

The Influence of Amplitude Stability Index Values in Mapping Land Movements on Sipora Island

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ABSTRACT

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Sipora Island in the Mentawai Islands Regency is prone to land movement disasters that can damage and cause losses to the people who live on Sipora Island, plus very little database related to land movement maps on the island. To reduce the risk that will arise, it is necessary to map land movement using the PS-InSAR method, using 48 scenes of Sentinel-1A images and comparing the amplitude stability index parameters 0.65, 0.75, and 0.85 to get differences in the distribution of land movement points and the number of land movement points on the island of Sipora, to see the relationship between the value of the amplitude of the stability index is done fisher test, amplitude stability index parameters 0.65 and 0.75 can map points with subsidence value up to -99 mm/year while the amplitude stability index parameter 0.85 can map points with subsidence value -87 mm/year all parameters have a maximum uplift value of 5 mm/year. The number of points obtained with an amplitude stability index of 0.65 is 27561, 0.75 is 961 and 0.85 is 255. The distribution of land movement points parameter value amplitude stability index 0.65 covers the entire surface of the island of Sipora, the distribution of land movement points amplitude stability index 0.75 focuses on the north and south of the island and the distribution of land movement points amplitude stability index 0.85 in the northern part of the island. The difference parameters of the amplitude stability index are 0.65, 0.75 and 0.85.

Keywords: Geography; Ground movement; Amplitude stability index; Fisher; Remote sensing; GIS

1. Introduction

Land displacement has occurred in many areas, especially in big cities located in coastal areas or alluvial plains, which are loose deposits that are transported to other places or are not around granular parent rocks in the form of sand and clay [1]. Land movement can trigger various other natural phenomena such as flooding in coastal areas, which is caused by falling land surfaces so that seawater can reach or enter land or can be called tidal flooding [2]. Taking land movement data can be done in various ways, either directly in the field or with remote sensing techniques such as permanent scatterer interferometric synthetic aperture radar (PS-InSAR). The main principle is to utilize multi-temporal synthetic aperture radar (SAR) image observation data over a long period to detect potential points of coherence. Permanent Scatterer (PS) points are generally solid objects on the earth's surface that become natural reflectors that are relatively coherent in the time dimension [3]. In data processing using the PS-InSAR technique, there is one parameter that affects the processing results, namely the Amplitude Stability Index (ASI) value, this parameter functions as a value or threshold in the formation of the PS (permanent scatterer) point to be formed, this value is also influenced by the value of the permanent scatterer.

Many areas in the world have experienced land movement phenomena such as Padang-Indonesia, Ulubelu-Indonesia, Kaligawa-Indonesia, Sidoarjo-Indonesia, Bengaluru-India, Pakistan, Surabaya-Indonesia [4], [5]. [6],



[7], [8], [9],[10]. In this research, Sipora Island is made the object of research because Sipora Island has a high risk of disaster, one of the natural disasters that often occurs is earthquakes, recorded on May 5, 2021, an earthquake centered at 3 kilometers from Tua Pejat with a magnitude of 5.8, this earthquake is thought to have occurred during the subduction of the Indo-Australian Plate under the Eurasian Plate [11]. However very few studies have been conducted in non-urban areas [12], one of which is Sipora Island, so Sipora Island lacks a database for mapping disaster areas in the case of land movement. This must be taken seriously because this data itself can be used as one of the materials in determining policies both in the field of infrastructure or in disaster mitigation, in addition, Sipora Island is the center of government in the Mentawai Islands Regency and frequent earthquake activity, so Sipora Island is very suitable to be the object of research.

By using the permanent scatterer interferometric synthetic aperture radar (PS-InSAR) data processing technique that can map the area of Sipora Island.

2. Research method

2.1 Research location

Sipora Island is one of the large islands in the administrative area of the Mentawai Islands Regency, this island has two sub-districts namely North Sipora and South Sipora with thirteen villages spread six in North Sipora and seven in South Sipora, with an island area of 651.55 km² Geographically, Sipora Island is located at 2°00'0 "S to 2°024'0 "S and 99°028'0 "E to 99°052'0 "E.

