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A preliminary study: An agent-based spatial simulation of human-coastal environment interaction in coastal urban tropical area

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Abstract- Reported, 65% of Java island population are living in coastal area where one of the most affected areas on climate change. Disaster related to hydrological cycles such as flooding caused by tidal is the most frequent happen in the low area zone as well as Semarang city in Central Java province. Many process impacted tidal flood: land subsidence, sea level rise, and coastal land use change as a consequences of population pressure. It will getting worse when heavy rainfall is occur. Predicted, 2672, 2 Ha of coastal area at Semarang city will inundate caused by 16 cm sea level rise due to global warming impact. By this fact, coastal community is the most vulnerable group due to the flood. This paper is a preliminary study to simulate the interaction of human-coastal environment to response, adapt and mitigate the tidal flood through agent-based modelling (ABM) within spatial concept. ABM frameworks have been portrayed to function well in a socio-environment context, modelling efforts for coupled human-coastal environment system that described as a process-based design framework. In this research, human actions are interpreted as an aggregate social response to stimuli from the physical system with both aspects being explicitly modelled at the scale of emergence of the hydrological phenomenon in coastal areas. The natural (coastal-hydrology) system is set, in modelling terms, through physical (tidal, land subsidence, land use change) models; the response of human units (settlements, fisherman, industry communities etc.) is then studied as a reactive mechanism to physical model output, such as tidal flood. In the other word, ABM is an empirical methods for building agent decision models in spatial planning.

Keywords**:** *agent-based model, coastal environment, human interaction, spatial planning.*

1. Introduction

Coastal zones has an important key role in the development of all manner of human activities and a substantial influence on the economies of their respective hinterlands. Recently, coastal cities and population are facing various sensitive problem on natural ecosystem including their coastal management particularly in era of climate change. Semarang municipality is located in northern part of Java Island where to be Central Java Province capital city. It has unique topography throughout its region, coastal in the

northern part and hilly in the southern part. In coastal area, Semarang city is facing serious problem in abrasion and sedimentation where caused by natural action and getting worst because man-made action. Tugu sub-district is one of the worst of environment degradation caused by abrasion and tidal flood where inundate settlement and fish ponds. Recorded, 2,25 km length of coastal line was degraded which are occupying Kelurahan Mangunharjo, Kelurahan Mangkang Wetan, Kelurahan Randugarut, Kelurahan Karanganyar, Kelurahan Tugurejo (Dinas Kelautan dan Perikanan Kota Semarang, 2009).

Since coastal community is the most vulnerable group due to climate change era, the interaction pattern of human-ecological behaviour is important to understand. This research is a preliminary study to explore between spatial and human interaction in coastal city through spatial agent based model. Assumed, a causality relationship is happening during some period which configure existing social-spatial feature. Tidal flood that occur in delta region caused by marine activity is the physical-spatial environment variables that we observed. Then, we will simulate how human response their environment and how the space where they are living is change as the consequences of human-nature interaction. Normally, other scientist is separating spatial pattern and human behaviour in conservation planning study. Here, we integrate social and spatial consideration into conservation planning to achieve environment sustainable goal from planner perspective.

2. Method

The literature review and observation method is written to investigate the physical-spatial environment aspect and local community daily activity related coastal conservation in Kelurahan Mangunharjo, Mangkang Wetan, and Mangkang Kulon, Semarang municipality.

Social consideration in spatial planning

Many approaches have been studied for expanding the inclusion of social considerations in conservation planning. Social consideration is emphasizing on the implementation strategies and the importance of stakeholders throughout the process where the aim is to reflect local knowledge when gathering information about the region under our consideration (Knight et al, 2006). There are two categories as a result of practical development of social consideration in conservation planning, (1) appropriate spatial data to extract existing resource, and (2) the addition of social assessments, including identification of areas where conservation has more chance to succeed (NC Ban et al, 2013). Recent, a common component of conservation planning is social assessment which expose existing social system in planning region. It will describes the social, cultural, economic, and politic in focus area.

