Spatial planning of small island to anticipating climate change effect (case study of Harapan and Kelapa Islands, Indonesia)

A P Zulriskan¹, H S Hasibuan ² and R H Koestoer ²
¹Graduate Student Magister Program of School of Environmental Science, Universitas Indonesia, Salemba 4 Jakarta
²School of Environmental Science, Universitas Indonesia, Salemba 4 Jakarta.

Abstract The vulnerability is a sequence of conditions that determine whether a hazard will lead to disaster or not. Small islands easily affected by climate change, which promotes extreme waves, sea level rise, rob floods, and other disasters. The limited area of the small islands requires integrated and sustainable management. Harapan and Kelapa Islands are some of the vulnerable islands that susceptible to climate change. The problem in this research is the lack of spatial arrangement of small islands region based on climate change adaptation. This study aims to create a model of land use for spatial arrangement of small islands, especially the land area in terms of changes in land use. The methods used in this study were analysis of land use change, analysis of climate change impacts on social, economic, and environmental conditions, and predict future land use scenarios using spatial modeling. The results showed that with increasing population growth, rising sea levels, rising temperatures and salinity, and erratic rainfall patterns, land requirements for settlements increased. The conclusion of this study is the additional area in Harapan and Kelapa islands should restrict, so the mitigation and adaptation due to the impact of climate change can be done well and the risk of disasters becomes small.

1. Introduction
Indonesia is one of the largest archipelagic countries in the world, has 17,508 islands and 92,181 km long of coastline (the fourth longest in the world) [1]. Coastal and small islands are rich in natural resources, such as fisheries, mangrove forests, coral reefs, petroleum, mining materials and gas and minerals [2]. In sustainable development, the existence of small islands is a very strategic resources for the new growth to overcoming current economic problems. Understanding sustainability refers to the ability of diverse earth systems, including human and economic cultural systems, to survive and adapt to changes in environmental conditions [3]. This small island has potential high economic value for increasing local and regional community income.

The development of small islands based on conservation and socio-economy is a concrete manifestation of efforts to manage natural resources for sustainable use [4]. Besides that the management strategies of small islands must be able to accommodate stakeholders in small islands with a coordinated system, there are at least five coordination system processes which include social processes, economic processes, natural processes, climate change processes, and processes meeting between land and sea [5].

At present, the spatial planning of coastal areas and small islands are separated, because there is no integration between land (terrestrial) and sea/coastal planning. The purpose of integrated spatial planning is to maintain vital ecological processes that connect between land and sea/coastal, limiting
cross-regional threats, balancing the benefits and trade-offs generated from the use of land resources and coastal waters of small islands [6].

Predicted by the IPCC in 2007, shows that an average increase in sea level is 2.5 mm per year and is estimated to reach 31 mm in the next decade [7]. A number of studies that have been carried out in several countries indicated changes or shifting of extreme weather behavior in relation to climate change activities. Global climate change increases extreme events, such as extreme rainfall, extreme air temperatures, and storm intensity [8]. In anticipating the impacts of climate change, it is necessary to arrange the spatial arrangement of small islands based on climate change impact adaptation.

The purpose of this study is to provide input to stakeholders and the community so that spatial planning is based on adaptation to climate change impacts so that people in small islands can adapt to their areas that are vulnerable to disaster risks due to climate change impacts.

2. Data and method
The research was carried out in the Thousand Islands Administration District, which included Harapan Island and Kelapa Island. The scope of research on these two islands includes land use, spatial planning (space pattern) and socio-economic, environmental, and climate change impacts on both islands.

![Figure 1. Map of study area year 2017](image1)

![Figure 2. Flowchart of spatial modeling](image2)
The data used in this study include land use data and satellite imagery (NOAA image), socioeconomic, administrative boundary, sea level rise, salinity and sea surface temperature, and spatial plan. Primary data collection is carried out by conducting a field check between existing land use and land use data according to satellite imagery. Secondary data collection was carried out by collecting socioeconomic statistical data, and literature related to research.

