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SAND DUNE CONSERVATION ASSESSMENT IN COASTAL AREA USING ALOS PALSAR DInSAR TECHNIQUE

Ratih Fitria Putri[1*], Sunu Wibirama[2], Sukamdi[1] and Sri Rum Giarsih[1]
[1]Department Geography and Environmental Science, Faculty of Geography, Universitas Gadjah Mada, Yogyakarta, 55281, Indonesia
[2]Department of Electrical Engineering and Information Technology, Faculty of Engineering, Universitas Gadjah Mada, Yogyakarta, 55281, Indonesia

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Abstract: A big earthquake occurred in the southern coastal of Java on July 17th, 2006. The earthquake caused Tsunami waves in the coastal area of West Java, Central Java, and Yogyakarta. In particular the potential of Tsunami hazard in southern part of Yogyakarta Province is high. Parangtritis is located at the southern part of Yogyakarta Province. Sand dune in Parangtritis coastal area has been a natural barrier of Tsunami hazard. In this case, minimizing impact of Tsunami can be conducted by estimating Tsunami hazard zones. In this research, we observed actual condition of sand dune and predicted the Tsunami inundation area using Remote Sensing and Geographic Information System application on ALOS PALSAR Differential Interferometric Synthetic Aperture Radar (DInSAR) technique. We propose a novel sand dune monitoring approach using DInSAR analysis on L-Band. The scenario on water depth was used to estimate Tsunami inundation area and wave direction. The monitoring accuracy was compared with the results of GPS measurements. We argued that the southeast Tsunami wave scenario with 30 meters elevation produced big hazard. Based on our study, we propose a sand dune conservation mapping and protection management plan of sand dune coastal area that can be used to improve awareness of local stakeholders.

Keywords: Sand dune; tsunami mapping; conservation; ALOS PALSAR; DInSAR

* Correspondence to: Ratih Fitria Putri. E-mail: ratihfitria.putri@ugm.ac.id

INTRODUCTION

Indonesia has been the most vulnerable area of natural disasters due to its closeness to the collision area of three main tectonic plates. According to the Tsunamis catalogue in the Indian Ocean, 80% of the Tsunamis are from Sunda arc region. In average, Tsunamis are generated once in consecutive three years with different scale events (Diposaptono & Budiman, 2006). In 2006, a Tsunami occurred in the southern part of West Java that shifted to the eastern part. All parts of south coastal zone in Java were affected by the Tsunami. In particular sea of the south coast in Bantul Regency, Yogyakarta is potential to be the main cause of Tsunami as there is a subduction zone between the Indian Plate and Eurasian Plate (Putri *et al.*, 2011; Mardiatno *et al.*, 2011). The Tsunami history in Indonesia is described in **Fig. 1** and **Table 1**.

Tsunami has been argued as a destructive disaster causing great losses of life and extensive damage area although it happens infrequently. The largest Tsunami in Indonesia was caused by Krakatau Volcano in 1883, which documented more than 38 meters height of wave and 2.5 kilometers through inland both of Java and Sumatra islands. The second largest one happened in 2004 was caused an earthquake with 9.1 Magnitude. The earthquake was recorded as the biggest since 1900. This earthquake generated Tsunami wave with more than 30 meters of height and 4 kilometers inland while destructing all buildings and houses. Soetart *et al.* (2001) argued that coastal area is constantly changing and very dynamic. Change in Indonesian coast consists of short term, medium term, and long term changes. These changes can be seen as various kinds of natural hazards, gradual or intermittent advance or retreat shoreline. Furthermore, these changes affect land uplift of subsidence or sea level rise and fall.

On July 17th, 2006, a Tsunami occurred in southern coastal area of Java. A huge damage happened in Pangandaran, one of the most preferred areas for tourism in Java. The Indonesian Ministry of Health reported that more than 600 people died, more than 60 were missing, and more than 9200 were in treatment as a result of disaster. The Tsunami was triggered by an earthquake of 7.7 Magnitude located at 220 km of Java Island (Gunawan, 2007). The Tsunami caused several damages to infrastructure, land use, and agricultural area including paddy field.

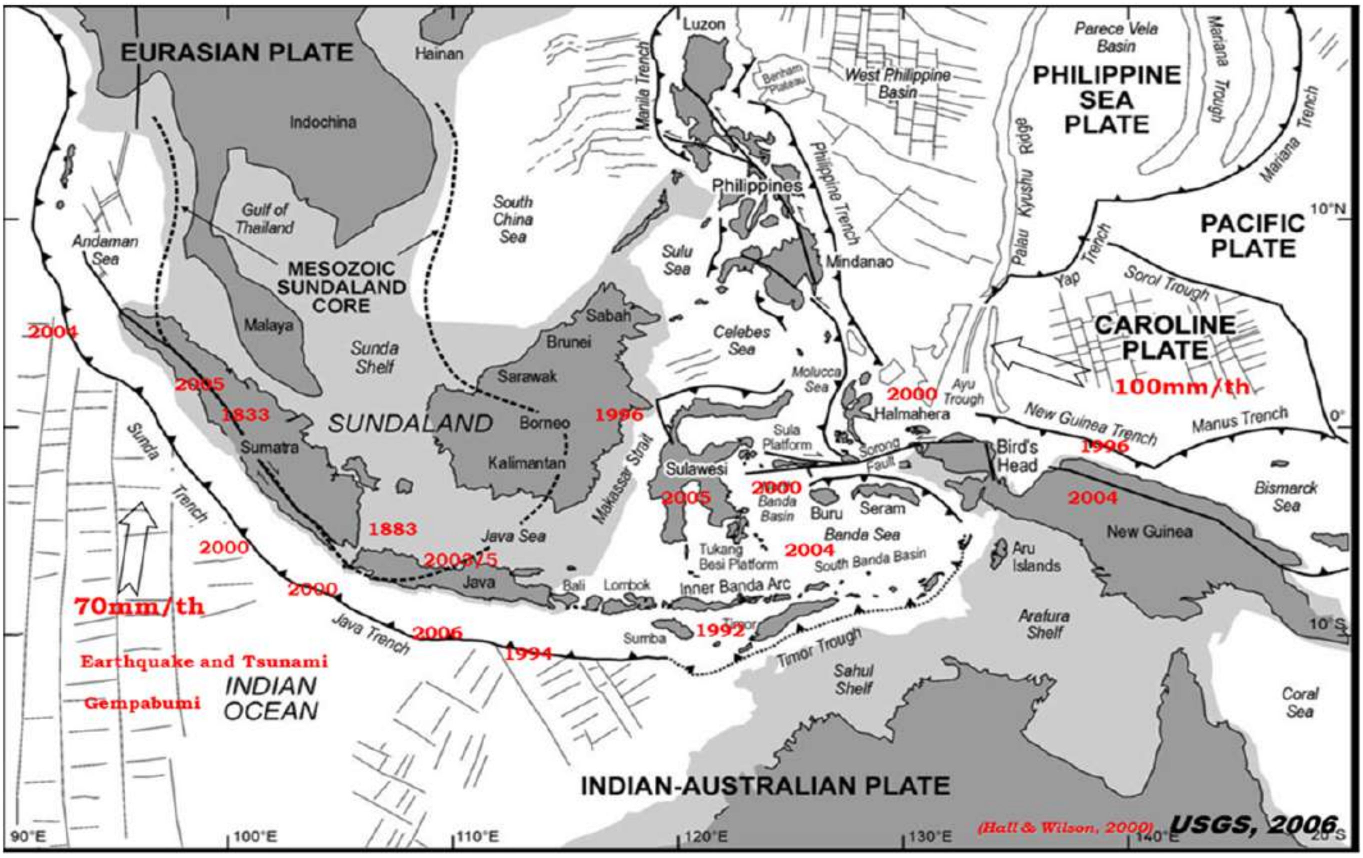

Fig. 1 Earthquake and Tsunami Record in Indonesia during 1983-2006 (USGS, 2006).

Table 1. Tsunami Record in Indonesia (1883−2006)

Year	Magnitude	Location	Victims (Dead/Injured)
1883	Volcano	Krakatau	36000
1961	-	NTT, Flores Tengah	2/6
1964	-	Sumatera	110/479
1965	7.5	Maluku, Seram, dan Sanana	71 Dead
1967	5.8	Tinambung (South Sulawesi)	58/100
1968	7.4	Tambo (Center Sulawesi)	392 Dead
1969	6.9	Majene (South Sulawesi)	64/97
1977	-	NTB dan P. Sumbawa	316 Dead
1977	8	NTT, Flores, and P. Atauro	2/25
1979	-	NTB, Sumbawa, Bali, and Lombok	27/200
1982	-	NTT, Larantuka	13/400
1987	-	NTT, East Flores, and P. Pantar	83/108
1989	-	NTT and P. Alor	7 Dead
1992	7.5	NTT, Flores, P. Babi	1952/2126
1994	7.8	Banyuwangi (East Java)	38/400
1996	8	Palu (Center Sulawesi)	3/63
1996	8	P. Biak (Irian Jaya)	107 Dead
1998	-	Tabuna Maliabu (Maluku)	34 Dead
2000	-	Banggai, Center Sulawesi	4 Dead
2004	9.1	NAD and Nort Sumatera	> 200 000
2005	-	P. Nias	-
2006	7.7	South Java	665

Source: Diposaptono & Budiman (2006).

Parangtritis area is located at the south coast of Java subduction zone directly facing the Indo-Australian plate and Eurasian plate. The threat of natural disasters originates from earthquakes generated in the second subduction zone plate located in the Southern part of Java (Marfai *et al*., 2009). Southern part coastal zone of Parangtritis has a unique sand dune phenomenon. Sand dune in this area is considered as the only one sand dune in South East Asia. Sand dune in Parangtritis area had been a natural barrier to protect hazard caused by Tsunami. Unfortunately, the sand dune is not in ideal condition. Parangtritis has been highly vulnerable to the impact of the Tsunami as there are many buildings in the coastal area located only a few meters from the coastline. Intense sand river tailing activities also exacerbate vulnerability of Parangtritis area. Various human activities that worsen sand dune condition are not prevented due to lack of awareness of local government towards the sand dune conservation.

A remote sensing approach combined with Geographic Information System (GIS) is useful for establishing spatial extent of potential hazard inundation as well as to calculate the spatial agricultural damage over large areas (Marfai *et al*., 2009). Nowadays, technology of satellites images is increasing rapidly in term of its development and application. Satellite data for coastal agricultural land use is becoming increasingly important source of information for precision farming. A hyperspectral sensor such as IKONOS has dramatically increased spatial, spectral, and temporal frequencies that makes them appealing to applications in precision agriculture and non agriculture land. The Landsat and ALOS satellites are also important in precision farming due to the large synoptic view and reasonable spatial resolution.

Remote sensing approaches for coastal morphology have been developed rapidly in the last 2 years. The Landsat ETM and DEM data of the coastal area produced spatial information representing coastal morphology (Marfai & King, 2008). Digital image processing methods have been used to produce hill shade, slope, minimum, and maximum curvature maps based on SRTM DEM for detection of morphologic traces. Combining these maps with Landsat ETM and seismo-tectonic data in a GIS database allow the delineation of coastal regions. This approach is useful for Tsunami analysis.

