Physical Resilience Assessment of Coastal Settlements in Semarang City, Indonesia

Santy Paulla Dewi*, Novia Sari Ristianti and Rina Kurniati
Department of Urban and Regional Planning, University of Diponegoro, Semarang, INDONESIA
*santy.paulla.dewi@pwk.undip.ac.id

Abstract
The Semarang coastal areas face water and sediment-related disasters such as flood, land subsidence and erosion threatening the livelihood of its communities and undermine coastal resources and quality of environment. Likewise, lack of adequate infrastructure and facilities make the coastal area included as slum area. Hence, living in slum settlement and facing water-related disasters makes people more vulnerable and difficult to face disasters.

Therefore, thid study focuses on the assessment of the physical quality of settlements as part of physical capital that reduces vulnerability and increases the community's adaptive capacity to overcoming adversities. The study adopted quantitative approach through the scoring and descriptive comparative analysis by comparing the physical condition of each resilient settlement based on a set of indicators.

Keywords: Assessment, coastal settlements, physical resilience indicators

Introduction

Coastal area is an important part of a city because of its strategic location and rich natural resources. Coastal area is also considered as an important biosphere element because it sustain habitat diversity.[28] However, climate change has caused extreme weather changes and increased the incident of disasters in past few years, especially in the coastal areas as the front line.[28]

Climate change exposed the coastal areas to various challenges, most of which are water and sediment-related disasters.[28] The location of the coastal area which is close to the ocean makes this area largerly exposed to coastal flooding and erosion.[15,22,24]

In addition, the coastal area also encountered non-physical challenges related to socio-economic and health. Characteristics of the population which are largerly low income households resulted in improperly constructed houses with lack of adequate infrastructure and facilities. This situation, in return, created poor physical quality of settlements and their residents. Poor quality of life makes people more vulnerable to disasters and offer limited financial and human capacity to build back better after disasters.[28] Several studies have been conducted to measure the vulnerability of coastal areas in facing disasters. Research on coastal area resilience assessments conducted so far has emphasised on community vulnerability from the aspect of flooding[1,6,20], land subsidence[14] and the community.[7,10,23]

Review of these studies shows that the most research conducted so far was mainly focusing on the context of vulnerability (pressure) and the ability of community or victims to adapt (response).

However, thorough research of resilience coastal community particularly from the context of community capitals for building resilience has not been carried out in depth. An assessment of community capital using a capital index has been proposed by Mayunga.[21]

However, Mayunga's capital index is still newly formulated and not being implemented or tested in the field yet. This physical capital specifically focused on the physical quality of settlements including housing and infrastructure.

In fact, there have been studies conducted to assess the physical quality of resilient settlements but they have not focused on the aspects of settlements as a whole. Study conducted by Dasgupta[11] in India uses a resilience assessment framework consisting of five dimensions namely socio-economic, physical (structural), institutional, coastal zone management (ecological) and environmental/natural resilience. From Dasgupta's study, the physical dimension consisting of infrastructure and housing indicators was studied. However, the assessment framework conducted by Dasgupta focuses on the assessment of community resilience, not settlement as a whole.

Study carried out by Usamah[27] in Philippines explained that the physical vulnerability of settlements can be seen from the aspect of construction. However, the study is limited on the context of slums in the general context and not in the context of coastal areas. Therefore, it can be concluded that there are limited parameters specifically made to assess the physical resilience of settlement in coastal areas.

Various problems in the coastal areas are experienced by many countries including in Indonesia. As an archipelago consisting of 17,000 islands, Indonesia is constantly exposed to floods, tides, abrasion and land subsidence which are threats to its coastal areas.

One of the coastal areas experiencing these problems is the Seribu Islands (one of the regencies in DKI Jakarta Province) . Various studies have been conducted to analyse

the coastal resilience in the Seribu Islands including by Farhan and Lim[12] hat assessed four factors that affect landscape conditions in the Seribu Islands.