The method of analysis in this research consists of analyzing land use change with data on 2007, 2012, and 2017. All three of these data are overlapped (overlay), then observed the changes in various uses of the land. The method of analysis of the suitability of land use to spatial planning is carried out using the land use data in 2017 in overlaying with the data plan of spatial patterns from the study area.

The results of these data are used to see the existing land use suitability with the spatial pattern. The method of analyzing the impact of climate change on socio-economic conditions is carried out by descriptive analysis, linking the condition of the population and the livelihoods of the population with the related phenomenon of climate change impacts. In addition, in-depth interviews were conducted with stakeholders and communities in the study area. Spatial dynamics modeling using spatial dynamics modeling using the land attractiveness approach. Land extraction is derived from the benefits and costs of driving forces multiplied by the weight of land use [9].

3. Result and discussion

3.1. Analysis of land use change for the 2007-2012 and 2012-2017 period

Based on the results of NOAA image interpretation in 2017, the area of study in 2017 is 38.93 Ha, with details of Kelapa Island covering 26.58 Ha and Harapan Island area of 12.35 Ha. The area of study within 10 years is always increasing, the area increased in both islands with details of Harapan Island in the period of 10 years increased by 1.52 Ha, while for Kelapa Island within 10 years increased by 2.41 Ha. Based on field observations, the extent of the study area is influenced by the reclamation.

| Land Use Change          | Kelapa Island | Harapan Island |
|--------------------------|---------------|----------------|
| Sea Water ---> Body Water | 0.14          | 0.14           |
| Sea Water ---> Jetty      | 0.02          | 0.00           |
| Sea Water ---> Open Land  | 0.29          | 0.18           |
| Sea Water ---> Settlement | 1.02          | 0.21           |
| Sea Water ---> Green Open Space | 0.23 | 0.00 |
| Open Land ---> Built Area | 0.00          | 0.06           |
| Open Land ---> Green Open Space | 0.00 | 0.18 |
| Open Land ---> Disposal Site Garbage | 0.00 | 0.05 |
| Open Land ---> Jetty      | 0.02          | 0.00           |
| Open Land ---> Green Open Space | 1.02 | 0.00 |
| Body Water ---> Settlement | 0.03          | 0.00           |
| Green Open Space ---> Open Land | 0.03 | 0.09 |
| Green Open Space ---> Settlement | 0.01 | 0.01 |
| Green Open Space ---> Disposal Site Garbage | 0.00 | 0.03 |
| Total (Ha)                | **2.81**      | **0.96**       |

The land use changes in 2012-2017 which had the largest area in Kelapa Island was Green Open Space with an area of 0.65 Ha, followed by the changes of seawater with an area of 0.54 Ha. The smallest
land use change in Kelapa Island in the period 2007-2012 was a change that occurred in open land with a changing area of 0.32 Ha.

In 2012-2017, seawater area had the widest changes in Harapan Island, with the area of change is about 0.9 ha which used for open space and settlements.

**Table 2.** Area of land use change in study area year 2012-2017

| Land Use Change                      | Kelapa Island | Harapan Island |
|--------------------------------------|---------------|----------------|
| Sea Water ---> Open Land             | 0.41          | 0.79           |
| Sea Water ---> Settlement             | 0.13          | 0.12           |
| Body Water ---> Open Land            | 0.17          | 0.00           |
| Body Water ---> Settlement            | 0.35          | 0.00           |
| Open Land ---> Settlement             | 0.11          | 0.00           |
| Open Land ---> Kids Playground       | 0.12          | 0.12           |
| Open Land ---> Green Open Space      | 0.09          | 0.00           |
| Green Open Space ---> Open Land      | 0.05          | 0.02           |
| Green Open Space ---> Settlement      | 0.32          | 0.35           |
| Green Open Space ---> Kids Playground| 0.27          | 0.00           |
| **Total (Ha)**                       | **2.04**      | **1.39**       |

The land use change in generally occurs around the coast. land use, the change in Kelapa Island occurs in the western, north and the southern coast of Pulau Kelapa. While land use changes in Harapan Island occur in the west, the northern part, and south of the coast of Harapan Island. The lands are used for settlements or for economic activities. Increasing land needs, from year to year, will reduce the availability of land, both on land and coastal waters, so it must be adapted to the needs and carrying capacity of the environment. This is in line with Muijo’s opinion [10].