Social assessments (also termed situation analyses, social analyses, or stakeholder assessments) are a common component of conservation planning. These assessments contextualize aspects of the social systems that exist in the planning region, describing the social, cultural, economic, and political conditions in the area (Knight et al. 2006; Conservation Measures Partnership 2007; Cowling and Wilhelm-Rechman 2007). Social assessments is focusing on the local opportunities for conservation that emerge where social factors align to create a willingness among community stakeholders to implement

conservation actions; these may be community-led initiatives or may be linked to regional planning (Cowling and Wilhelm-Rechman 2007).

Spatial data on social assessment

The usage of spatial data in conservation assessment usually represented as threats to biodiversity or as cost associated with conservation action. In other word, when human activities represent a threat to biodiversity (eg land clearing), planners either avoid highly threatened areas (eg areas slated for land clearing) to minimize conflict (when other, less sensitive areas exist that have the same biodiversity values) or give priority to areas of high biodiversity value that are under threat to protect them before land clearing occurs (where there are no viable alternatives) (Pressey and Taffs 2001).

Connectivity between social-environment

The interaction between social and environment have potential approach to investigate and understand the best model of conservation initiatives. The effectiveness, efficiency, and sustainability of the initiative can be more realistic in order to linkage complex connection between people and the environment at multiple scale. The linkage between social-environment or social-ecological system (SES) was developed to provide an understanding of the governance processes that lead to improvements in or deterioration of renewable natural resources (Ostrom 2009). SES framework is working interdisciplinary and divided into subsystems, based on the resource (eg forests, coastal areas, etc), resource units (eg trees, fish), governance systems (eg management of a forest or a coastal area), and actors (ie stakeholders, such as hikers, loggers, and fishers). These four subsystems interact with each other and with the overarching social, economic, and political settings and related ecosystems (ie interactions and outcomes, with variables like harvesting levels, deliberative processes, activities carried out by communities, and social and ecological performance measures), leading to resource management outcomes (Ostrom 2009).

Agent-based model (ABM)

Agent-based models consist of agents that interact within an environment. The agent defined as distinct parts of a program that are used to represent social actors—individual people, organizations such as firms, or bodies such as nation-states. ABM is a decision model in spatial developments are driven by human action and interaction. It is a logical choice for simulating these process, agents are a natural representation of actors that make decisions. Here, agents are represent as a group of actors that can interact on a high level, used to simulate competition and interaction between environmentalists and locals (Ligtenberg et al., 2005). Their interaction is global, and after that their result is visible local. Interaction between agents in itself does therefore not take place at the local level. Therefore these agents are particularly suitable to simulate top down effects.

Research emphasize

This research will emphasize in human-environment spatial interaction in Semarang urban coastal areas. The concept that we build is how agents' decision models designed and parameterized to capture behaviour and interactions in the real world situations? Whereas the spatial representation and modelled landscapes in ABMs often need to

capture spatial heterogeneity of inputs and outputs across multiple spatial scales. Expected, our research can be reveal the social-spatial environment interaction pattern in urban coastal and modelled the best conservation planning based on local characteristic.

3. Result and Discussion

Our research basic idea is coming from Ministry of Maritime Affairs and Fisheries through the Directorate General of Marine, Coastal and Small Islands (KP3K) program namely Coastal Resilient Village Development (PDPT). Based on it, Kelurahan Mangunharjo, Mangkang Wetan, and Mangkang Kulon are the village where KP3K focus on. Based on the observation, environment degradation is the serious problem in these village. Sea water intrusion, tidal flood, abrasion, are the disaster risk in coastal environment. Population pressure and industrial activities, mainly influence coastal abasion and tidal inundation in this area. The abrasion hits the closest land, ponds and building, where tidal is inundate the settlement since sea breaker cannot work well anymore.