Farhan and Lim[12] adopted GIS method to observe the dynamics of these four factors and assessed the effects on the condition of the Seribu Islands landscape. Semarang, the capital of Central Java, is one of the coastal areas on the north coast experiencing various coastal problems. The coastal area of Semarang covers 20 district (Figure 1) spanning from Tugu District to Genuk District.[17-19] Three settlements located in Tugu District namely Mangkang Kulon, Mangunharjo and Mangkang Wetan Village are experiencing the most severe tidal floods and land subsidence.[4]

Moreover, these three villages are located adjacent to two main watersheds, namely Plumbon and Bringin, so that these villages are also categorized as "Prone to River Flood" areas.[25] Mangkang Kulon, Mangunharjo and Mangkang Wetan experience severe water-related problems. In the study area, tidal flood occurs every month and rises in a fast time because it is driven by river flow and global warming.[17]

River flood occurs during the rainy season (October to February) due to the overflowing of the Plumbon River and the Bringin River. River floods that occur every year and cause sedimentation in the settlement environment. Sedimentation caused by river floods is further exacerbated by land subsidence when many buildings in the study area were built being lower than the ground level.

In addition, flooding also affects the quality of infrastructure. Roads are damaged, accessibility is impaired and there is a shortage of clean water supply. Sources of water in the study area were obtained from artesian wells and *PAMSIMAS* (Provision of Community-Based Drinking Water and Sanitation is one of the programs implemented by the Government of Indonesia with support from the World Bank for communities in rural and suburban areas that are not served by the clean water pipeline network provided by the Government or *PDAM* – pamsimas.org).

However, water obtained from wells and *PAMSIMAS* is only safe for washing clothes and showering and not suitable for drink or consumption.

As a result, settlements in Mangkang Kulon, Mangunharjo and Mangkang Wetan villages ended up to be slum quarters. To prevent the spread of socioeconomic issues, these villages are included in the Neighborhood Upgrading and Shelter Project Phase 2 (NUSP-2) of the city without slums (Kotaku) program established by Semarang City Government. Of all the three settlements, Mangunharjo given higher priority.

In addition, the socio-economic condition of the people is also low, higher incident of poverty making the community in this area vulnerable to disasters.[4] But how and what kind of capital owned by the community to be resilient still requires further examination.

Therefore, to analyse the resilience of this area, researchers conducted an assessment of the physical quality of settlements as part of physical capital that reduces vulnerability and increases the community's adaptive capacity.

Physical resilience indicators: The context of resilience in this study is defined as a more technical matter focused on the physical aspects of housing and infrastructure.

According to Liao[16], the concept of resilient settlement that focuses on the physical aspects of housing and infrastructure is adapted to the concept of engineering resilience. The concept emphasised on the ability of community to maintain stability and be resistant to events that occur.[16] The assessment of physical resilience of the settlement was carried out based on the standard of habitable housing and the recommendation of housing for the coastal area (Table 1).

Choosing the right indicators is important as it is for the basis of the assessment. The assessment of the physical resilience includs both natural physical and man-made physical such as housing and infrastructure. Physical resilience indicators used to assess physical resilience are presented in table 1.

Methods

This study uses quantitative approach that requires an understanding of theories to build a strong research foundation. The theoretical framework that has been compiled is used to determine the research model related to the selection of variables and the determination of the initial deduction of research.[13]

Resilience is a condition where a system or community has the ability to fight, absorb or recover from danger by rearranging through adaptive processes and actions[9,11] so that the concept of settlement resilience can be interpreted as the ability of a settlement system to adapt[2] whereas in the context of this study, settlement resilience is focused on the physical context. Physical resilience can be seen through the availability of physical capital that is able to support the system or community in achieving resilent resettlement. This physical capital focused on built environment including housing and infrastructure.[21]

Data collection is carried out through questionnaires, field observations and document review. Questionnaires were distributed to the sample of population using the form of open and closed questions. The study uses simple random sampling because everyone who belongs to the population of the study has the same opportunity to be selected as a sample.[3,5]