![Map of land use change](image)

**Figure 3.** Map of land use change of study area year 2007-2012 and 2012-2017

### 3.2. Suitability analysis of land use against spatial planning

The Land Use suitability map of the study area can be concluded that land use mismatch in Kelapa Island is dominated by the west and east of the island of Kelapa, while land use discrepancies in Harapan Island are spread to the east, north and south and a small portion is located in the east of Harapan Island.
### Table 3. Area of land use suitability to spatial planning of study area

| Suitability to Spatial Planning | Kelapa Island | Harapan Island |
|-------------------------------|---------------|----------------|
| Suitability to Spatial Planning | 18.20         | 7.84          |
| Unsuitability to Spatial Planning | 8.38         | 4.50          |
| **Total (Ha)**                  | **26.58**     | **12.35**     |

#### Figure 4. Land suitability map of the study area

#### 3.3. Analysis of the impacts of climate change on social economic condition

People’s livelihoods in the study area as fishermen are highly exposed to the phenomenon of climate change impacts. Catching fish is more difficult for them nowadays, so some of them changing the jobs to become a tour guide or homestay guard. Some of the socio-economic impacts identified in this research are the impacts of housing damage and settlement environments caused by tornadoes and tidal waves in residential areas, isolation of small island populations, declining incomes as a result of the difficulty of determining fish catch areas, and increased risk of sea fishing.

The fishing communities in the study area felt ecological changes including sea level rise, storm, and high intensity, fishing ground changes and seasonal chaos. Fishermen feel that strong winds with the tidal waves in recent years are more common. In 2015, a whirlwind caused the destruction of several houses in the study area. In addition, the consequences of the climate affect social infrastructure in every region of small islands [11]. Therefore, an understanding of mitigation and adaptation for the community in the study area needs to be provided by the Regional Government, so that emergency response can be undertaken by the community in the study area [12].

Carter et al. [13] argue that in the context of adaptation planning, cooperation between local government, academia, business, the third sector, and communities will brings additional expertise, resources, and connections in building adaptive capacity. Whilst Subair [14] argue that adaptation strategies that need to be carried out are building breakwaters, turning fishing catching professions into aquaculture fishermen, group fishing, and adaptation to technological developments.

#### 3.4. Model of land use as a mitigation to the climate change impacts

Spatial planning model of small islands in an effort to anticipate the impacts of climate change using spatial modeling. The approach used is modeling land attractiveness. This model carried out in two scenarios. The first scenario is the model built with the assumption that settlements only grow in the type of open land use and coastal waters. The second scenario is the model is built with the assumption
that the area of study cannot be increased so that the settlements will only switch functions in the use of open land and some green open space areas.

This spatial model uses several driving factors that function as cost factors calculated based on distance, several indicators used as driving factors, including distance to the dock, distance to the road network, the distance to the economic center, distance to the coastline, and land slope.

Driving factor simulation results obtained the attractiveness of land for settlements. Furthermore, the model results are run from 2012 land use, with a residential growth of 1% per year from the settlement area, then from the results of the first scenario model simulation, it was found that settlements grew along the coastline in the study area, especially in Kelapa Island. This is because population growth is always increasing every year, so the need for settlements is higher, therefore from the results of the first scenario model, residential growth increases, with the way people in the study area always increase their land area (settlement) by doing accretion (adding land).

**Figure 5.** The result of the first and second scenario model simulation year 2032

The settlement area in the study in 2017 was 26.04 Ha, so with the simulation results of the model being implemented, then in 2032, the settlement area became 29.95 Ha. With the first scenario, the area of study in 2032 increased to 42.84 Ha, this is because there is an additional settlement area of around 3.91 Ha. The types of land use that can be converted into settlements in this model are only open land and seawater. Furthermore, in the first scenario, climate change impact variables are not used, because of the phenomenon of climate change is not comprehensively understood by the people in the study area.