In this research, we suggest a new approach to analyze sand dune development using DInSAR processing of ALOS PALSAR data. We carried out an assessment of impact of Tsunami inundation on a coastal segment in Parangtritis, Bantul, Yogyakarta Province of Indonesia. Three main reasons underlying this research are (1) The southern part of Java coastal area has been identified as one of the most vulnerable areas due to past Tsunami and is prone to damage caused by future occurrence of Tsunami (Mardiatno *et al*., 2011); (2) Observing sand dune condition in Parangtritis iportant for planning of conservation; (3) The local government is willing to formulate action plan for disaster risk reduction. In this case, results of our study will be used to support governmental program. Furthermore, to the best of our knowledge, coastal land-use planning in general failed to consider potential role of extreme hazard facing the coastal area.

The result of satellite analysis is compared with our ground survey data obtained in 2007 to confirm the reliability of the proposed method. We discuss the advantages and limitations of advanced DInSAR processing on ALOS PALSAR imaginary. We found that the DInSAR technique is able to map sand dune development for all type of coastal area.

STUDY AREA AND DATA

Parangtritis Coastal Area

Parangtritis is located at Bantul Regency, Yogyakarta Province, Indonesia. Bantul regency is one of five regencies in Yogyakarta and lies between 7044′ 04″ to 0800′ 27″ S and 110012′ 34″ to 110031′ 98″ E. The north, east, and west Bantul region are bordered by Sleman Regency while the south of Bantul is bordered by Indian Ocean. Parangtritis village is separated by 11 sub-villages. The study area of this research is Macingan sub village. The size of study area is 141 km^2 with 1436 population. The population data are based on family registration cards. That is, population density in the study area is 4.85 per km^2.

The south coast of Bantul Regency is relatively vulnerable to Tsunami hazards. In particular, the area surrounding the Parangtritis Opak river is vulnerable to Tsunami due its morphological condition. Based on the history of Tsunami in Cilacap and in Banyuwangi, the Tsunami reached 14 meters of height. Based on data from the Tsunami wave height in the south coast of Java Island, the sand dune area reached 1 kilometer wide and 4 kilometers long. Vegetations retained by a high Tsunami waves reached 14 meters. In addition, the sandbanks were also functioning to reduce the volume of flow Tsunami.

Some areas in Parangtritis have low vulnerability. For example, Parangtritis laboratory was secured against 14 meters height Tsunami as the laboratory was protected by sandbanks and luxuriance of vegetation. Settlements along the eastern part coastal area of the Opak river are very vulnerable because the river is the entry point of Tsunami waves. Destructive force of this wave may have been slow, but the volume of water remains high. If there is a Tsunami with 14 meters height, the plains along the River Opak and alluvial plain or wetland will become storage of water. Settlements and rice fields also have high vulnerability. **Figure2** shows the research area in Parangtritis Coastal area. The Tsunami that hit Java on July 17th, 2006 was not a small event. Initial estimation of height of wave was between 2 m and 3 m. However, it turned out that waves were more than 7 m high in some areas and traveled several hundred meters inland. The Tsunami destroyed scores of houses, restaurants and hotels. Cars, motorbikes and boats were left mangled amid fishing nets, furniture and other debris.

Fig. 2 Parangtritis Coastal Area of Bantul Regency, Yogyakarta Province, Indonesia.

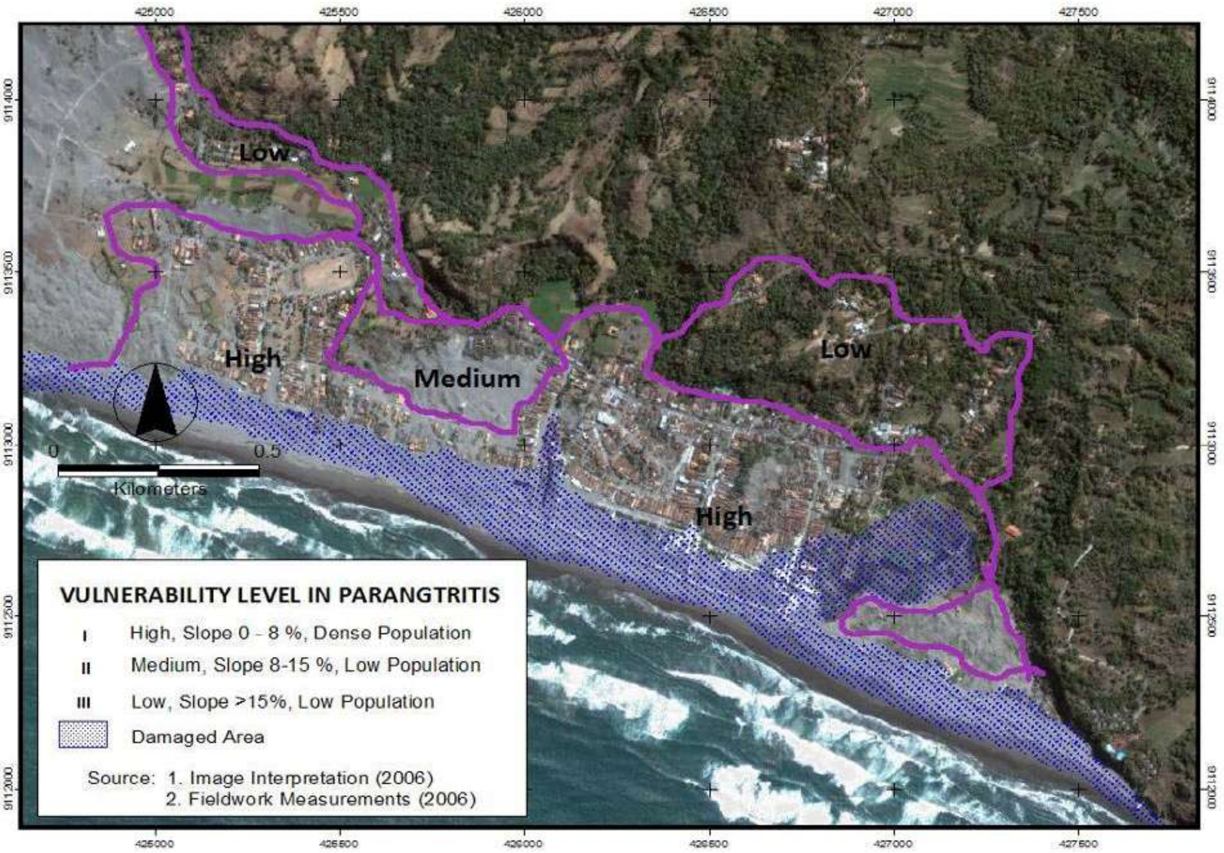

Fig. 3 Map of damage area in Parangtritis (Giyanto, *et al.*, 2007).

Previous research (Giyanto *et al.*, 2007) has made a damage area map as shown in **Fig. 3**. The research suggested three results. First, 18 % area was destroyed in last Tsunami in 2006. Second, close relationship of the coastal morphology and Tsunami impact shows that low land area has been highly destructed by Tsunami because it was crushed on the first place. This research also proves that sand dune has important role as natural barrier that act as water breaker. Third, eight building clusters were classified with different building characteristics and slope condition. It is concluded from the calculation that 75 % of total area are classified into highly vulnerable, 10% of total area are medium vulnerable, and 15% of total area are low vulnerable due to Tsunami disaster.

Figure 4 shows the map of Tsunami impact. In Parangtritis village, the elevation of 0–35 m can be found especially in the southern part that is bordered directly by the Indian Ocean. In the northern east, we can find hills with 350 m and 175 m of average elevation (Hara, 2007). Most of beach topographies are flat, especially in the eastern part near the cliff, and gradually steeper toward the west near the Opak river. In the landward of the beach, we can find large areas with sand dune of several types such as barchans and longitudinal dunes (Sutikno *et al.*, 1998). Parangtritis beach stretches along approximately 7 km in east-west direction, started from cliff in the east to the Opak river mouth in the west. According to Sunarto (2008) Parangtritis is classified as a depositional coast.

The geomorphological processes in this area were fluvial, Aeolian, and Marine origin, such as river deposition, coastal erosion, and windblown deposition. Coastal sedimentation process is caused by wind and sea waves (Trihatmojo, 2000). Winds generate sea waves and it shifts along the shoreline and transports the sediment. Winds also generate specific landform in this area and forms sand dune in the coastal area. Sand dune has specific requirements: it can be developed in humid area with high speed windblown and open coastal area. In Parangtritis beach, we can find some sand dunes that are formed more than 15 meters height and have specific shape like barchans. Parangtritis landform unit area is shown in **Fig. 5**.

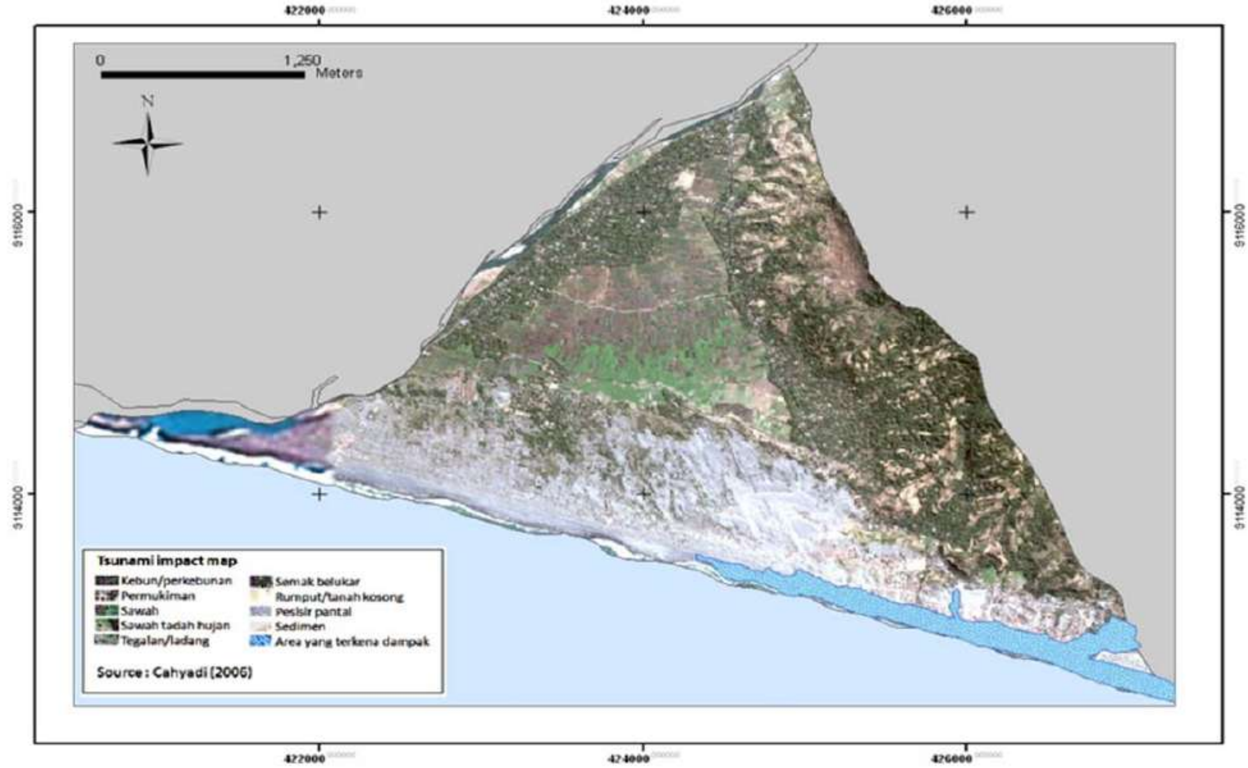

Fig. 4 Tsunami impact map.