Table 1
Settlements Physical Resilience Indicators

Indicators	Standards	Source
1. Land topography	Slopes that suitable for residential land use are 0-15%	Regulation of the Minister of Public Works and Public Housing Number
2. Coastal buffer zone	The coastal buffer zone is at least 100m away from the highest tide point	Semarang City Spatial Planning 2011-2031
3. River stream buffer	The river stream buffer that have dikes within urban areas are determined to be at least 3 (three) meters from the outer edge of the dike along the river channel.	Regulation of the Minister of Public Works and Public Housing Number 28/PRT/M/2015
4. Density of population	Population density > 1000 people/km^2 is included in the class of high exposure, 500-1000 people/km^2 is included in the medium exposure class and < 500 people/km^2 is included in the low exposure class	Regulation of the Head of the National Disaster Management Agency Number 2/2012
5. Density of buildings	Building density > 100 units/ha is included in the high class, 80-100 units/ha are included in the middle class and <80 units/ha are included in the low class	Guidelines for Identifying Slum Settlement Areas, Minister of Public Works and Public Housing
6. Quality of housing constructions	Permanent housing way more resilient than semi-permanent housing or even non-permanent housing	Module 01 SNI Housing Settlement Research and Development Center, Minister of Public Works and Public Housing
7. Water demand and consumption	The standard for clean water needs a person is 0,06 m^3/day	Minister of Home Affairs Regulation Number 23/2006
8. Water supply	The availability of clean water is obtained from *PDAM*s and *Pamsimas* through the government programs	Semarang City Medium Term Development Plan 2016 - 2021
9. Water quality	Clean water quality standards are the water that is used for daily needs whose quality meets health requirements and can be consumed	Regulation of the Minister of Health Number 416/MENKES/ PER/IX/1990
10. Drainage systems	To prevent flooding is by having a retention pond and pump	Fauziah
11. Sanitation systems	The effluent from a septic tank must not be directly discharged into the environment, requiring further processing as follows: recharge system; up flow filter; sanitation pool	SNI 03-2398-2002
12. Coastal defense structures	Tidal flooding will be worse if the development occurs adjacent to the coastal system or directly adjacent to the sea without a barrier	Marfai[17,18]
13. Accessibility to evacuation route	Availability of planning and routes for disaster evacuation	Sharifi and Yamagata

Source : analysis results from various sources, 2019

Determination of sample size uses the Slovin calculation (error rate 10%) on the population of 4,972 households.[8] The sample size obtained consists of 100 households. Observations were carried out to obtain information about the availability and quality of housing and infrastructure in the study area while document review was carried out to find information about demographic condition of the study area.

The assessment utilises 13 indicators. The assessment conducted for each indicator is based on answers given by respondents whereby the value of "0" denoted "not compatible" and "1" denoted "compatible". The value of each indicator will be added up to obtain the final score for the physical assessment of settlements. In this light, the maximum score given by respondents would be 13 and the minimum score is 0. The range of scores will serve as a basis in determining category intervals. With 3 classes, the intervals for each class are 5. The first category is "not resilient" with intervals of 0-4, the second category is "less resilient" with intervals of 5-9 and the third category is "resilient" with intervals of 10-14.

Results and Discussion

This research was comparing indicators of settlements physical resilience with existing conditions of each settlement in the field. The scoring process is based on standards compiled from policies and regulations in Indonesia related to the provision of good housing and

facilities in settlements. The assessment of settlements physical resilience in Mangkang Kulon, Mangunharjo and Mangkang Wetan villages is described in table 2.

The results indicated that a physical resilient settlement can be achieved if its components meet the criteria of 13 indicators as mentioned in table 2. Based on the resilience of urban form's framework made by Sharifi[26], these 13 indicators are included in the "Resilience of What" quadrant which in detail outlined shocks and stress. Identified from this study are floods, land subsidence and sedimentation.

The indicators used by this study to assess the physical of settlement are not only related to water-related problems that occur in coastal areas but also to basic needs of settlement such as sanitation and clean water supply. Settlements are not only about housings, but also about infrastructure and environment. So that the 13 indicators of resilient settlements are including the conditions of housings and infrastructure as man-made physical as well as topography and coastal defense structure as natural physical.

In general, these three villages have several similarities; first, most of the houses (54%) are included as permanent category (the definition of a permanent house according to the Indonesia Central Statistics Agency is a house whose walls are made of walls or wood, the roof is made of zinc or tile or shingle or asbestos and the floor is made of tiles or ceramics) ; secondly, all rivers in these villages have 8 m river stream buffer but facing sedimentation so that it overflows during high water discharge or during the rainy season.