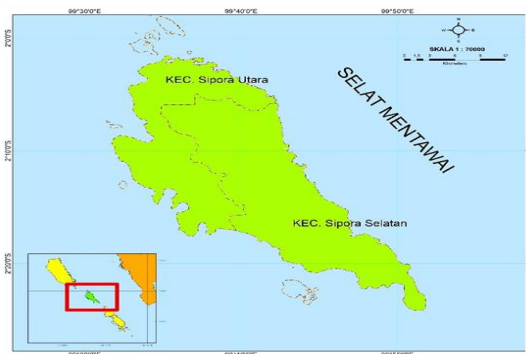


Figure 1. Sipora island in map

2.2 Data collection

The data used in this study are Sentinel 1 images of 48 image scenes with Flight Direction Ascending specifications, path 142 with frame 1,174 as many as 24 sin images, and frame 1,168 as many as 24 sin images, as well as VV polarization, Digital Elevation Model (DEM) data Shuttle Radar Topography Mission (SRTM) 1 second with a resolution of 30 meters. Selection of master and slave image data to be processed, the results of this selection are carried out automatically by the system following the master and slave images obtained:

Table 1. Master and slave image data

Master	Slave	Bperp (m)	Btemp (d)	Master	slave	Bperp (m)	Btemp (d)
06-Jan-2022	11-Jan-2021	46	-360	06-Jan-2022	06-Jan-2022	0	0
06-Jan-2022	04-Feb-2021	29	-336	06-Jan-2022	11-Feb-2022	12	36
06-Jan-2022	12-Mar-2021	3	-300	06-Jan-2022	19-Mar-2022	-38	72
06-Jan-2022	05-Apr-2021	59	-276	06-Jan-2022	12-Apr-2022	60	96
06-Jan-2022	11-May-2021	-30	-240	06-Jan-2022	06-May-2022	158	120
06-Jan-2022	04-Jun-2021	14	-216	06-Jan-2022	11-Jun-2022	-98	156
06-Jan-2022	10-Jul-2021	23	-180	06-Jan-2022	05-Jul-2022	-5	180
06-Jan-2022	03-Aug-2021	-16	-156	06-Jan-2022	10-Aug-2022	4	216
06-Jan-2022	08-Sep-2021	31	-120	06-Jan-2022	15-Sep-2022	-80	252
06-Jan-2022	02-Oct-2021	-32	-96	06-Jan-2022	09-Oct-2022	59	276
06-Jan-2022	07-Nov-2021	1	-60	06-Jan-2022	02-Nov-2022	95	300

Master	Slave	Bperp (m)	Btemp (d)	Master	slave	Bperp (m)	Btemp (d)
06-Jan-2022	01-Dec-2021	31	-36	06-Jan-2022	08-Dec-2022	-62	336
07-Nov-2021	11-Jan-2021	43	-200	07-Nov-2021	18-Jan-2022	39	72
07-Nov-2021	04-Feb-2021	30	-276	07-Nov-2021	23-Feb-2022	-36	108
07-Nov-2021	12-Mar-2021	-1	-240	07-Nov-2021	07-Mar-2022	4	120
07-Nov-2021	05-Apr-2021	61	-216	07-Nov-2021	12-Apr-2022	60	156
07-Nov-2021	11-May-2021	-31	-180	07-Nov-2021	06-May-2022	161	180
07-Nov-2021	04-Jun-2021	17	-156	07-Nov-2021	11-Jun-2022	-97	216
07-Nov-2021	03-Aug-2021	-14	-96	07-Nov-2021	17-Jul-2022	-15	252
07-Nov-2021	15-Aug-2021	9	-84	07-Nov-2021	10-Aug-2022	4	276
07-Nov-2021	08-Sep-2021	31	-60	07-Nov-2021	03-Sep-2022	-193	300
07-Nov-2021	14-Oct-2021	3	-24	07-Nov-2021	21-Oct-2022	101	348
07-Nov-2021	07-Nov-2021	0	0	07-Nov-2021	14-Nov-2022	17	372
07-Nov-2021	01-Dec-2021	27	24	07-Nov-2021	20-Dec-2022	86	408

From Table 1, it can be seen that if the mater data used is 2 master data, the results of data processing are obtained into 2 parts, and these two parts are combined and obtain the distribution of land movement points and data processing with different values of the amplitude stability index parameter.