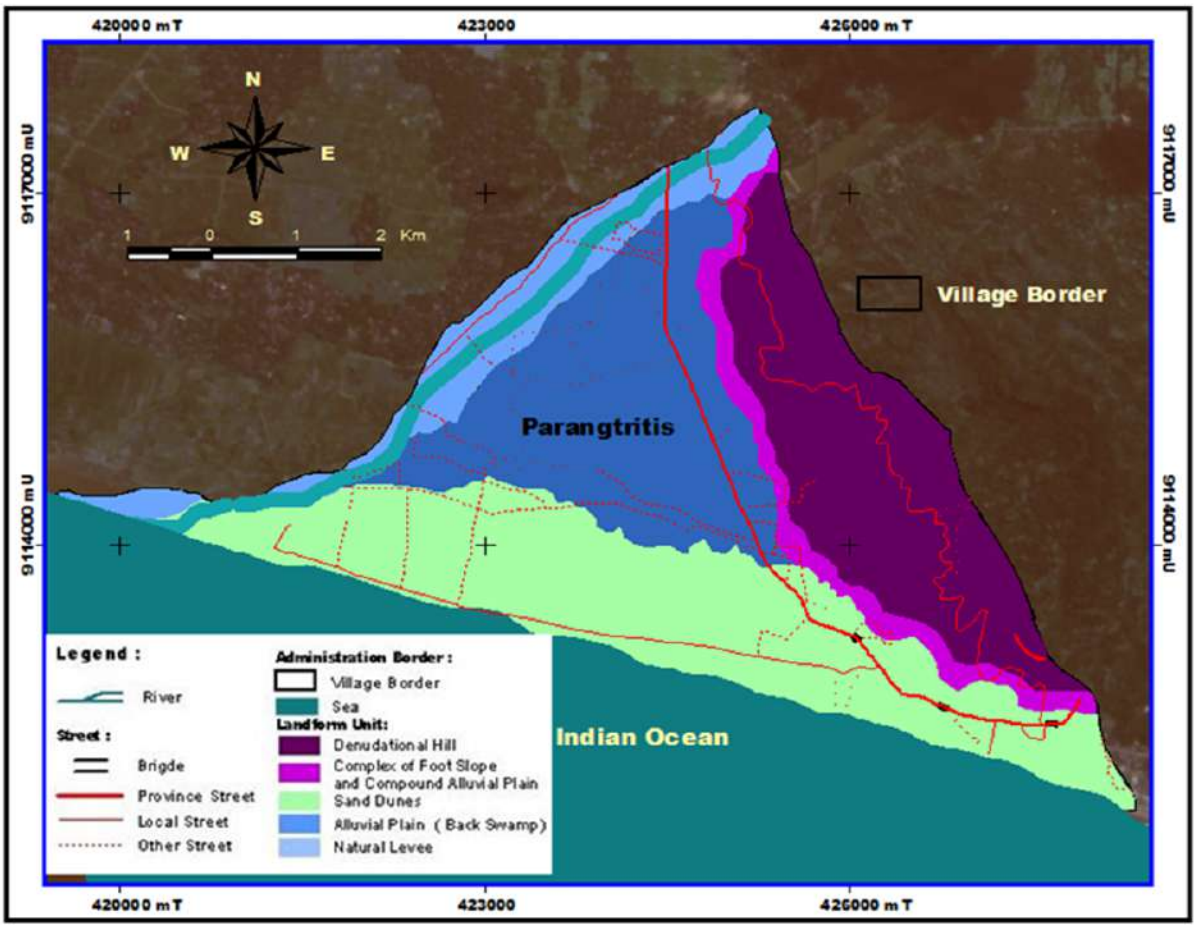

Fig. 5 Landform unit map of study area.

As a result, this coastal area was delineated into three parts, old, mature and young beach ridges. Furthermore, there are swales between these beach ridges. Sometimes the swales are filled up by water and they generate swamp or lagoon if there is a marine process. The old beach ridge has gentle slope with some undulating dunes. The mature beach ridge has almost flat slope and some parts consist of big sand dune. In the young beach ridge, the dominant process is marine origin with very active sedimentation and erosion processes shifting each others. Geological condition of the study area is quaternary alluvium deposition. Lithological composition consist of sand (in young beach ridge), sand combined with gravel, and clay in old beach ridge. In 3 meters depth, we can find sand beach deposition. Lagoon deposit can be found in 3−3.6 meters depth. Hendratno & Karnawati (2000) divided Parangtritis into two landforms: Parangtritis coastal lowland and Parangtritis coastal highland. Parangtritis coastal lowland is characterized by sandy volcanic beach, while coastal highland is marked by limestone cliffed coast and andecite cliffed coast. The beach profile in the coastal lowland shows the existence of foreshore, backshore and dune. In coastal highland, coastline is directly coincide with cliff. Distribution of grain size in Parangtritis beach gradually changes in diameter from east to west (Sutikno *et al.*, 1998). The sand dune phenomena is described in **Fig. 6**.

Sand Dune and Tsunami Data

In this research, simulation of Tsunami flow is based on the original terrain or topography as the condition of this area is not natural. Government has built the dike to protect the surrounding area. Potential Tsunami flow inundation is created based on original DEM and this scenario is useful to simulate and to predict how far the inundation will be in certain direction and heights of Tsunami wave. This stage consists of a set of practical work described below:

(a) Generating original DEM.

This map represents the terrain before Tsunami of July 17th, 2006. It is derived from topographic maps. This DEM will be used to simulate the potential inundation of Tsunami flow for 5, 10, 15, 20, 25, and 30 m. The grid-based DTM was generated from topographic maps at a scale 1:10 000 using krigging interpolation. The grid size is 10 meters to maintain its relief detail and accuracy.

(b) Generated actual DEM

This map represents the relief changes on the study area. The preparation phase comprises such as literature study, ancillary data collection, and fieldwork preparation. The literature study mostly deals with the Tsunami hazard, GIS Simulation, and RS sand dune analysis and conservation. The ALOS PALSAR and data availability are showed in **Tables 2–3**. Sand dune conservation mapping and Tsunami hazard modeling map use several satellite data as follow:

1. ALOS PALSAR, IKONOS, ALOS AVNIR and LANDSAT satellite image of Parangtritis, South Coastal Bantul Regency (this data are used to get landcover check accuration).

Fig. 6 Quickbird Image of Study Area; Inset: Sand Dune (Source: Google Earth, 2006)

Table 2. ALOS PALSAR Data of Parangtritis coastal area

No	Scene Center Date	Observation Mode	Observation Path	Center Frame Number	A/D Quality	Scene ID	Product Level
1	2007/08/10	FBD (HH, HV)	432	7020	Ascending	ALSPSRP' 082207020	1.0 (Raw Data)
2	2008/08/12	FBD (HH, HV)	432	7020	Ascending	ALSPSRP 135887020	1.0 (Raw Data)
3	2009/08/15	FBD (HH, HV)	432	7020	Ascending	ALSPSRP 189567020	1.0 (Raw Data)
4	2008/05/12	FBD (HH, HV)	432	7020	Ascending	ALSPSRP 122467020	1.0 (Raw Data)

Table 3. Data availability

Data type	Available	Source	Description	Processing Phase
Tsunami Events Data	√	NGDC, 2007	Historical Events Database	Frequency analysis
Tsunami 17th July 2006	√	Fieldwork, 2006	Evidence, validation aspects of the study result	Field database
Topoc Map - General - Detail	√ -	- BIF, 2000 - Fieldwork	-Use for generating DEM -Detailed DEM	DGPS Measurement
Landuse Map - General - Detail	√ -	- BIG, 2005 - Fieldwork	for calculating elements At risk	Calculating area of elements at risk.
Geological Map - General	√	DGTL, 1994	General description	General description
Bathymetry Map - General - Detail	√ -	-Dishidros, 1998 -Fieldwork	- General Bathymetry - Detailed Bathymetry	-Interpolating contours point - Echo-Sounding
Satellite Images - Low-res - Medium-res - High-res	√ √ √	-Landsat ETM,SRTM -ALOS AVNIR image recording in June 2006 -Ikonos,Quickbird -ALOS – PALSAR, 2007 – 2008	- General description of Landcover Detailed spatial distribution of inundation hazard - Detailed sand dune topographic mapping	Image Classification, Image interpretation and Simulation
Demography Data	√	Central Statistics Agency, 2008	Demographic condition (People, density, age, etc)	Demographic Analysis

2. Topographic map (Brosot, Bantul and Imogiri Sheet Year 2000) with 1 : 25 000 of scale.
3. SRTM satellite image with spatial resolution 30 meters (elevation information).

(a) ALOS PALSAR image correction

The beginning process or preprocessing as to make several satellite image can be used with correct data and give accurate information as geometric and radiometric correction. Processing of initial or pre-processing operations (preprocessing) is a conditioning operation to be used so that the image actually provides accurate information and radiometric geometrically. This is an image correction process either geometrically or radiometric, because this correction is an attempt to rebuild the spectral and the geometric appearance of the image as it should, then this correction is sometimes called a process of image restoration.

(b) Land cover interpretation

Land cover interpretation is very important to do before doing field survey. This interpretation used ALOS satellite image with spatial resolution 10 m and used 9 interpretation element of remote sensing. The land cover classification using Malingrau classification with modification.

(c) Landform interpretation using Landsat and SRTM & sand dune zonation using ALOS PALSAR and IKONOS.

(d) Making Terrain Mapping Unit.

(e) Sample Point Location Determination

Location of sample estimates of sand dune actual condition mapping is obtained by performing an overlay of a map of land forms and sand dune topographic detail maps.

(f) Delineating the land cover to determine surface roughness coefficient.

