated data than ASTER GDEM. With the higher R^2 (0.963) included strong criteria, lower RMSE (2.417 meters) and NSE (0.941). However, ASTER GDEM (R^2, 0.674; RMSE, 6.244 meters; NSE, -0.666). At this section, linear error 90% is also calculated, linear error

90% is commonly used to evaluate the accuracy of remote sensing data, such as DEMs (Dolloff and Carr 2016). Result show that DEMNAS has linear error 90% by 3.897 meters and ASTER GDEM by 10.3 meters. With this linear error 90% value, the Geospatial Information Agency (2014) has determined that, DEMNAS data can be used for mapping purposes at a maximum scale of 1:25,000 or smaller and ASTER GDEM at a maximum scale of 1:100,000 or smaller.

DEM Usage Analysis for Airport Plan Topographic Examination of Airport Feasibility Study

DEMNAS is the best subject as an alternative to examine the topographic condition of the airport plan. The topographic information that can be generated by DEMNAS has met the needs for the construction technical indicators in the feasibility study of a new airport in Mahakam Ulu Regency, East Kalimantan Province.

This study findings that to calculate the cut and fill volume requirement for airport topography examination to determine the most feasible location, elevation data generated by DEMNAS can be used. However, the analysis results show that DEMNAS still has an error value so that the elevation cannot represent 100% of the terrestrial survey elevation which is the actual elevation value. So, it can be conclueded that DEMNAS data can only be used during airport topography in airport feasibility studies, which will be used for condisderation of iussuing an airport location determination. But it cannot be used for the preparation of Detail Engineering Design (DED).

Conclusion

The differences between DEMNAS and ASTER GDEM performed based on terrestrial survey was obtained 2.04 meters and 8.89 meters. DEMNAS has higher similarity of the elevation patterns with terrestrial survey, this indicates that the elevation generated by DEMNAS and actual elevation has almost the same trend. The difference in elevation generated by terrestrial survey, DEMNAS and ASTER GDEM is highly influenced by different topographic data collection methods. DEMNAS has a strong capability in describing terrestrial survey data, as shown by the R^2 value of 0.963 and has a low error level by the RMSE of 2.417 meters and NSE with good interpretation by 0.941. In contrast to ASTER GDEM that has limited ability in describing terrestrial survey data, as shown by the R^2 value of 0.674 and higher in error level by the RMSE of 6.244 meters also with NSE with interpretation not qualified by -0.666. In addition, based on linear error 90% calculation, the 90% error or difference in the elevation value of the object on DEMNAS and ASTER GDEM compared to the acual elevation value is not greater than 3.897 meters (DEMNAS) and 10.3 meters (ASTER GDEM). Due to smaller differences and higher accuracy of DEMNAS than ASTER GDEM to terrestrial survey, the spatial resolution of each DEMs is highly influence in presenting spatial data. Furthermore, the scope of the data coverage that focuses on Indonesia, makes DEMNAS data better for providing spatial data in Indonesia compared to ASTER GDEM which is able to present almost all of the world's spatial data. Based on the overall results of the analysis in this study, DEMNAS data can be used to determine and analyze the topographic conditions of the new airport plan in Mahakam Ulu Regency, East Kalimantan Province, precisely on the Ujoh Bilang Airport for the airside facilities plan. However, since DEMNAS data cannot represent 100% of the actual data in the field, DEMNAS data can only be used up to the airport feasibility study, which is as a consideration in determining the location of a new airport and cannot be used for measuring topographic data in the study of preparing Detail Engineering Design (DED).

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