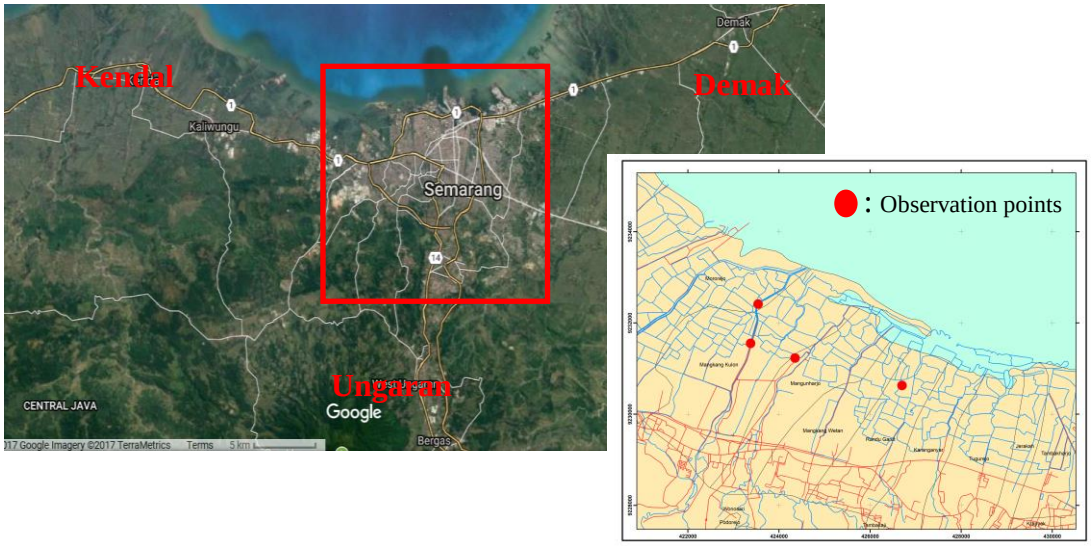

Fig 1. Propose research location and observation points

We propose three kelurahan (village) for our research focus areas, Kelurahan Mangunharjo, Mangkang Wetan, and Mangkang Kulon. They located in Tugu sub-district, Semarang. In these kelurahan, mangrove (*Rhizopora mocrunata* and *Avicennia marina*) are conserved. Usually, non-government organization (NGO), government official, and private organization, are held mangrove planting. However, they cannot manage the mangrove well and let them has broken or cut down.

Fig 2. Mangrove conservation at Kelurahan Mangunharjo

Fig 3. Facilities damage in Kelurahan Mangunharjo caused by tidal and abrasion

Infrastructure damaging, such as roads and buildings are the real impact of high abrasion in Semarang coastal area. Figure 3a is the broken road that connect between coastal and main road in northern part of Semarang, figure 3b is broken fish market, and figure 3c is broken fish ponds in kelurahan Mangunharjo

Fig 4. Boats in river estuary and coastal urban settlement in kelurahan Mangkang kulon

Concept model

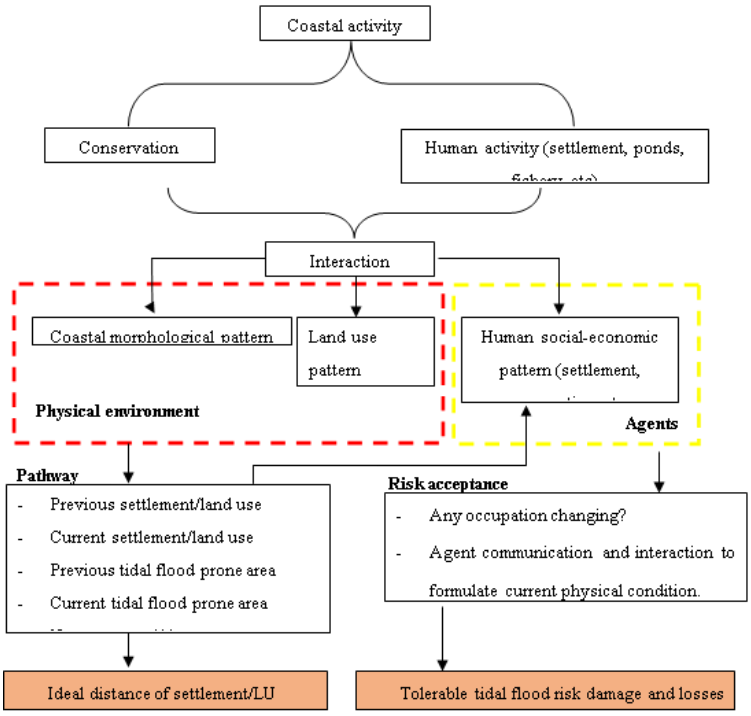

Fig 5. Conceptual framework of agent-based model for coastal urban area in Semarang