METHOD

The inundation zone due to tsunami would be determined using the predicted water depth scenario (Putri *et al.*, 2010; Putri & Sumantyo, 2012). This study intends to identify the inundation zone of the hypothetical water depth scenario and detecting sand dune areas. Unfortunately, we exclude the physical mechanisms or hydrodynamic characteristics of tsunami during generation, propagation, or inundation. Moreover, we do not consider factor such as tsunami source region and coastal configuration during inundation. Due to the lack of data and information pertaining to the detailed scale of the bathymetry on the study area, and take consideration that obtaining such data could be time consuming and very expensive, this study also ignored the bathymetry of the seabed for identification of the inundation zone. The formulation of Tsunami inundation wave simulation as below:

The relationship between the height of the tsunami, the coefficient of roughness, and distance towards land was formulated as follows:

$$X_{\max} = \frac{0.06H_0^{4/3}}{n^2} \quad (1)$$

where:

X_{max}: Maximum distance the Tsunami on land from the shoreline;

H_0: Height of waves at the shoreline;

n: Roughness coefficient (0.015 to 0.07)

To calculate the loss per 1 m wave height, it can be done with the derivative of equation 2 thus obtained to lose altitude to 1 m of the run-ins as shown in equation 3 (Berryman, 2006):

$$\frac{dH}{dX} = \frac{12Sn^2}{H_0^{2/3}} \quad (2)$$

To follow the condition of the surface which has a surface height variation, Equation 2 is modified by entering a determining factor as to lose altitude slopes of the Tsunami as shown in the following equation formulated by Berryman:

$$H_{loss} = \left(\frac{16.7n^2}{H_0^{1/3}}\right) + 0.5\sin S \quad (3)$$

where:

Hloss : Losing altitude for the 1 m distance Tsunami propagation

n : Roughness coefficient

H_0 : Initial height of the Tsunami on the coastline

S : Surface of Slope

The correlation between the speed of the Tsunami on the mainland can be formulated as shown in the following equation:

$$u = \sqrt{2gh} \quad (4)$$

where :

u : Wave Velocity

g : Gravitation Velocity

h : Depth of Inundation

Equation (4) shows that the velocity is proportional to the height of the Tsunami inundation. Tsunami in Parangtritis area was simulated with scenarios of 5 m, 10 m, 15 m, 20 m, 25 m and 30 m with different wave direction (i.e. West, South and South-West wave direction). These variations represented possible scenarios on South Coast of Java. Previous field measurement reported that the measured run up heights (RU) along the South Coast of Java between Batukaras and Baron ranged from less than 1 m to 15.7 m (Putri *et al.*, 2011). Since run up elevation is independent variable, the adding data **Eq. (4)** are slope and roughness coefficient form land use map. The surface roughness coefficient can be shown in **Table 4**. Tsunami wave scenario measurement is shown on **Fig. 7**.

Fig. 7 Tsunami wave scenario measurement.

Table 4. Landuse roughness coefficient

No	Landuse	Roughness Coefficient
1	River	0.007
2	Sand dune	0.018
3	Swamp forest	0.025
4	Dense Forest	0.070
5	Bush	0.040
6	Plantation	0.035
7	Dry Land	0.030
8	Build Up Area	0.045
9	Rice field	0.020
10	Barren land	0.015

The DEM can be generated to slope map as follow: the slope is obtained by topographic map and using raster data by Ilwis 3.3 processing software. Sand dune conservation zone mapping will be correlated to coastal regulation zone in Parangtritis coastal area. Determination of the conservation zone aims to optimize sand dune function as a barrier Tsunami inundation hazard.

Differential Interferometry Synthetic Aperture Radar (DInSAR)

The method used in this research is Differential Synthetic Aperture Radar Interferometry (DInSAR). DInSAR is a technique useful for accurate detecting the ground displacement or land deformation in the antenna line-of-sight (slant-range) direction using synthetic aperture radar (SAR) data taken at two separate acquisition times. The DInSAR method is complementary to ground-based methods such as leveling and global positioning system (GPS) measurements, yielding information in a wide coverage area even when the area is inaccessible.

However, the application of ALOS PALSAR data to detect sand dune in Parangtritis has never been done in previous literatures. In this research, we propose a novel sand dune monitoring approach using DInSAR analysis on L-Band, comparing the accuracy with the results of GPS measurements and DInSAR analysis. The ALOS PALSAR data was used, because this data could produce more detailed scale or high spatial resolution for sand dune monitoring in coastal area. The DInSAR analysis was implemented using the L-Band Data data from 2006 to 2016. The result of satellite analysis was compared with ground survey data taken by previous study in 2006 to confirm the reliability of the proposed method. The schematic of research method is described in **Fig. 8**.

In the first stage of the DInSAR technique, the phase data of SAR images are analyzed to derive the local topography (original InSAR). Subsequently, the phase difference between the two SAR data obtained at different acquisition times are employed to detect and quantify the ground displacement that has occurred in the slant-range direction between the two acquisitions (DInSAR) (Putri *et al.*, 2013). The two radar images are matched point by point to form the interferogram with the phase difference. The phase modification in the differential interferograms contains errors such as the DEM error in the digital elevation model (DEM) employed for the analysis, atmospheric error (or inhomogeneities if its effect is eliminated), residual orbital distortions and sand dune surface displacement. The phase difference between an InSAR data pair (ϕ_Int) can be derived as follows (Raucoules *et al.*, 2007):

$$\phi_{Int} = \phi_{disp} + \phi_{topo} + \phi_{atm} + \phi_{noise} + \phi_{flat} \quad (5)$$

where ϕ_{disp} is the phase due to the sand dune surface displacement, (ϕ_{topo}) is the phase because of topographical height, ϕ_{atm} is the phase due to atmospheric effect, ϕ_{noise} the phase due to noise from the radar device, ϕ_{flat} the phase due to error associated with the assumption of the ideally flat earth terrain. In the process of extracting the sand dune surface displacement, the topographic (ϕ_{topo}) and flat earth (ϕ_{flat}) phase differences should be eliminated using the DEM data coupled with accurate satellite orbital data. The result of DInSAR technique estimates the sand dune surface displacement in the slant-range direction. The sand dune surface displacement in the vertical direction, Δz, can be expressed as (Putri *et al.*, 2013):

$$\Delta z = \Delta s \cos\theta \quad (6)$$

where Δs the slant-range change caused by ground displacement, and θ is the incidence angle. In the present study, the entire incidence angle for the target area was in a rage of 20 to 45°.

Sampling Technique

We implement sampling technique for sand dune zonation using image interpretation and photogrametric method. Image interpretation in this research is done using IKONOS and ALOS PALSAR satellite image with SIGMA SAR processing software. SRTM satellite image with spatial resolution 30 meters can be used to get elevation information on Tsunami inundation model. This step was done in order to get the detail geomorphologic features of research area, landform classification based on their origin including here the geomorphologic process, lineament and geological structure identification, and land use mapping. During this phase, ground control point (GCP) was collected. The GCP was used to do DGPS measurement.

List of respondences (stakeholder, society and sand river minning worker) and coordinate information for each sand river minning and sand dune are was prepared. There were sand river minning worker in arround Opak river Bantul Regency. Based on information gathered from literature review and discussion with stakeholder (government, sand river minning worker and society in Parangtritis coastal area) is considered as the most suffered from Tsunami inundation area in around Sand dune conservation area, for that reason the sample in this area is larger than other. The different sampling fractions was used in every stakeholder for this research with purpossive sampling. The research methodology is shown on **Fig. 8**.

Data Accuration

Accuracy test is conducted to determine the accuracy of visual interpretation of the image of ALOS. This interpretation accuracy depends on each individual to recognize objects based on elements of interpretation.

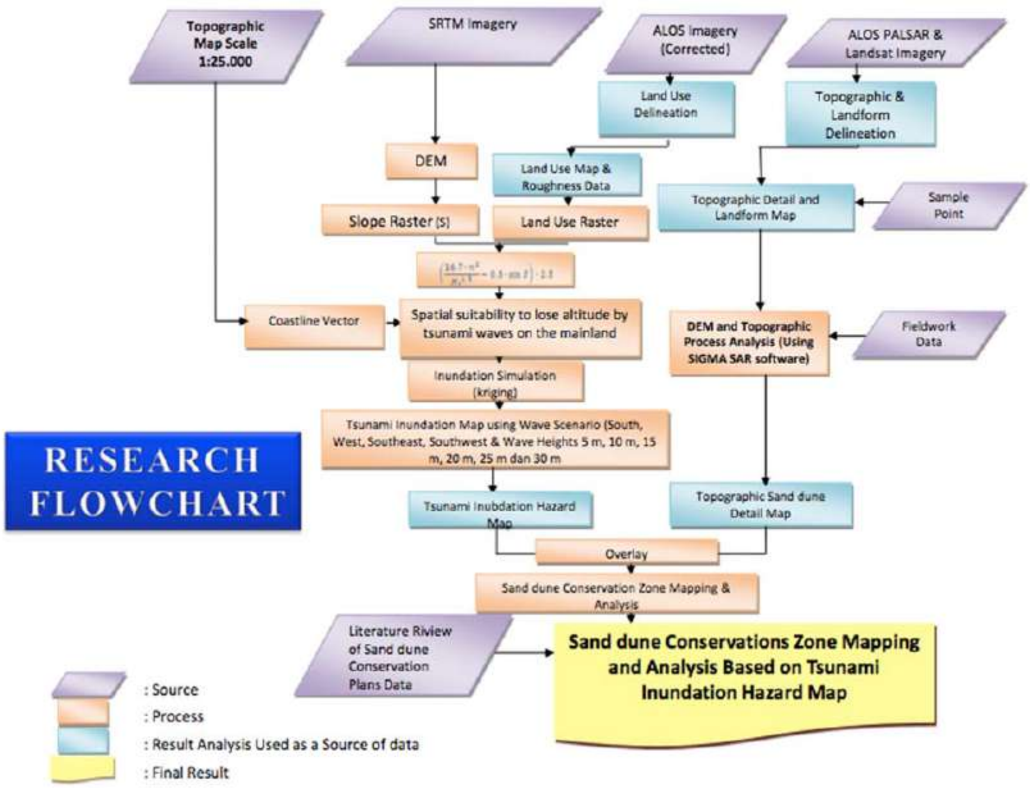

Fig. 8 Research methodology.

$$\text{Accuracy} = \frac{The\ number\ of\ correct\ interpretation}{The\ whole\ object\ in\ the\ field} \quad (7)$$

RESULTS AND DISCUSION

Sand Dune Using DInSAR Technique

Research of sand dune areas is challenging as not only the land cover (vegetation, biogenic soil crusts, human uses) varies in space and time, but also the topographic features of the landscape may change over short time spans of several years. Measuring these dynamics is essential for understanding of these areas. The Survey of Fieldwork DRMs constructed from 1:25 000 maps is unstatisfactory as it is based on 10 m contours. Whereas the average height of the dunes is about 10 m. **Figure 9** describes the coherence map of sand dune zone using DInSAR technique.

The DEMs (Digital Elevation Model) were created from detailed contours (vertical spacing of 0.5 m) that were measured with photogrammetry. The contours data were converted into a DEM using the triangulation method. A DEM with similar dune characteristics was used to calculate cos(i) values for the time of the two images. The method proposed in this treats is usually considered as unwanted additional variability in satellite images (the topographic effects) as a signal. The method also estimates the slope and aspect of the dune terrain. Sand dune data was obtained with high resolution DEMs for the different dune types-barchan, parabolic, transverse, and linier. For each dune, mean of length, width, spacing, orientation, and height were calculated.

