I. INTRODUCTION

A. Background

A low-lying area can be found at the mouth of a river which is positioned on the maximum 200 m above mean sea water level. Lowland has a unique geographic pattern that is built over time due to the interaction of river processes with ocean processes (mainly waves and tides). The area offers unprecedented economic opportunity due to their high productivity, rich biodiversity, and easy transport abundant waterways. Some cities were located close to the sea, along with a riverbank or in a lowland tend to be the largest cities in all region of the world (Deelstra, Girardet, et al. 2000, Güneralp, Güneralp, et al. 2015). Chan, Mitchell et al. (2012) and reported that more than 500 million people live in lowland regions (around 40 lowlands globally). In 2005, average population density in lowlands was estimated to be ~500/km^2 with the largest population in the Ganges-Brahmaputra lowland and the highest density in the Nile Lowland (Ericson, Vörösmarty et al. 2006), as a comparison the world population density was 45/km^2 and the US population density 31/km^2 (Overeem and Brakenridge 2009). Rivers and lowland regions are important ecologically and economically for the growth of Asian cities as half of the largest cities in the region developed along rivers that serve as gateways to coastal and inland areas (United Nations, 2012).

Standing with the opposition for accelerating land and coastal use for agriculture practices and human exploitation of ecosystem goods and services, today lowlands are subject to impacts of climate change and increasingly prone to natural hazards. Numerous hazards have threatened people who live in lowland areas. The human activities and human interventions into the processes of nature due to agricultural practices and deforestation have considerably changed the situation in the river basins and increased the exposition to the risk and vulnerability of the hazard-prone areas.

As one of the potential hazards, a flood is an extreme event of nature associated with an unusually high stage or flow of water over land or coastal area, which results in severe detrimental consequences in terms of social, physical and economic impacts. Most flood damages are the result of extreme, intense, and long duration floods caused by meteorological phenomena such as prolonged and intense rainfall, cyclones, typhoons, storms, and tidal surges. Some flooding can also be caused by increased runoff due to hydrological causes, such as land erosion, saturated land, low infiltration rates, impermeable surfaces, and land subsidence. As mentioned above, mankind plays a significant role in the magnitude and frequency of hazards in many different ways.

In general, the impacts include loss of human life, damage to agriculture areas, property, destruction of crops, loss of livestock, deterioration of health conditions due to waterborne disease, and potential psychological impacts for victims and their family for long periods of time. As a communication network and infrastructures such as electricity and transportation, are damaged and disrupted, some economic activities may come to a standstill, people are forced to leave their homes, and the life is disrupted. Similarly, the impact on the industry can lead to loss of livelihood, and the long-term impact on the infrastructure can leave communities in the region economically vulnerable.

Prevention has been practiced since ancient times, which refers to methods used to prevent or reduce the detrimental effects. For instance, sustainable flood control schemes usually include both structural and non-structural measures. Design modifications of physical structures, such as planting vegetation to retain extra water, terracing hillsides to slow flow downhill, the construction of canals, and the construction of levees, lakes, dams, and reservoirs to hold extra water during times of flooding, allow the maintenance of natural environment to a large extent. Integrating with the non-structural measures, such as water retention areas, restoration of wetlands, land use, zoning, risk assessment, early warning system, and disaster preparedness, can deliver benefits to humans and ecosystems at the same time can reduce economic damage and loss of human life.

In several cases, although attempts have been made for implementing hazards prevention, nevertheless floods happen everywhere; some places even were more severe. For instance, a number of flood defence measures have been implemented since 1996 along with the study areas both the structural measures, such as levees, pumps, and a drainage canal and non-structural measures, such as flood mitigation, within communities who live in flood-prone areas. Still, floods occur frequently in many parts during heavy rainfall and spring tides. One particular flood-prone area is the Siak river basin in Riau province, Sumatra. Although the Pekanbaru, the capital city of Riau has been protected by levees on both sides of the river, flood disasters still occur every year and have become a 'routine natural disaster' for the people in the city. The most affected areas were flooded between 50 and 150 cm, like figure out in the following Figure I-1.

Figure I-1 Annual flooding in location, during and after subsided

The annual flood events cause substantial damages, economic losses, victims, and increasing anxiety against the threat. Consequently, the residents have been forced to seek shelter in the houses of relatives and public buildings such as schools, public health services, although some people choose to continue to live in their homes even 10 to 50 cm of water inundates them. Many diseases arise, which are exacerbated by an unhealthy environment.