2.3 Research flow chart

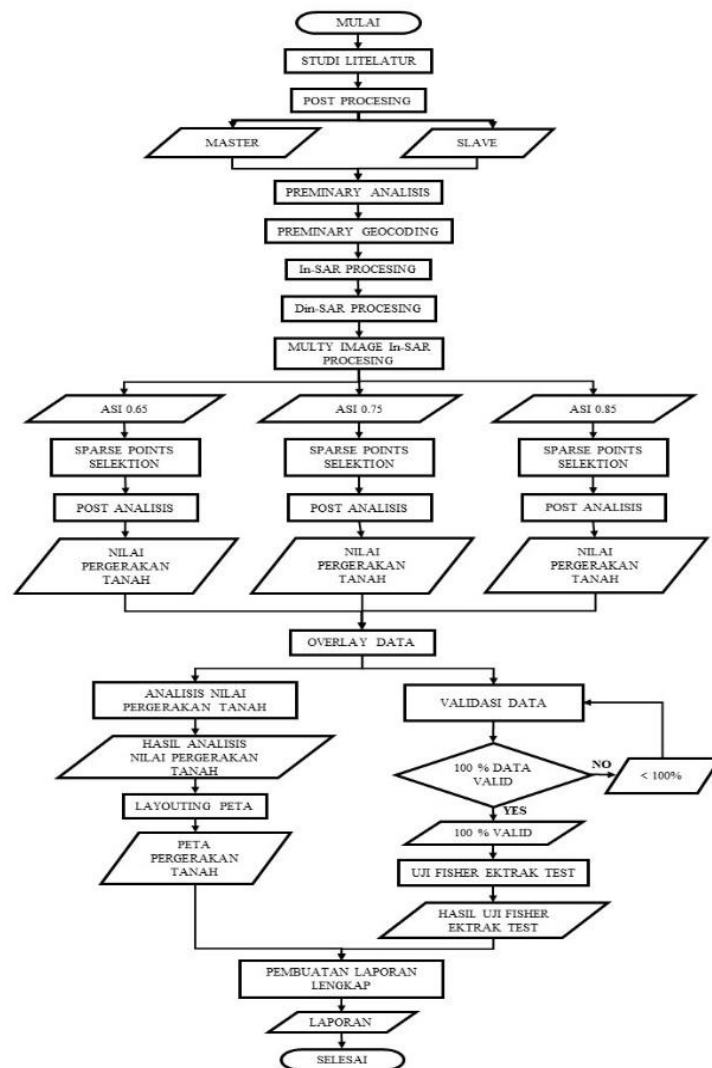


Figure 2. Research flow chart

2.4 Calculate the Amplitude Stability Index Value

In [3] explained that PS can be chosen to calculate the dispersion index of amplitude values relative to each pixel in the field of interest and consider only targets that show DA values below a certain threshold (typically $DA < 0.25$).

$$\sigma_v \approx \sigma_n I / g \approx \sigma_A / m_A = \Delta DA \quad (1)$$

Where (m_A) and (ad) are the mean and standard deviation of the amplitude values $(d,+)$. The dispersion index (DA) is then a measure of phase stability, at least for high SNR values. From this DA value, the amplitude stability index value will be obtained using the following equation:

$$ASI = 1 - DA \quad (2)$$

In data processing using the PS-InSAR method, the PS-InSAR method was first proposed in a research journal entitled Persistent Scatterers Interferometry at the International Geoscience and Remote Sensing Symposium, June 28-July 2, 1999, in Hamburg-Germany. This research gave rise to the concept of scene coherent pixels research which was later defined as Permanent Scatterers (PS), using many SAR image pairs to obtain DEM accuracy in the sub-centimetre order as well as surface movement values in high-coherence areas on a pixel-by-pixel basis. The PS-In-SAR technique is a development of the conventional In-SAR and Din-SAR techniques. The main advantage of developing this technique is to overcome the problems in In-SAR and Din-SAR techniques related to temporal and geometric decorrelation [6].

2.5 Fisher Test

From the results of data processing with the PS-InSAR method, a land movement point is obtained which will be taken several sample points to carry out the statistical test of the fisher test located in the northern part of Sipora Island, to get the test results whether the difference in the amplitude value of the stability index used affects land movement significantly or not.

This test uses the Fisher distribution with certain degrees of freedom and confidence levels as the comparison. The comparison in question is the standard deviation value obtained for each amplitude stability index value. Mathematically, this test can be formulated with the following equation:

$$F = (S_i)^2 / (S_{ii})^2 \quad (3)$$

With the value (S) is the average value of the standard deviation of the PS formed at each ASI value used (0.65, 0.75, and 0.85), (F) is the calculated F value, which will be compared with the F table with the hypothesis:

$$F \leq F_{((\alpha/2, df1, df2))} \quad (4)$$

$$H_0 = F \leq F_{((\alpha/2, df1, df2))} \quad (5)$$

$$H_a = F > F_{((\alpha/2, df1, df2))} \quad (6)$$

Where F is the value in the Fisher distribution table with α as the confidence level where the confidence level in this study is 95% in the F table, and degree of freedom (df) is the value of the number of samples. Acceptance of H_0 fulfils equation (11), so the coherence value fulfils this equation and means that there is no significant difference in the cumulative displacement and velocity results at each different coherence. While the rejection of H_0 will be fulfilled.