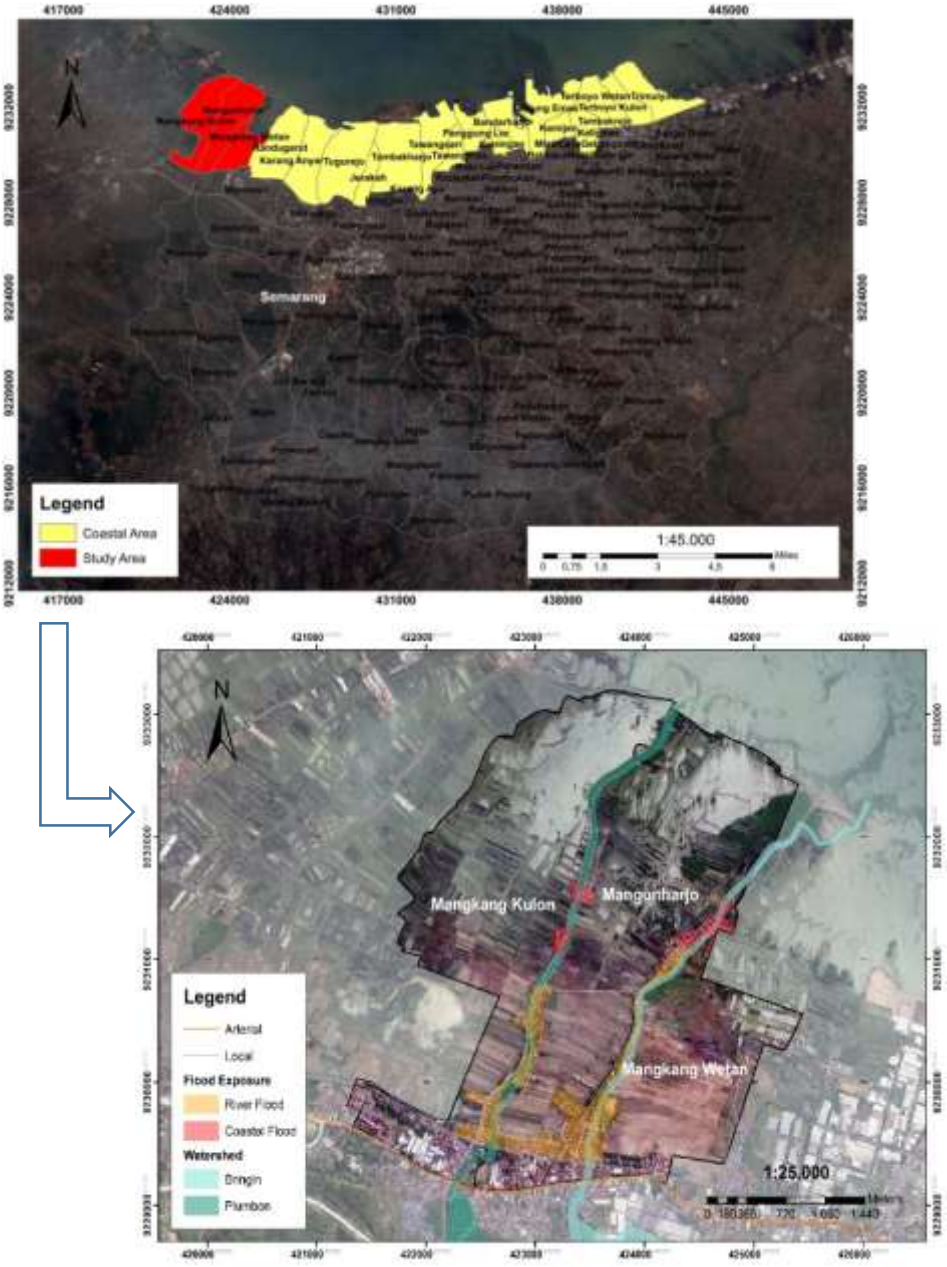

Figure 1: Flood Exposure
Source: Regional Development Planning Agency Semarang City, 2011