To predict the expected shading on a given sand dune's area, the DEM was chosen according to the dune type and the rotated and stretched to fit the actual orientation and spacing (that could be visually estimated). The developed method offered new opportunities for studies of Aeolian geomorphology, proposing ability to analyze dynamic aspects of sand dunes topography in time and space. The Three Dimensional Sand dune elevation of Parangtritis using DInSAR technique are described in **Fig. 10** and **Table 5**.

A uniform image grid was passed with Krigging interpolation mapping. Variance of each interpolated sample was calculated based on the distances between the data, the position of the cell to be interpolated, and the estimated error variance on each data sample. This calculation was performed to obtain more accurate results. The areas affected by foreshortening in one satellite acquisition mode (e.g. ascending) gave rise to high variance samples; since only a few data were available, the average distances between them was large and usually they were strongly affected by geometrical decorrelation. The result of DInSAR Processing on sand dune area can be shown in **Fig. 9**.

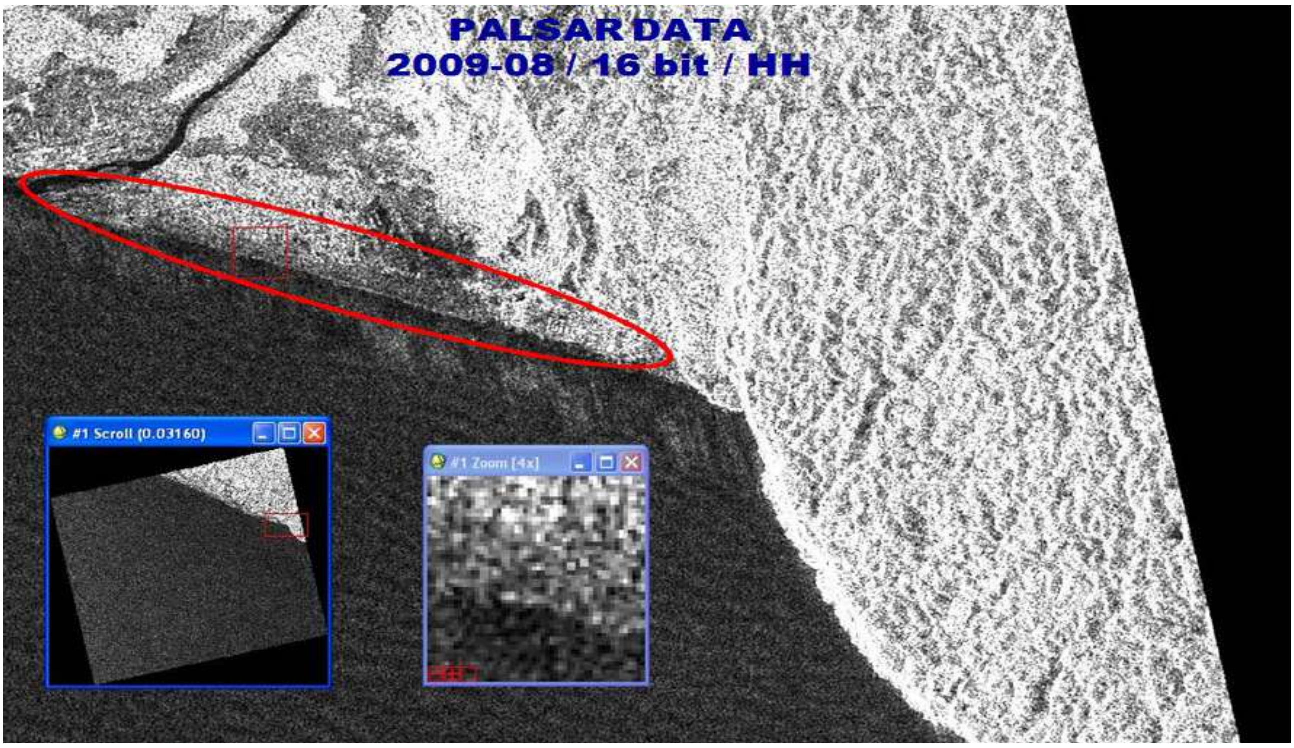

Fig. 9 Coherence map of Sand Dune Zone using DInSAR technique.

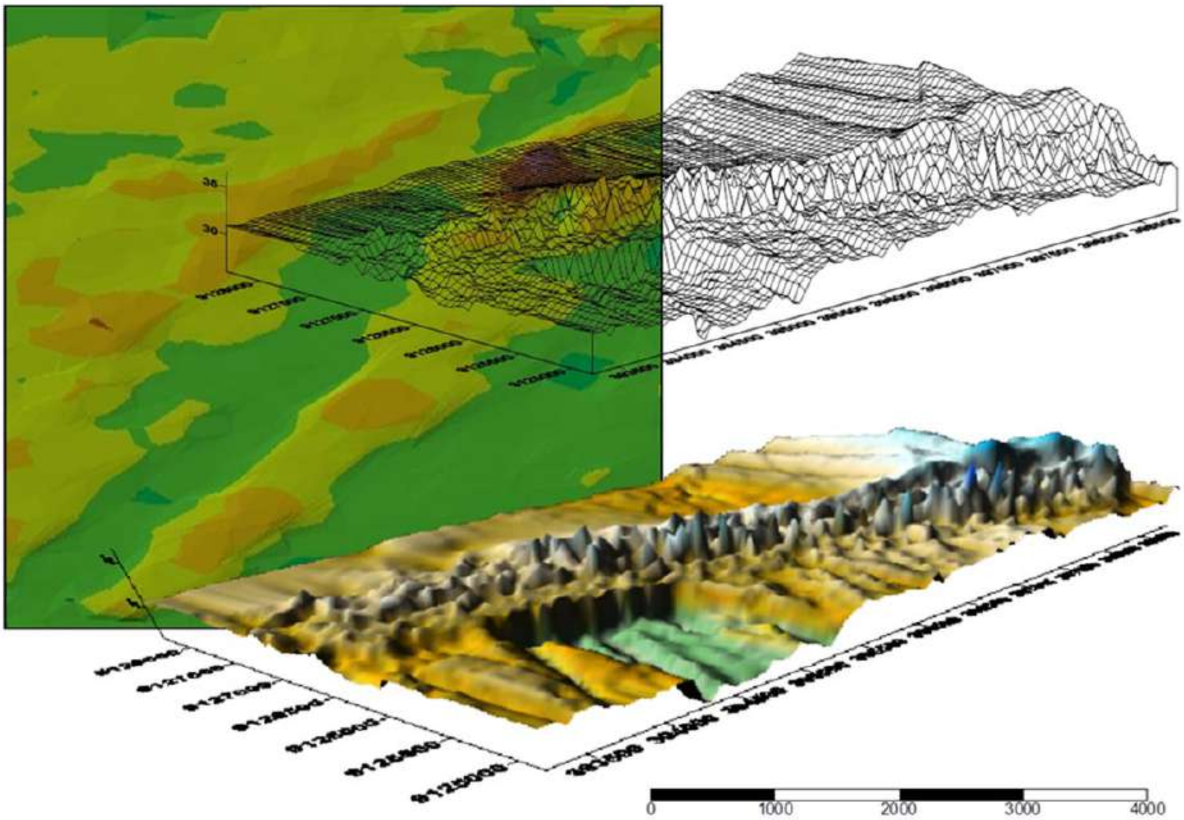

Fig. 10 Three dimensional Sand Dune mapping in Parangtritis Coastal Area.

Table 5. Sand dune elevation zone

No	Sand dune Elevation	Hectare (Ha)
1	1 m	3,675
2	2 m	197,577
3	4 m	44,351
4	5 m	3,172
5	6 m	72,992
6	7 m	0,512
7	8 m	0,445
8	9 m	24,497
9	10 m	15,286
10	12 m	0,538
11	13 m	53,56
12	16 m	0,688
13	19 m	0,136
14	20 m	2,174
15	50 m	0,809

Source: Data Calculation, 2016

Figure 10 shows Digital Elevation Model of Parangtritis area. Final DEM of these areas resembles topography estimated from data relative to the opposite acquisition geometry (descending), where the spatial sampling (for areas not in shadow) is good and the geometrical decorrelation is lower. The Three Dimensional of Sand Dune visualization using DEMs was used to predict the expected shading on a given sand dune área. The DEM was chosen according to the dune type, the rotated, and the stretched to fit the actual area orientation and spacing.

Tsunami hazard modeling

The Tsunami inundation hazard map was simulated by estimating the propagation of inundation per pixel with consideration of slope, surface roughness coefficient, wave direction, and wave height variations. Inundation model was done based on roughness coefficient parameter, the wave per meter of inundation distance, and slope in study area. Delineation of land use were used to determine surface roughness coefficient. This roughness coefficient is important because consequently influencing when inundation was done of this simulation. We detected propagation calculations per pixel that passes through the use of certain land and a certain slope, and the reduction in height of the Tsunami.

To obtain the Tsunami inundation maps, various approaches have been done, for example through a simple model based on contour lines or slope, based on the coefficient of surface roughness (roughness coefficient) and complex mathematical models. Because of the limited available data, the Tsunami inundation maps were displayed using the events in the year 2006 of Tsunami occurrence in southern Java. Measurement was done through a search incident track record in the