3. Results and discussion

The following ground movements are obtained using 3 different values of the stability index amplitude used. The land movement points generated by each parameter are different from one another, resulting in different point distributions. Figure 3 (A) is a map generated by using the amplitude stability index value parameter of 0.85, where land movement on Sipora Island is dominated by the range of land movement values that experience land uplift, which is spread in the northern and southern parts of the island with a percentage of 57.65% or as many as 147 points, seen in the blue range with the highest land uplift value of 5 mm/year. Land subsidence seen in the lowest subsidence value obtained is -87 mm/year, high land subsidence is spread in the eastern, western, and central parts of the island, with a percentage of the number of land movement points as much as 42.35% or as many as 108 points of land subsidence. This can occur because the distribution of land movement points tends to be small and only focuses on the northern part, while in other parts there are only a few points scattered, so the resulting map is easier to classify because the data tends to be homogeneous and small.

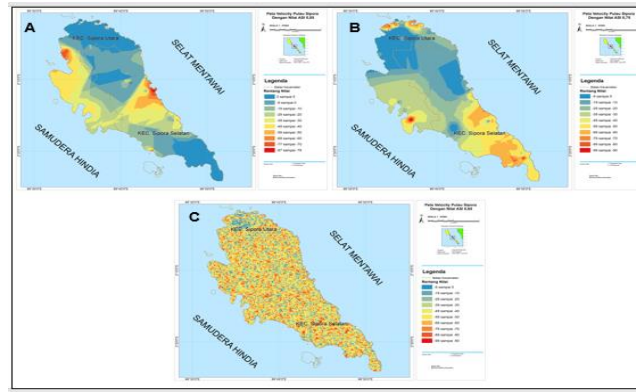


Figure 3 Land Movement Map (A) ASI Value 0.85, (B) ASI Value 0.75 And (C) ASI Value 0.65

Figure 3 (B) is a map generated in the data processing process using the amplitude stability index parameter value of 0.75, seen in the figure the lowest range of land movement values is sub-99 mm/year, and the highest range of land movement values is 5 mm/year. The distribution of land movement points with a stability index amplitude value of 0.75 focuses on the north and south of the island, this can occur due to low land cover such as settlements. The land movement that was successfully mapped was dominated by land subsidence, which was 71.63% or 548 points of land movement spread in the southern, eastern, western and partly in the middle of the island and partly at the far end of the island, while the area that had a range of land uplift was in the northern part of the island with a percentage of the number of points of 28.37% or 217 points. The resulting map with an amplitude stability index parameter of 0.75 can be easily classified because the points are not too many and not too dense, and some points are homogeneous or the same so that certain areas have movement values that tend to be the same.

Figure 3 (C) is a map of land movement with a stability index amplitude value of 0.65 obtained from the results of data processing with a stability index amplitude parameter of 0.65. The resulting land movement value is spread across the surface of the island, land movement with an ASI value of 0.65 can map land movement points with a subsidence land movement value of -99 mm/year to uplift of 5 mm/year. This explains that the value of ASI 0.65 can reach very many diverse points. The distribution of land movement is dominated by the subsidence phenomenon with a percentage of 86.90% of all land movement points or as many as 23951 points, which focus on the central part of the island, while the percentage of points experiencing land uplift is only 13.10% or 3610 points, the range of land movement values dominated by uplift is in the northern part of the island which is marked in blue in the northern part of the island. But in Figure 4.7 it is still very difficult to classify this can occur because the values of the range of land movements are overlapping and random or not homogenous so that the colours of the ranges mapped collide with each other and the observations become inaccurate even though the distribution of data is comprehensive on the surface of Sipora Island.