In our study, ABM is the extension of modelling techniques, including analytical and statistical modelling through socio-spatial approaches. By this model we will represent the human actors in more realistic way, accounting for bounded rationality, heterogeneity, interactions, evolutionary learning and out of equilibrium dynamics, into a dynamic heterogonous representation of the spatial environment (fig .5)

Fig 6. Interaction of actors and environment

Shortly, our model will represent the interaction between actors and environment (fig. 6). The actors are designed as decision making who has ability to bind the rationality, learn the risk, and network. The actors also configure in household dynamics, and migration at multiscale (fig. 7). Here, the actors are coastal community it selves. The coastal environments are defined as endogenous function and exogenous impacts, both are stated in some spatial factors and rules (fig. 8). In standard approaches of decision making, it will focus on general assumption, general model of decision making, analytical traceability, and power to change something. While in our ABM, we focus on varying decision model, varied actors, actors interaction, local interaction, and simplicity leading complexity

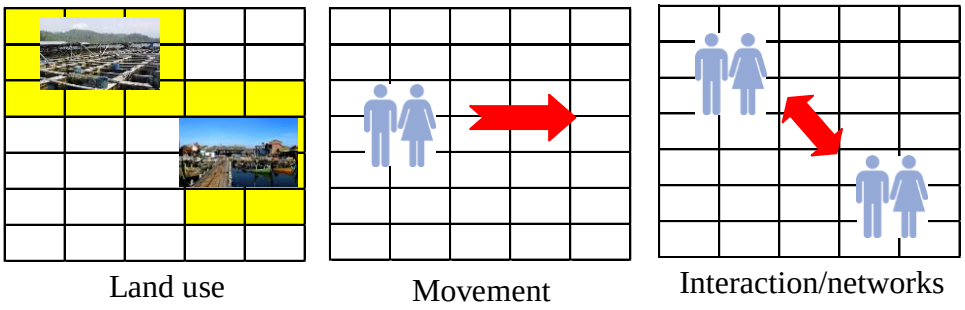

Fig 7. The actors position in ABM

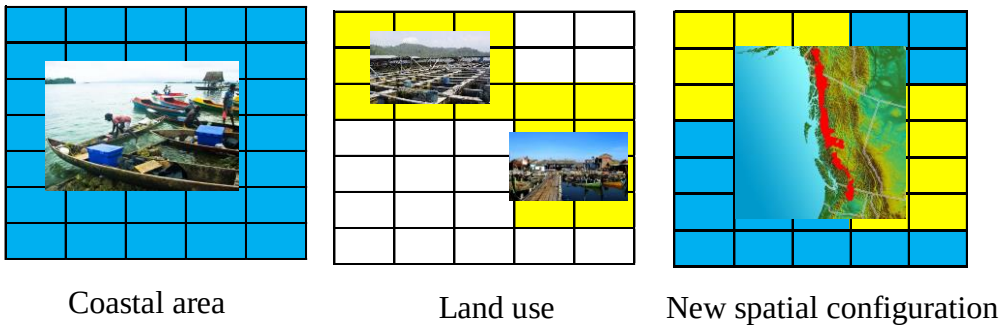

Fig 8. The coastal environments position in ABM

The dynamic life in urban coastal where we can illustrate from the model is actors must work (fishing, business, crop, etc) and looking for housing to find their needs. However, their activities are potential for environment degradation and facing disaster risk related to sea. We expect, during some simulation, we can build the best conservation planning model in actors rational and environment consideration.

4. Conclusion

In order to investigate local condition in kelurahan Mangunharjo, Mangkang Kulon, and Mangkang Kulon, a preliminary observation and literature review were done. From the observation, we found that abrasion, sea water intrusion and tidal flood are the main problem in focus area where has direct impact to infrastructure damage. We also find that some settlements was relocated as an impact of severe abrasion. To understand and govern the best model for conservation planning that more rational an agent-base model was proposed. ABM is a decision making model which represent human-environment interaction. ABM is need actors as a decision maker who can make some movement and interaction, where the environment is needed as the spatial factor to develop. In regional ABM, we need some complexity think and scale to simulate socio-spatial environment pattern for next conservation planning model.

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