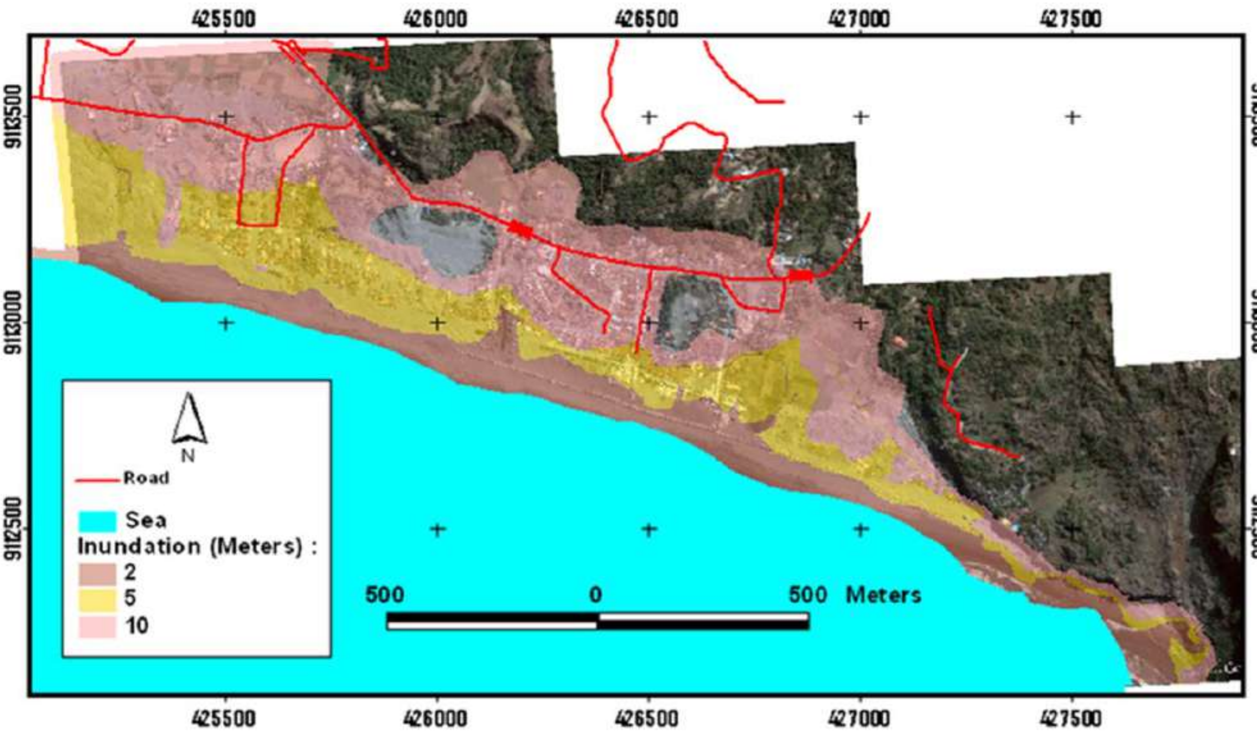

Fig. 11 Tsunami inundation map scenario

field to observe the remnants of which still left a puddle on the ground, like at the beach, trees, house walls, etc. This method is therefore considered as a simple method. However, this would make the methodology attractive for local authorities and coastal manager. **Figure 11** shows Tsunami Inundation Map Scenario in Parangtritis coastal area. Simulation of Tsunami inundation, sand dune actual condition, and human activity (e.g. sand river mining) can be used for some planning on conservation model based on physical and social condition that has influence of sand dune development. Qualitative data can be used to support the quantitative data. Further, sand dune conservation assessment can be made base on Tsunami inundation area and analysis of quantitative-qualitative data.

We can observe the direction of waves arrival in the stagnant area of influence based on simulation results of Tsunami inundation on the mainland. At the 30 meters of height, the most extensive inundated area occurs when the waves come from the southwest or an angle almost perpendicular to the coastline. The inundation area is 419 144 hectares. The smallest inundated area occurs if the direction of the incoming waves is from the southeast. The 30 meters Tsunami waves scenario inundates the broader agricultural area.

If the waves come from the south, it inundates an area of 3038 hectares of rice fields. The most extensive inundation occurrs when the waves come from the southwest. The inundated area is about 18,209 hectares. When the Tsunami comes with 5 meters of run up scenario, the whole model shows that there is no field flooded.

Inundation area from this scenario has linear regression relationship. Linear regression attempts to explain this relationship with a straight line fit to the data. Regression analysis is the statistical method for defining an algorithm that describes a set of data. The advantage of regression is that it will find a pattern or trend in the data. The disadvantage of regression analysis is that the pattern may not be useful or valid. Distribution of inundation depends on the direction of the Tsunami wave coming, wave height, surface roughness, and slope. Tsunami inundation zone for 30 meters scenario has 178.280 hectares (west wave direction); 369.138 hectares (southwest wave direction); 365.402 hectares (south wave direction); and 266.041 hectares (southeast wave direction). Tsunami inundation zone for 15 meters scenario has 95.246 hectares (west wave direction); 276.742 hectares (southwest wave direction); 247.954 hectares (south wave direction); and 153.249 hectares (southeast wave direction). Spatial distribution on a variety of Tsunami wave height and direction is presented in **Figs 12–13**. The description of Tsunami wave distribution is showed in **Table 6**.

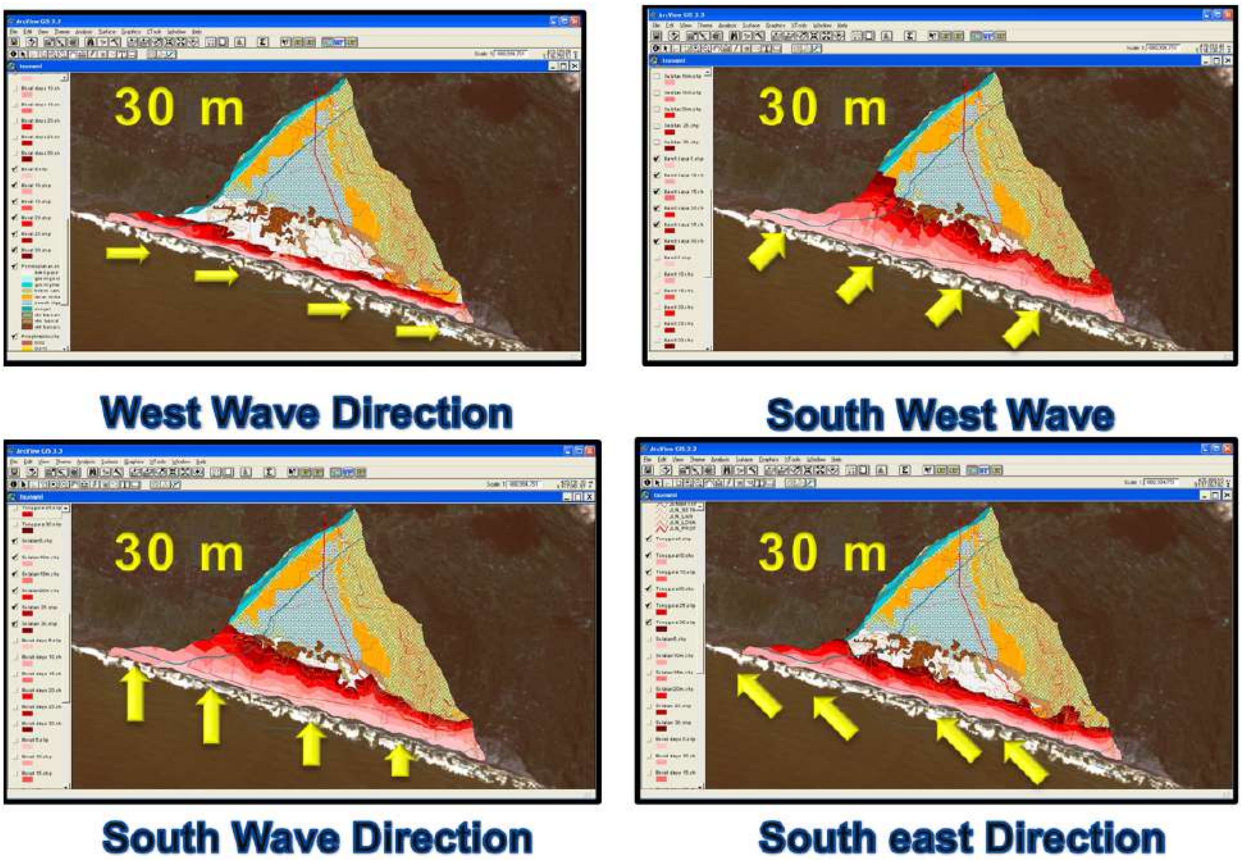

Fig. 12 Tsunami elevation scenario in 30 meters.

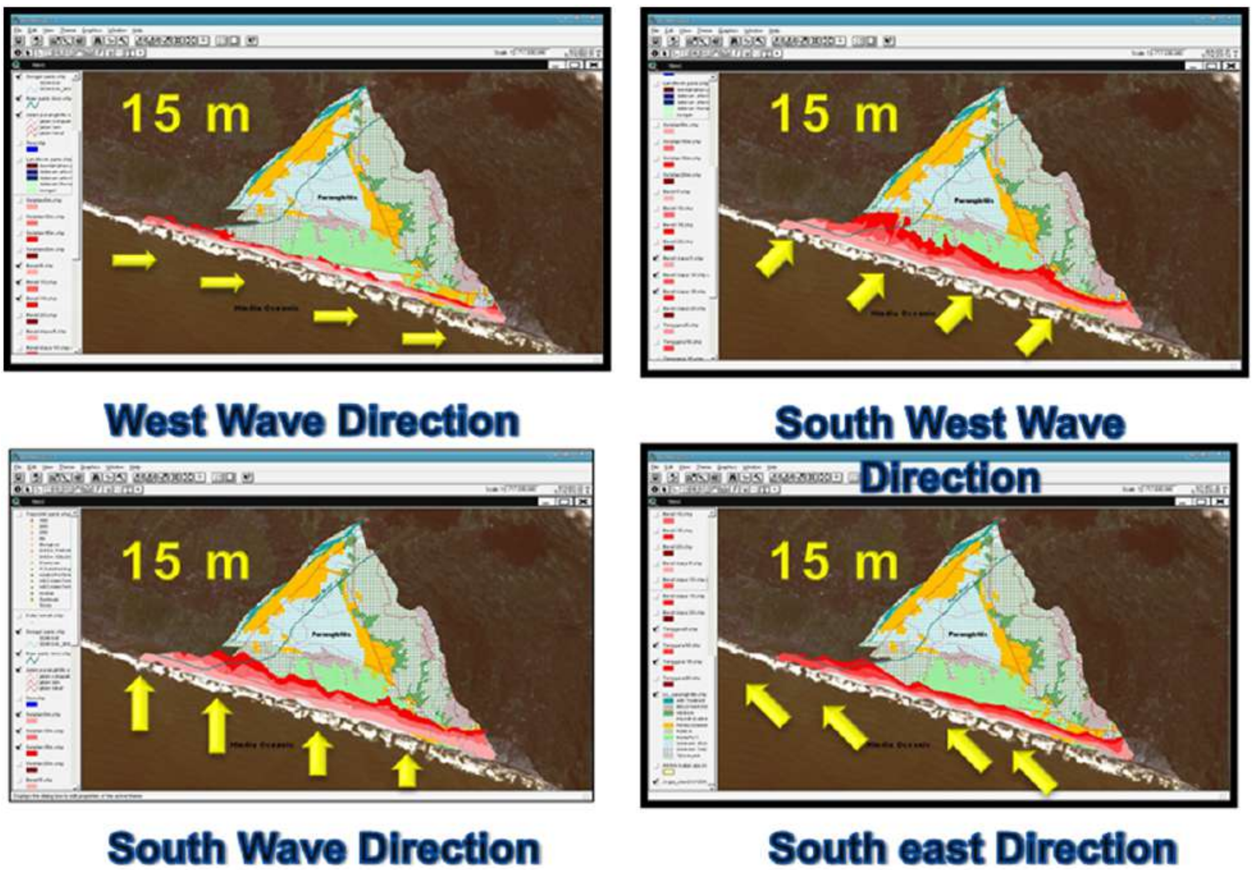

Fig. 13 Tsunami elevation scenario in 15 meters.