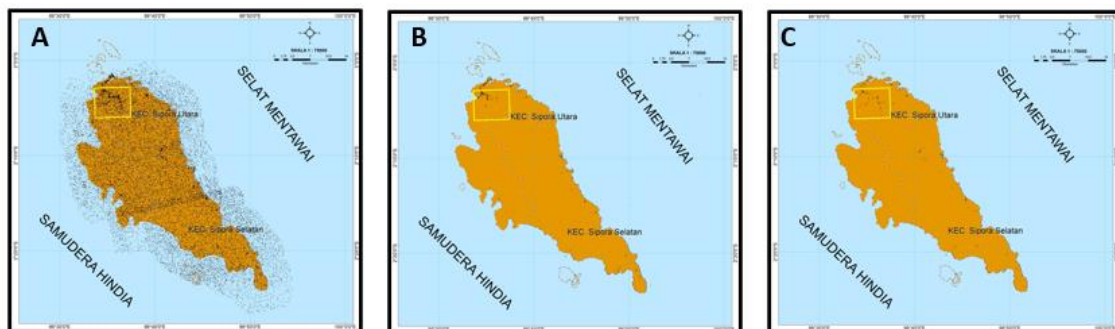


Figure 4. Sampling location

From the sample points that have been obtained, a statistical test is carried out to determine the effect of the amplitude stability index value used on land movement in the northern part of Sipora Island, with the results obtained. Table 2 is the result of the calculation of the fisher value, from the table it can be seen that the results of the parameter test of ASI 0.65 with ASI 0.75 produce a calculated F value of 4.5536, and this value is greater than the F table value, so it can be concluded that the results of the fisher test between ASI values 0.65 and 0.75 on land movement, do not significantly affect. Similarly, the test results of the ASI value parameter 0.65 with

0.85 resulted in a value of 4.7659, and this value is greater than the F table value, so it can be concluded that there is no significant effect between the ASI value parameter 0.65 with 0.85 on land movement mapping. While the results of the fisher tests 0.75 and 0.85 have results that are lower than the F table value of 0.9555 so it can be concluded that there is a significant influence on land movement mapping. Mathematically it can be written as follows:

Table 2. Fisher's exact test results

Amplitude Stability Index	F Count	F Table	Hypothesa
0,65 & 0,75	4,5536	3,2400	REJECT
0,65 & 0,85	4,7659	3,2400	REJECT
0,75 & 0,85	0,9555	3,2400	ACCEPTED

Calculated F value of ASI 0.65 and 0.75 > from F table value

Calculated F value of ASI 0.65 and 0.85 > than F table value

Calculated F value of ASI 0.75 and 0.85 < than F table value

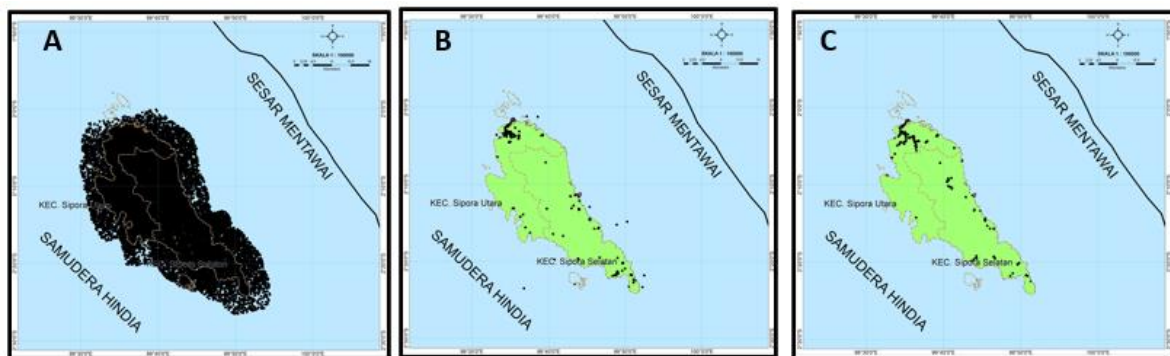


Figure 5 Distribution of ground movement points on the Mentawai fault (A) ASI value 0.65, (B) ASI value 0.75 and (C) ASI value 0.85

The condition of the island's surface is also influenced by fault activity near the island, the Mentawai fault is an active fault located approximately 35 kilometers from the edge of the island (Puspasari, 2022), due to the activity of the Mentawai fault and sea water rise so the area has the potential for land movement disasters or other disasters such as ROB floods. And following the results of previous mapping it shows the area that experienced an increase in the north and south of the island while the decline in the eastern part of the island is directly opposite the Mentawai fault.

4. Conclusions

Based on the research that has been done, the conclusion is that the distribution of land movement points generated by the parameter of the amplitude value of the stability index 0.65 covers the entire surface of Sipora island with land subsidence reaching -99 mm/year and uplift 5 mm/year. The distribution of land movement points generated with a stability index amplitude value of 0.75 covers the entire surface of Sipora island but focuses on the northern and southern parts of the island with land subsidence reaching -99mm/year and uplift 5mm/year, and the distribution of land movement points generated with a stability index amplitude value of 0.85 covers the entire surface of the island by focusing on the northern part of the island with land subsidence reaching -87mm/year and uplift 5mm/year.

As well as differences in the parameters of the amplitude stability index values of 0.65, 0.75 and 0.85 affect the number of ground movement points, the smaller the ASI value used the more points are generated, but from the sample test results obtained the results of the ASI parameter test do not significantly affect the resulting ground movement points, and the hypothesis is rejected because the calculated F value is lower than the F table in the ASI 0.65 & 0.75, and 0.65 & 0.85 tests.

5. Declaration of competing interest

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