Table 2
The Assessment of Settlements Physical Resilience

Indicators	Mangkang Kulon			Mangunharjo			Mangkang Wetan		
	Results	**Desc.**	**Score**	**Results**	**Desc.**	**Score**	**Results**	**Desc.**	**Score**
Land topography	Compatible	Slope 2-15%	1	Compatible	Slope 2-15%	1	Compatible	Slope 2-15%	1
Coastal buffer zone	Compatible	770 meters	1	Compatible	846 meters	1	Compatible	318 meters	1
River stream buffer	Compatible	8-9 meters	1	Compatible	8 meters	1	Compatible	7-8 meters	1
Density of population	Low exposure	3 people/km^2	1	Low exposure	1 people/km^2	1	Low exposure	2 people/km^2	1
Density of buildings	Low density	2 units/ha	1	Low density	3 units/ha	1	Low density	5 units/ha	1
Quality of housing constructions	49% of total unit housings is permanent	• P: 294 units • S-P: 188 units • N-P: 118 units	0	61,6% of total unit housings is permanent	• P: 836 units • S-P: 400 units • N-P: 120 units	1	51% of total unit housings is permanent	• P: 630 units • S-P: 507 units • N-P: 100 units	1
Water demand and consumption	Not yet fulfilled	The supply of Pamsimas tanks is still not evenly distributed	0	Not yet fulfilled	The clean water network that is used does not meet service standards	0	Not yet fulfilled	The lack of clean water storage services	0
Water supply	Available	Pamsimas and wells	1	Available	Pamsimas and wells	1	Available	Pamsimas and wells	1
Water quality	Bad water quality	Muddy and had a brackish taste	0	Bad water quality	Muddy and had a brackish taste	0	Bad water quality	Muddy and had a brackish taste	0
Drainage systems	Not available	No retention ponds and pumps	0	Not available	There is no retention pool. There is a pump in RW 4 but it does not function properly	0	Not available	No retention ponds and pumps	0
Sanitation systems	Not compatible	Directly channelled into tertiary drainage channel that empties into the sea without any further processing	0	Compatible	There is a communal sanitation system from the government, but it is only used by several households	1	Not compatible	Directly channeled into tertiary drainage channel that empties into the sea without any further processing	0
Coastal defense structures	No barrier	No beach or break water as a barrier	0	No barrier	No beach or break water as a barrier	0	No barrier	No beach or break water as a barrier	0
Accessibility to evacuation route	Not available	Mitigation activities have not been carried out	0	Not available	Mitigation activities have not been carried out	0	Not available	Mitigation activities have not been carried out	0
Final Score			**6**			**8**			**7**

Source : analysis results from various sources, 2019

Third, all villages use PAMSIMAS and deep ground water wells to fulfill their water needs and fourth, all villages have tried to plant mangroves as a barrier to anticipate sea erosion. Although the progress of developing this mangrove is different, Mangunharjo has the highest mangrove area (9 ha) compared to Mangkang Wetan (0.84 ha) and Mangkang Kulon (1.04 ha). This is because there are community groups concerned about mangroves (namely Mangrove Lestari) that concern and cooperate with other parties such as academics and private sectors.

Regarding the score, the Mangkang Kulon Village has the lowest score because the number of permanent houses is least compared to the two villages. However, the existing physical condition shows that Mangkang Wetan Village is more vulnerable than Mangunharjo and Mangkang Kulon villages. This is caused by several things; first, most of the settlements in the Mangkang Wetan Village are located in the coastal area so that they always experience tides while settlements in the other two villages are more linearly distributed along the road to the south. Hence, the occurrence of flooding in these two villages is more due to river sedimentation so that the water overflowed or the river embankment collapsed.

Moreover, Mangkang Wetan Village also has the highest slum area (13.59 ha) compared to Mangunharjo (1.56 ha) and Mangkang Kulon (3.79 ha). Likewise, Mangkang Wetan Village is also considered to have the highest sanitation risk in the entire Tugu District. It means that this village has experienced a decline in the quality of life, public health, buildings and the environment due to poor sanitation management and unhealthy community behavior (kotaku.pu.go.id). Sanitation management in Mangkang Wetan Village is carried out by dumping it directly into the sea, similar situation with Mangkang Kulon Village whereas in Mangunharjo Village, it has communal sanitation management even though it can only cover a few households; currently the condition is also poorly maintained.