Table 6. Tsunami wave scenario on Sand Dune area

Tsunami Inundation Scenarios (Height & Direction of Wave)		Non Inundation Area of Sand dune Zone (ha)	Inundation Area of Sand dune Zone (ha)
West	30 m	0	178.280
	15 m	0.030	95.246
South	30 m	0.809	365.402
	15 m	2.859	247.954
Southwest	30 m	0.809	369.138
	15 m	2.739	276.742
Southeast	30 m	0	266.041
	15 m	6.265	153.249

Source: Data Calculation, 2016

Sand dune conservation zone is created in this research by assessment on Tsunami area impact in Parangtritis. The scenario of Tsunami wave has different impact in every elevation sand dune zone. **Figures 14–17** show sand dune conservation zone based on Tsunami hazard for every direction wave scenarios. CRZ symbol on the map describes the coastal regulation zone of landuse area priority for sand dune conservation zone. Explicit legal protection was afforded to the Parangtritis coastline by the Coastal Regulation Zone (CRZ) Notification, 1991, issued under the Environment (Protection) Act, 1986. The protection was conducted by firstly zoning the entire coast on the basis of the demographic and ecological characteristics into CRZ-I, II and III areas. CRZ-I are ecologically sensitive areas where activities are largely prohibited (Conservation Area), CRZ-II comprise developed areas and CRZ-III comprise all rural areas as well as undeveloped areas in urban limits. The notification declares all coastal stretches of seas, bays, estuaries, creeks, rivers and backwaters which are influenced by tidal action (in the landward side) up to 500 m from the High Tide Line (HTL) and the land between the Low Tide Line (LTL) and the HTL as the Coastal Regulation Zone. The CRZ overlaid regulations on development, namely a set of prohibited and permitted activities pertaining to each zone. The CRZ Notification explicitly mandated the protection of sand dunes. According to the notification, sand mining is a prohibited activity on the mainland coast. Percentage area of coastal regulation zone is explained on **Table 7**.

Table 7. Coastal regulation zone based on tsunami inundation area

Tsunami Inundation Area (Scenario : Wave Direction)	CRZ 1		CRZ II		CRZ III	
	Hectare	%	Hectare	%	Hectare	%
West	326.193	78.48	77.923	18.74	11.503	2.76
Southwest	361.058	87.12	53.213	12.80	0.307	0.07
South	360.107	86.56	55.606	13.36	0.307	0.07
Southeast	362.100	87.12	53.217	12.80	0.307	0.07

Source: Data Calculation, 2016

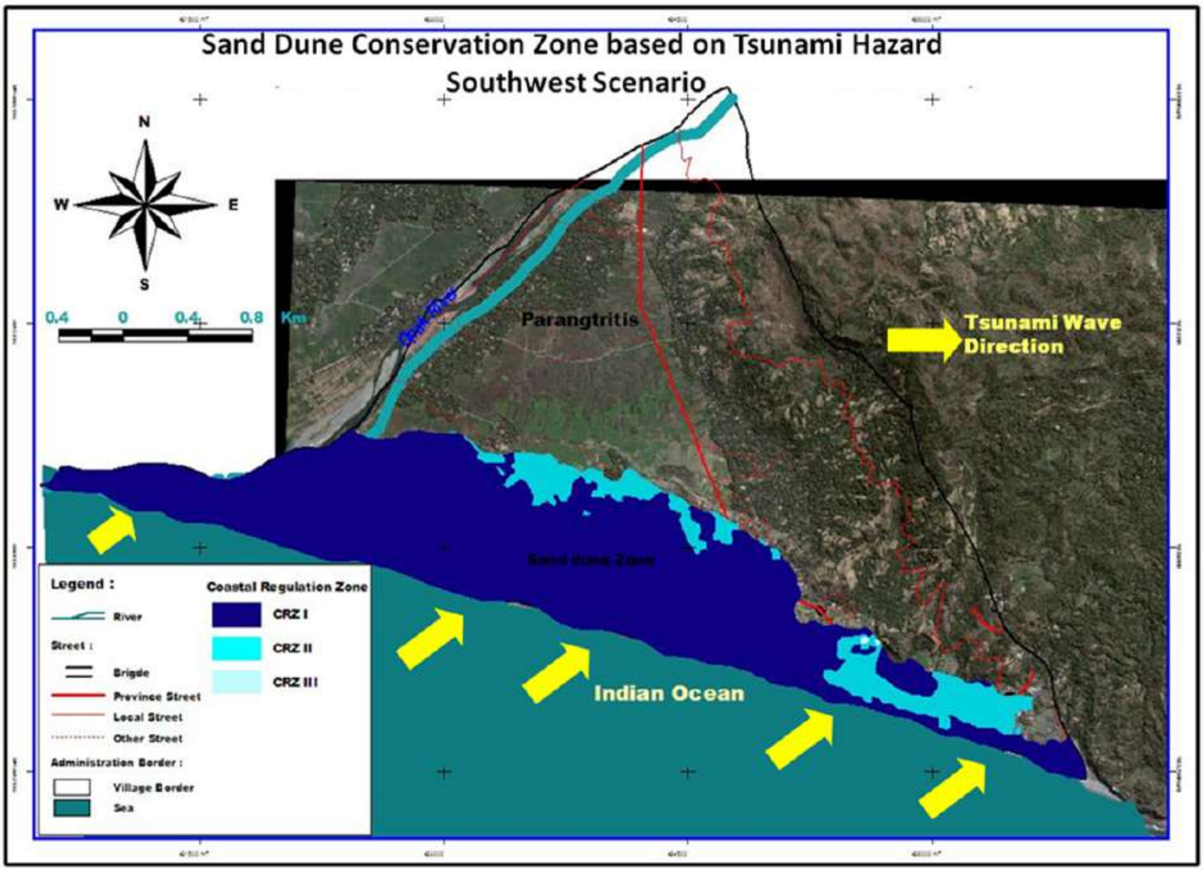

Fig. 14 Sand dune conservation zone map based on Tsunami hazards (Southwest wave scenario).

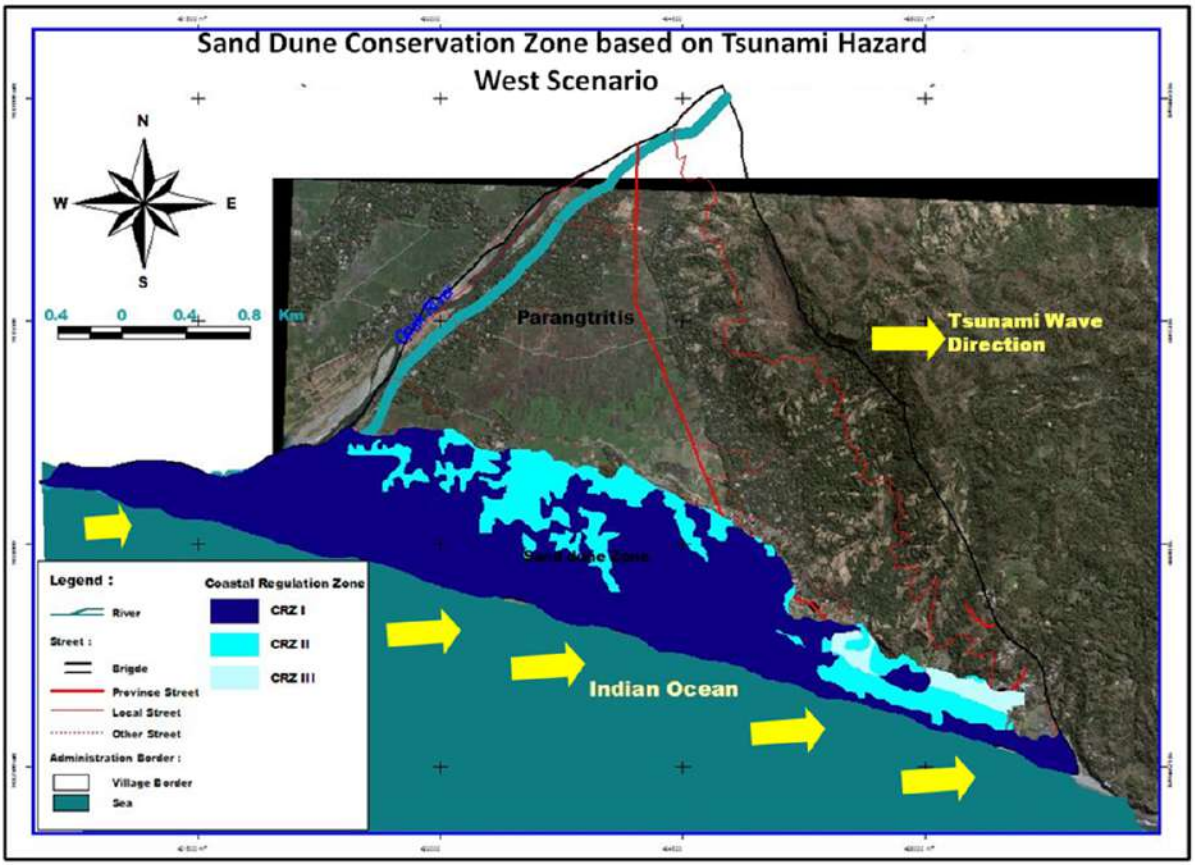

Fig. 15 Sand dune conservation zone map based on Tsunami hazards (West wave scenario).

Total percentage of CRZ area is obtained based on data calculation sand dunes area is flooded by the Tsunami inundation scenario. **Table 7** indicates that the Tsunami inundation scenario (southwest wave direction) has 87.12% CRZ I with an area of about 362.058 ha, CRZ II (12.80%) with an area around 53.213 ha, and CRZ III (0.073%) with an area of 0.307 ha. Sand dune conservation is needed in Coastal Regulation Zone I as these areas are ecologically sensitive areas where activities are largely prohibited (explicitly mandates the protection of sand dunes). In Parangtritis Coastal Area, although the dune systems are protected by CRZ regulations they are still facing many anthropogenic stresses. There has been considerable amount of citizen action over the protection of sand dunes. Coastal Regulation Zone based on Tsunami inundation of west wave direction scenario such as CRZ I approximately 362.193 hectares (78.48%) are ecologically sensitive areas where activities are largely prohibited (explicitly mandates the protection of sand dunes), CRZ II approximately 77.923 Ha (18, 74%) are developed acres agriculture land areas for cultivation and CRZ III approximately 11.503 hectares (2.76%) comprise all rural areas as well as undeveloped areas in urban limits.

Land Use Assessment

Spatial planning in Bantul Regency has been regulated by Regent's Decree No. 4/2002 about Spatial Planning. Regarding to the development activities in coastal area, the Government of Bantul Regency has established semi detailed plan and detailed plan known as "Rencana Detail Tata Ruang Kawasan Pantai Selatan Kabupaten Bantul" or RDTRK Pantai Selatan and "Rencana Teknis Tata Ruang Obyek Wisata Kawasan Parangtritis" or RTOW Kawasan Parangtritis respectively. Concerning with land utilization in coastal area, the buffer zone of 100-200 meter from highest high water line has been established. Further, based on Tsunami and high wave events, Bantul local government established another buffer zone approximately 300 m from highest high water.