Risk assessment is an essential component of any disaster planning. The assessment is essential for the hazards forecasting and warning, which plays a pivotal role in saving lives, properties, and crops. However, uncertainties in the hazards forecasting activities can potentially cause more damage than the reduction of losses (Yang, Scheffran et al. 2015, Hyndman and Hyndman 2016). It is argued hence that solutions to hazard problems require identification and understanding of factors that contribute to the cause of hazards. Drivers of change, including land use change and climate change, and geographic characteristics of floods may have large-scale implications for the intensity of the floods. This yields adaptive approaches into local ecosystem management and social institutions to reduce the threat of increased disasters.

B. Problem Statement

Tropical peatland forests represent approximately 60% of peat in SEE Asia land areas, of which 80% is situated in Indonesia (Page, Rieley et al. 2006, Konecny, Ballhorn, et al. 2016, Page and Hooijer 2016). Southeast Asian peatland forests are among the last vast tracks of rainforest in the region. They are home to many rare animal species and critical for world carbon storage. Peatlands in the coastal areas, such as on the Siak river basin in Riau province, Sumatra, act as freshwater buffers against saltwater intrusion and they protect valuable agricultural areas between the peat and the sea.

Peatlands are essential for water regulation. A volume of peat soil consists of 90% of water (Wösten, Clymans, et al. 2008, Hillel 2012). Peat soils are generally meters deep, and they store and maintain large quantities of water. Therefore, the peatland forests play an essential role as a retention area for adsorbing floodwater for preventing or mitigating floods in downstream areas.

A large area of peat swamp forests has disappeared due to either legally or illegally logging, drainage, agricultural conversion, fire, deforestation or large-scale developments for residential centers and industries. By 2006, close to 45% of the remaining forests had been severely affected (Wösten, Van Den Berg, et al. 2006). In Indonesia, less than 3% of the remaining forest is protected; the rest is available for logging and conversion to other land uses (MacDicken 2002, Gibbs, Ruesch, et al. 2010). The original area of peat swamp forest in Sumatra was 7 million ha (Aboukhaled, Alfaro, et al. , Andriesse 1988). By 1988, over 93% of the remaining swamp forests in Sumatra had been profoundly degraded (Silvius and Giesen 1992). Vast areas of the forests in Indonesian have been cleared for transmigration programs. Large-scale plantation companies are now finding the swampy areas increasingly attractive for various reasons (Sundari 2005). Indonesia is the largest producer of palm oil; oil palm plantation has been the core of plantation in Sumatra since the late 1990s and rapidly expanded because of their vast forests and climate conditions that are suitable for the oil palm.

Change the land use to agriculture dramatically changes the characteristics of the peat substrate. Once drained, peat is highly flammable, and the fires can burn for month challenging to extinguish. Swamp forest fires of Kalimantan and Sumatra have been known since 1988. In 1997, due to the peatland fires in both islands, 240 people were killed, 3 million were affected, and the damage cost 8 billion US dollar (Cochrane 2009). The fires can clear layers of peat causing additional land subsidence, which follows immediately by increasing the depth of flood water, generating of floods in the river basin, and leading to an increase of downstream flood.

There appears to be no capacity to deal with this massive problem of degradation of the tropical peatland forests in Sumatra (individually) and generally in Indonesia (Murdiyarso and Suryadiputra 2004, Wösten, Van Den Berg, et al. 2006). Consequently, the undisturbed tropical forest areas have become extremely rare, even in the protected areas. It is argued then, in order to cope with the current conditions of the forests, the need for an integrated assessment of all indirect and direct factors that contribute to the potential impacts become apparent.

C. Research Objectives

This research aims to assess the potential impacts on lowland areas due to the tropical peatland forest conversion to agricultural practices and develop empirical and spatial models in certain points and spatially as their consequences. Human activity on the conversion of the tropical peatland forest areas into agriculture practices may lead to damages and disasters. The research work was exploring factors that have direct and indirect implications from the activity of tropical peatland forest conversion on lowland areas. It focuses on a number of issues as the consequences of land management practices, such as deforestations, land use change, and agriculture improvement. In particular, the assessment measures the potential impacts of the conversion of tropical peatland forest. The framework of the assessment is conducted under two scenarios: recent and future prediction regarding preventing the increasingly severe impacts in the future. The theoretical framework of the risk assessment will be based on the review study; the modelling of the impacts of the forest conversion will be focused on a specific threatened area on lowland of Siak river basin in Riau province, Sumatra. These assessments will point out some recommendations based on the literature survey, field observation, work analysis, model development for sustainable future works, and policies.

In order to achieve the aim, the following objectives have been devised:

1. To understand the changing and occurring on Siak river basin in Riau province, Sumatra peatland forest which is located in lowland areas.
2. To identify the land and water characteristics from the upstream, middle stream to the downstream area of Siak river basin, through observation and analytical process.
3. To develop and establish Adaptive modelling using the Empirical method and Spatial approach.
4. To Predict the long-term impact as consequences of the tropical peatland forest conversion into the agriculture practices; in certain points and spatially on land and water interaction.