Sanitation risk is also shown by the unhealthy community behavior by throwing garbage into the river, so that water flow is obstructed; the Mangkang Wetan government does nothing in this regard. Communities in the Mangunharjo and Mangkang Kulon villages dump garbage in the trash and then transported to a temporary landfill. Waste management is carried out by the local village government; the community pays 20,000 rupiah / month for garbage fees.

Conclusion

Overall, the quality of the settlement in Mangkang Kulon, Mangunharjo and Mangkang Wetan is compatible to the indicators of resilient settlement. However, there are several indicators that have not yet been met related to the availability of clean water, retention ponds and drainage pumps to prevent flooding. Besides that, the sanitation system in Mangkang Kulon and Mangkang Wetan tends to be conventional, namely by channelling sanitation networks to the sea. Another important factor that has not been fulfilled is the absence of barriers or walls between land and sea. The total score shows that the three villages are included in the "less resilient" class because they are only able to meet 6-8 of the 13 available indicators.

Mangkang Kulon, Mangunharjo and Mangkang Wetan Kelurahan are included in the "less resilient" class because the Government programs established in these three villages are only concerned about prevention that minimizes the impact of flooding on communities such as mangrove planting and road elevation.

Other problems related to clean water and sanitation have not been intervened by the Government so that people are more vulnerable because of the lack of community capital. It is shown from the result that the indicators fulfilled by the three villages are related to the basic things of habitable settlements including the suitability of land use, proximity to the coast and sea borders and housing permanency whereas indicators that are not fulfilled are factors that are closely related to infrastructure such as sanitation and water systems and disaster mitigation systems.

Acknowledgement

This study is part of the International Publication Research funded by Dipoengoro University from non-APBN funds in 2019 entitled Resilience Settlement Model in Semarang Coastal Area through Sensitive Urban Design Approach.

References

1. Adeniyi O., Perera S., Ginige K. and Feng Y., Developing maturity levels for flood resilience of businesses using built environment flood resilience capability areas, *Sustainable Cities and Society*, https://doi.org/10.1016/j.scs.2019.101778 **(2019)**

2. Alarslan E., Disaster resilient urban settlements (Doctoral dissertation), Retrieved from TU Dortmund, http://dx.doi.org/10.17877/DE290R-248 **(2009)**

3. Alvi M., A manual for selecting sampling techniques in research, University of Karachi, Iqra University **(2016)**

4. Ambariyanto and Denny N., Kajian pengembangan desa pesisir tangguh di kota semarang, *Riptek*, **6(2)**, 29–38 **(2012)**

5. Bacon-Shone J., Introduction to Quantitative Research Methods, https://doi.org/10.13140/2.1.4466.3040 **(2015)**

6. Bertilsson L., Wiklund K., Tebaldi I.D.M., Rezende O.M., Veról A.P. and Miguez M.G., Urban flood resilience - a multi-criteria index to integrate flood resilience into urban planning, *Journal of Hydrology*, https://doi.org/10.1016/j.jhydrol.2018.06.052 **(2018)**

7. Bott L.M. and Braun B., How do households respond to coastal hazards? A framework for accommodating strategies using the example of Semarang Bay, Indonesia, *International Journal of Disaster Risk Reduction*, https://doi.org/10.1016/j.ijdrr.2019.101177 **(2019)**

8. BPS, Kecamatan Tugu dalam Angka 2018 **(2018)**

9. BSN, SNI Desa dan Kelurahan Tangguh Bencana **(2017)**

10. Chowdhooree I., Indigenous knowledge for enhancing community resilience: An experience from the south-western coastal region of Bangladesh, *International Journal of Disaster Risk Reduction*, **40**, https://doi.org/10.1016/j.ijdrr.2019.101259 **(2019)**

11. Dasgupta R. and Shaw R., An indicator based approach to assess coastal communities ' resilience against climate related disasters in Indian Sundarbans, *Journal of Coastal Conservation*, 85–101, https://doi.org/10.1007/s11852-014-0369-1 **(2015)**