Parangtritis local government have to coordination with Bantul for reduce the risk of Tsunami impact and to maximize sand dune function as Tsunami barrier in coastal area. Bantul Local government in cooperation with Yogyakarta Central Government has installed siren systems in some vulnerable areas of Parangtritis. Those completed systems are: 6 Public addresses, 1 tower, 1 amplifier and 1 receiver. The systems were installed in 8 different locations by connecting repeaters placed in hilly places to an active system in Head of Local Government of Bantul. The systems are based on radio analogue technology with FM wave. Beside giving siren for evacuation, the systems also give information about types of earthquake that may trigger a Tsunami wave. Local Government of Bantul has organized some places for evacuation purposes and has figured out Tsunami drill to face Tsunami hazard.

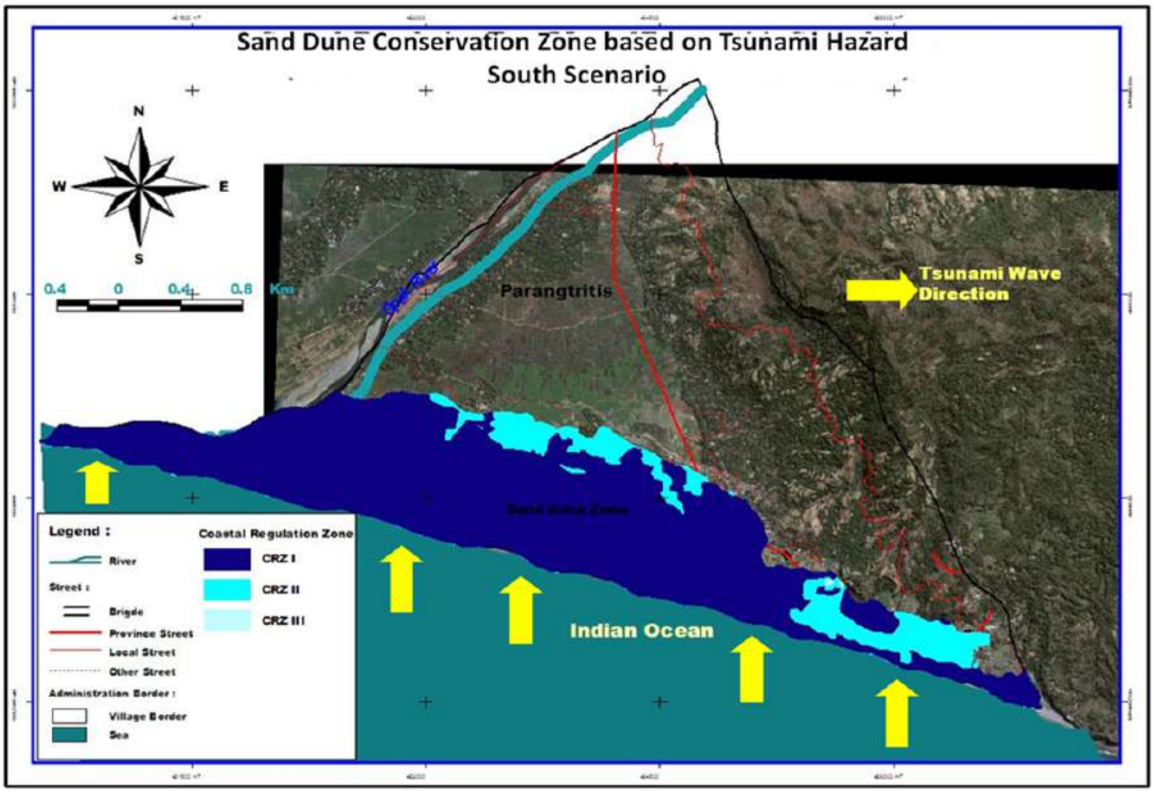

Fig. 16 Sand dune conservation zone map based on Tsunami hazards (South wave scenario).

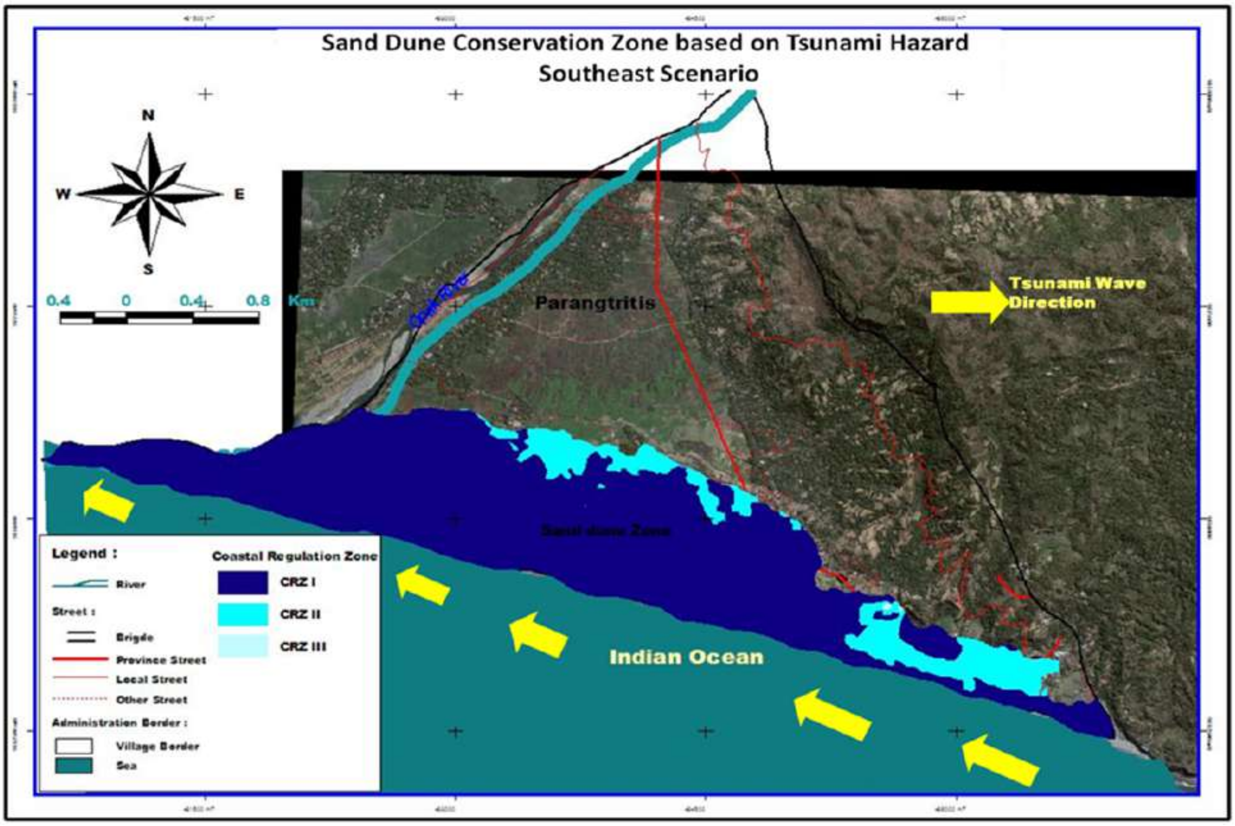

Fig. 17 Sand dune conservation zone map based on Tsunami hazards (Southeast wave scenario).

CONCLUSION

People living around coastal area in Indonesia have not been educated enough on big impact of Tsunami. During Aceh Tsunami in 2004, the impact of Tsunami and the resulted damage had opened eyes of people on dangerous impact of Tsunami. Nevertheless, Tsunami is a natural phenomenon that cannot be prevented. However, this fact does not imply that no one should live in coastal areas. Maximizing mitigation effort to minimize negative impact of natural disaster has been an important topic for research and discussion.

Southern coastal area of Central Java is frequently affected by Tsunami. We undertook a preliminary Tsunami vulnerability assessment in a part of the coastal segment in southern coastal area of Central Java as a support for the disaster management system. In particular, agricultural land and non agricultural land appear to be at significant risk to the impact of a future Tsunami event. The result of our study may have important implications for various stakeholders. Additionally, our results are useful for agencies whom tasked with coastal zone management. Results of our study may help those agencies to focus their resources in the area of Parangtritis coastal area.

Based on our study, some recommendations have been developed: (a) further research that considers the occurrence of Tsunami, run up model, coastal characteristics, hydrodynamic and detail coastal geomorphology shall be conducted; (b) detailed land use mapping shall be developed to identify the impact of the Tsunami inundation and to calculate the detail potential loss in comprehensive approach. Furthermore, the result also suggests that integration of GIS and satellite image is a suitable method for detecting damage caused by Tsunami inundation. In term of risk management, there are many ways to address risk and hazard issues as described in Coastal Planning and Management. They consists of: (i) Event protection (hard or soft engineering), (ii) Damage prevention (avoidance, mitigation), (iii) Loss Distribution (transfer) and (iv) Risk Acceptance (do nothing).

The role of spatial planning for disaster management consist of:

- Keeping areas free development
  Spatial planning has the instruments at hand to keep free those areas of future development that are (a) Prone to hazards (e.g. flood-prone areas, avalanche-prone areas), (b) that will be needed to lower the effects of a hazardous event (e.g. retention areas) and (c) That will be need to guarantee the effectiveness of response activities (e.g. escape lanes, gathering points etc.).
- Differentiated decision on land use
  Besides of keeping certain areas free of development, spatial planning may also decide on land use type according to the intensity and frequency of the existing hazard (e.g. agricultural use

of a moderately hazardous flood area might be allowed whereas residential use may be forbidden).

- Recommendations in legally binding land use or zoning plans: Although recommendations about certain construction requirements belong to the area of building permissions, some recommendations can already be made on the level of land use or zoning plans (e.g. minimum elevation height of buildings above floor, prohibition of basements, prohibition of oil heating, type of roof).
- Influence on hazard intensity and frequency (hazard potential) by spatial planning
  Spatial planning can also contribute to a reduction of the hazard potential, e.g. protection or extent of river flood retention areas, protective forest etc.

Management of sand dune conservation should be coordinated between stakeholders and local community. Although traditional conservation methods are commonly used for conservation and restoration, advanced scientific research and ecological studies should be used as supplementary methods to achieve optimum results. For example, scientific research may suggest suitable species as vegetation cover, plantation techniques, and method of site selection, which will effectively serve restore dunes. In case destruction of the dune system has passed a stage where simple methods such as removal of stress factors and protection may not reverse the damage, restoration efforts may be necessary. Dune restoration efforts not only help in dune formation, but also help in bringing back floral and faunal diversity, which previously existed in the healthy system. Further research to enhance visual salience and usability of coastal planning map and sand dune conservation map can be done by considering spatial cognitive behavior of users (Kiefer *et al.*, 2016). In this case, eye tracking or other physiological devices can be incorporated in the study (Wibirama & Hamamoto, 2013; Wibirama & Hamamoto, 2014) .

Key Acronyms

ALOS PALSAR : ALOS Phased Array type L-Band Synthetic Aperture Radar
DInSAR : Differential Interferometry Synthetic Aperture Radar
GPS : Global Positioning System
SAR : Synthetic Aperture Radar

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