D. Hypothesis

In natural conditions, forest swamp areas function as a retention area by adsorbing flood water, thereby preventing or mitigating floods in downstream areas. It was noted before the reclamations in 1982 that, Riau was covered by nearly 80% forest, 50% of which were peat forests and most of them were located downstream of the original forests. The vast peat swamp forests have disappeared due to human activities such as illegal logging. Logging by groups from the surrounding villages had been very high until recently. It was reported that some of this logging has been conducted by local villagers, but also larger operations that involve logging crews from outside this area. Many peat swamp forest areas have been subject to un-controlled (illegal) development activities, including illegal logging and urban developments. Illegal logging and forest fires have been blamed for the rapid destruction of lowland forest of Riau over a past few years. Lowland forests are continuing to decline. Large-scale plantation companies, however, are now finding the swampy areas increasingly attractive for various reasons.

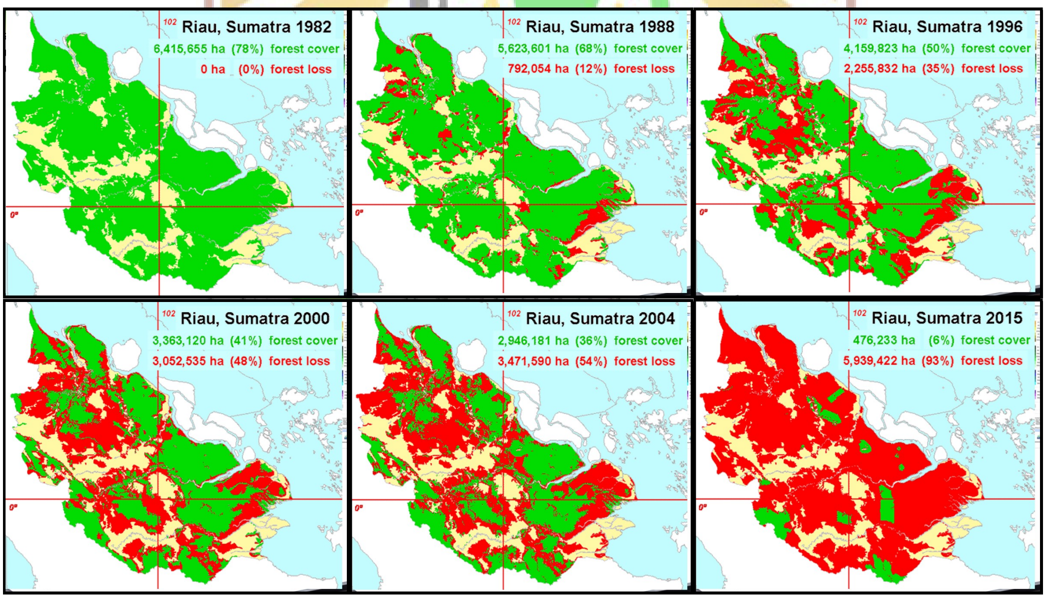

Figure I-2 Forest loss in Riau Province, Sumatra due to logging and conversion to agriculture practices. The red depicts forest loss until 2015 (Belinda Arunarwati, Svetlana, et al. 2012, WWF 2012)

In addition, large scale clearing for agriculture and transmigration also continued as government policy for distribution of the population., through in 2015, Riau province covered by remaining 6% forest (Figure I-2).

The change of forest without considering the impacts on the hydrological system and the environment cause disturbances to natural processes. The forest changes to the agricultural practices and other uses, adversely affect areas that naturally absorb waters such as; swamps, forests, etc. Loss of these natural water absorbents results in an increase of storm water runoff, a decrease in groundwater recharge, and increasing of groundwater extraction for agriculture will accelerate the land surface subsidence (Figure I-3). These are leading to damage in the river basin.

Learning from the past and recent disasters in the lowland areas, the types, causes, and impacts of the disasters are identified as an early assessment. Synthesis of each separate idea is about the land and water interaction in lowland as reasoning due to an increase in runoff, land subsidence, and rising sea levels accompanied by tidal influences.