12. Farhan A.R. and Lim S., Ocean & Coastal Management Resilience Assessment on Coastline Changes and Urban Settlements : A Case Study in Seribu Islands, Indonesia, *Ocean and Coastal Management*, **54(5)**, 391–400, https://doi.org/ 10.1016/j.ocecoaman.2010.12.003 **(2011)**

13. Fischer H. et al, Quantitative Research Designs and Approaches, In Handbook of Research on Science Education, Volume II, Taylor and Francis (Routledge), January 2014. Quantitative Research Designs and Approaches, 1-83 **(2014)**

14. Husnayaen Rimba A.B., Osawa T., Parwata I.N.S., As-syakur R., Kasim F. and Astarini I.A., Physical assessment of coastal vulnerability under enhanced land subsidence in Semarang, Indonesia, using multi-sensor satellite data, *Advances in Space Research*, https://doi.org/10.1016/j.asr.2018.01.026 **(2018)**

15. Knutson T.R. et al, Tropical cyclones and climate change, *Nature Geoscience*, **3(3)**, 157 **(2010)**

16. Liao K.H., A Theory on Urban Resilience to Floods — A Basis for Alternative Planning Practices, *Ecology and Society*, **17(4)**, 48 **(2012)**

17. Marfai M. and King L., Coastal Flood Management in Semarang, Indonesia, *Environ Geol*, 1507–1518, https://doi.org/ 10.1007/ s00254-007-1101-3 **(2008a)**

18. Marfai M. and King L., Potential Vulnerability Implications of Coastal Inundation due to Sea Level Rise for the Coastal Zone of Semarang City, Indonesia, *Environmental Geology*, 1235–1245, https://doi.org/10.1007/s00254-007-0906-4 **(2008b)**

19. Marfai M., King L., Sartohadi J., Sudrajat S., Budiani S.R. and Yulianto F., The Impact of Tidal Flooding on a Coastal Community in Semarang , Indonesia, *Environmentalist*, 237–248, https://doi.org/10.1007/s10669-007-9134-4 **(2008)**

20. Matthews E.C., Friedland C.J. and Orooji F., Integrated Environmental Sustainability and Resilience Assessment Model for Coastal Flood Hazards, *Journal of Building Engineering*, https://doi.org/10.1016/j.jobe.2016.08.002 **(2016)**

21. Mayunga J.S., Understanding and applying the concept of community disaster resilience: a capital-based approach, *Summer Academy for Social Vulnerability and Resilience Building*, **1(1)**, 1–16 **(2007)**

22. Nicholls R.J. and Cazenave A., Sea-level rise and its impact on coastal zones, *Science*, **328(5985)**, 1517–1520 **(2010)**

23. Sajjad M. and Chan J.C.L., Science of the Total Environment Risk assessment for the sustainability of coastal communities : A preliminary study, *Science of the Total Environment*, **671**, 339–350, https://doi.org/10.1016/j.scitotenv.2019.03.326 **(2019)**

24. Senior S.N., Coastal erosion and accretion in Kuwait - Problems and management strategies, *Ocean and Coastal Management*, 1–16, https://doi.org/10.1016/j.ocecoaman.2017.05. 014 **(2017)**

25. Setyani R.E. and Saputra R., Flood-prone Areas Mapping at Semarang City by Using Simple Additive Weighting Method, *Procedia - Social and Behavioral Sciences*, **227**, 378–386, https://doi.org/10.1016/j.sbspro.2016.06.089 **(2016)**

26. Sharifi A., Urban form resilience: A meso-scale analysis, *Cities*, **93**, 238–252, https://doi.org/10.1016/j.cities.2019.05.010 **(2019)**

27. Usamah M., Handmer J., Mitchell D. and Ahmed I., Can the vulnerable be resilient? Co-existence of vulnerability and disaster resilience: Informal settlements in the Philippines, *International Journal of Disaster Risk Reduction*, **10(PA)**, 178–189, https://doi.org/10.1016/j.ijdrr.2014.08.007 **(2014)**

28. Uy N., Takeuchi Y. and Shaw R., Local adaptation for livelihood resilience in Albay, Philippines, *Environmental Hazards*, **10(2)**, 139–153, https://doi.org/10.1080/17477891.2011. 579338 **(2011)**.

(Received 03rd January 2021, accepted 04th March 2021)