The second scenario model simulation results, the model is run from 2012-2032, with the assumption of 1% settlement growth in the year, then the simulation results that are carried out that the settlement area increases from the conversion of land use types, water bodies, and kids playground, then the settlement area is obtained in the study area increased to 4.01 Ha. The area of settlement in the study area in 2017 was 26.04 Ha, so in 2032 the settlement area about 30.05 Ha. In this second scenario, the variables of climate change impacts are used as interventions in running the model. In addition, the growth of settlements along the coast on both islands can be stopped, because if settlements are always built around the coast, then the occurrence of abrasion disasters will easily occur. Furthermore, in the waters near the coast, it is necessary to add mangrove ecosystems and seagrass beds. In addition, the manufacture of coastal embankments and breakwater is one of the efforts to anticipate rising sea levels, increasing seawater intrusion, and increasing the intensity of extreme waves.
4. Conclusions
Within 10 years the area experienced a growth of 3.9 Ha. There is 12.88 ha of the incompatible area between the existing land use compare to Detail spatial plan. The impact of climate change on socio-economic conditions has a direct impact on people's incomes, especially those who earn a living as capture fishermen. Therefore, in the study area, many fisheries fishermen switched their livelihoods into aquaculture and tour guide fishermen. The model of land attractiveness for spatial planning in the study area was built by making two scenarios, the results of the model simulation showed that the second scenario with climate change impact intervention was more likely to be used for spatial planning in the future.

Acknowledgments
This Research is funded by the Grant of Indexed International Publication for Final Project of Students/Publikasi Terindeks Internasional untuk Tugas Akhir Mahasiswa (PITTA) Universitas Indonesia 2018.

References
[1] WRI 2001 Coastline Length (Virginia: World Resources Institute)
[2] Dahuri R, Rais J, Ginting S P and Sitepu M J 2001 Integrated Coastal and Marine Resource Management Revision Edition (Jakarta (Indonesian): Pradnya Paramita)
[3] Miller G 2006 Environmental Science: working with the earth, eleventh ed. (Belmont, USA: Thomson Corporation)
[4] Neksidin 2016 Management of Social Ecological Dynamics In Pari Island DKI Jakarta Province (Bogor (Indonesian): Institut Pertanian Bogor)
[5] Adrianto L 2004 Sustainable Development and Management of Small Islands (Bogor (Indonesian): PKSPL IPB)
[6] Álvarez-Romero J G, Adams V M, Pressey R L, Douglas M, Dale A P, Augé A A, Ball D, Childs J, Digby M, Dobbs R, Gobius N, Hinchley D, Lancaster I, Maughan M and Perdrisat I 2015 Integrated cross-realm planning: A decision-makers' perspective Biological Conservation 191 799-808
[7] IPCC 2007 Climate Change: The Physical Science Basis Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change ed S Solomon, D Qin, M Manning, Z Chen, M Marquis, K B Averyt, M Tignor and H L Miller (Cambridge: Cambridge University Press)
[8] Frich P, Alexander LV, Della-Marta P, Gleason B, Haylock M, Tank A M and Peterson T 2002 Observed Coherent Changes In Climatic Extremes Climate Research 19
[9] Priyanto D 2017 Spatial Modeling On Land Attractiveness For Sustainable Development In Surabaya (Bogor (Indonesian): Institut Pertanian Bogor)
[10] Mujio 2016 Coastal Spatial Planning Model with Land and Coastal Linkage Approaches (Bogor (Indonesian): Institut Pertanian Bogor)
[11] Carter J G and Lawson N 2011 Looking back and projecting forwards: GM’s weather and climate (Manchester: The University of Manchester)
[12] Cutter S, Boruff B and Shirley W 2003 Social vulnerability to environmental hazards Social Science Quarterly 84 242–61
[13] Carter J G, Cavan G, Connelly A, Guy S and Handley J 2015 Climate change and the city: Building capacity for urban adaptation (Manchester: The University of Manchester)
[14] Subair 2014 Adaptation to Climate Change and the Resilience of the Community of Fisherman Villages: A Case Study in the North Coast of Ambon Island, Maluku (Bogor (Indonesian): Institut Pertanian Bogor)