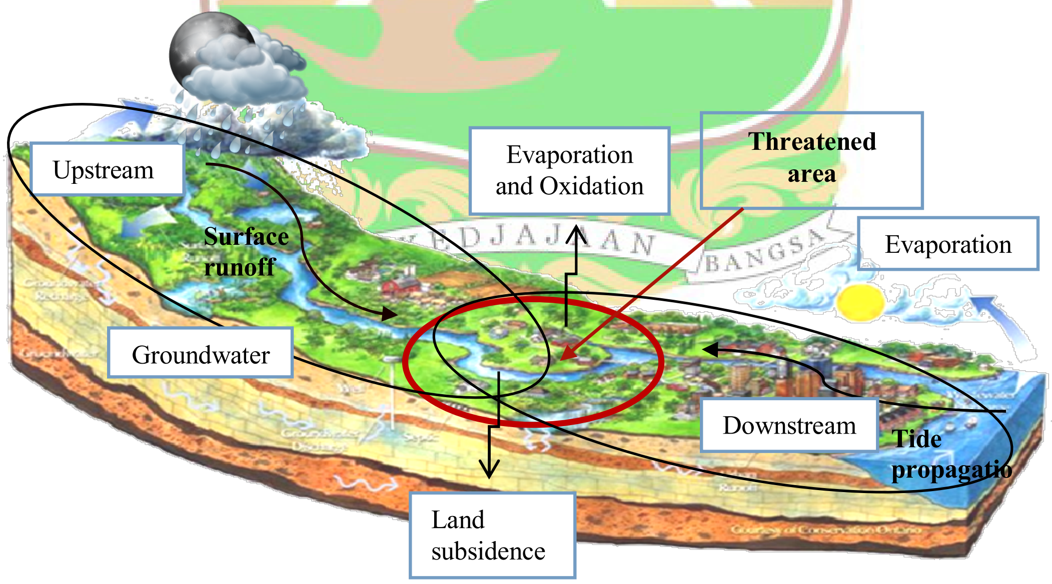

Figure I-3 An overview of the hypothesis in a river basin system

The overview of the hypothesis figured out the whole aspects and the way to find out the problem solution by listing the step of the following hypothesis:

1. The great changing has been occurring on Riau peatland forest, especially located in lowland areas.
2. The land and water characteristics vary from the upstream, middle stream to the downstream area, which can be identified through observation and analytical process.
3. Adaptive modelling using the Empirical method and Spatial approach will be developed and established.
4. The long-term impact as consequences of the tropical peatland forest conversion into the agriculture practices can be predicted in certain points and spatially on land and water interaction.

E. Research Novelty

In this research, the STATE OF THE ART needs to be sorted sequentially in order to support scientific research merit and NOVELTY. Two adaptive models have been developed;

1. Empirical modelling using linear reservoir concept dealing with land subsidence due to oxidation on organic soils has resulted from land management practices.
2. Spatial modelling was using Matrix D8 model in order to figure out widely the land and water interaction. In this spatial modelling, the calibration was conducted on the scheme where the phenomenon without land subsidence occurs, and the validation was implemented after land subsidence.

F. Dissertation Overview

The schematic view of the chapters of this dissertation is structured as follows.

Chapter 1 – Introduction

This chapter presents an introduction to the dissertation including background, problem statement, research objectives, hypothesis, research novelty, justification, aim and objectives, a brief introduction of research methodology, and the dissertation overview.

Chapter 2 – Literature Review

A literature review pertaining to the study is provided, presenting the review results from literature about the descriptions about the tropical peatland forest, flood, land subsidence, and sea level rise for further integration assessment. This chapter discusses flood-related issues along with lowland areas in Siak river basin, Riau province, Sumatra. The processes and characteristics of the issues are described in this chapter. In this chapter also describe the modelling subsidence of peat soil and Geographic Information System (GIS) based hydrology modelling.

Chapter 3 – Research Methodology

The chapter presents the research framework, the description of the study area, data observation and acquisition, to develop an empirical method and spatial analysis sequentially in order to support the scientific research merit and novelty in this research.

Chapter 4 – Result and Discussion

The chapter presents a synthesis of each separate ideas about the analysis of hydrology, land subsidence rate, surface water feature and their interaction in lowland as reasoning due to an increase in runoff, land subsidence and rising sea levels accompanied by tidal influences. This chapter also presents a synthesis of each separate ideas about land and water interaction in lowland as reasoning due to an increase in runoff, land subsidence, and rising sea levels accompanied by tidal influences. In this chapter, I also figure out the actual impacts due to the conversion of tropical peatland forest. At the end of this chapter, it comes up with the future land and water management strategies in order to prevent and reduce the future impacts from the present situation and take into the consideration the additional actions for the current hazards.

***Chapter 5 – Conclusion and recommendation*.**

The chapter concludes the work on linkages flood, land subsidence, and tide as the consequences of (legal/illegal) land management practices on tropical peatland forests. This chapter also points out some recommendations based literature survey and the research study for future work and policy.