DETERMINING RELATIONSHIP OF CROP YIELD CHANGE AND FLOOD STAGE USING REMOTE SENSING AND HYDRODYNAMIC MODEL: A CASE STUDY OF THE 2007 SOLO RIVER BASIN FLOOD

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INTRODUCTION

The existing evaluation methods to understand flood impact on agricultural crop are mostly to utilize a damage function representing the relationship of the change or loss and flood stage. However, constructing a damage function is time-consuming as it requires ex-post survey data and experimental analysis based on historical events (Brémond et al., 2013).

This study is aimed to develop an alternative approach to understand the relationship of crop yield change and flood stage using remote sensing and hydrodynamic model (Chen et al., 2017). The study used the capability of near real-time remote sensing technology to record vegetation greenness conditions to build an empirical crop yield model. Whereas, the inundation and flood parameters were simulated by a hydrodynamic model. A case study of the rice crop was employed in this study to examine the approach and to develop an alternative flood-loss relationship curve.

MATERIAL AND METHOD

Case study and flood event

Paddy crop field along Solo river basin Indonesia (Fig.1) was selected as a case study to investigate flood impact on crop yield loss. Total paddy field area in this basin accounts for 28% of the total paddy field area in the province, which has a significant amount of production in Java Island and even in the national scale.

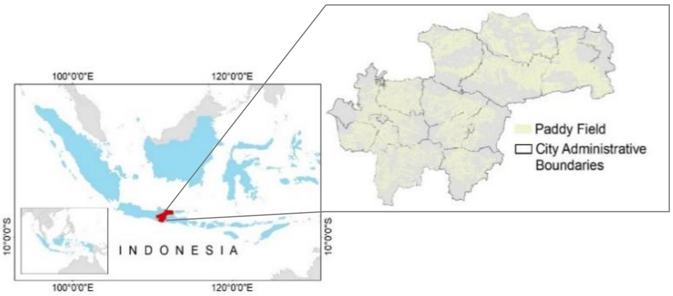

Figure 1 Case study area

From 25 December 2007 to 10 January 2008, an extreme flood occurred in the river basin affecting people and other damage in some sectors. There were approximately 60,000 people displaced, 127 people died, and 60,630 ha paddy field damaged (Shresta et al., 2016). In this study, we modeled the 2007 flood event in Solo river basin.

Methodology

Crop yield model

City-level Vegetation Indices (NDVI and EVI) from MOD13Q1 and yield statistic (ton/ha) were used to develop a multiple linear regression model to estimate crop yield change or loss due to flood. The ratio between crop yield in the flood year and a benchmark year was used to obtain the yield change or yield loss in the 2007 crop season. We selected 2014 as the benchmark year as it has an average crop yield within the cities based on the historical data.

In this study, both raw and smoothed NDVI and EVI were used as potential variables. Smoothing was done by the Savitzky-Golay filter to remove the noises that affect significant change to phenology timeseries due to the cloud. While the raw value was used to retain the original characteristic of timeseries phenology obtained from MODIS satellite, including the spectral disturbance due to natural phenomena such as water inundation resulting in different spectral color.

Raw and smoothed NDVI and EVI in timeseries were masked by the city boundary area and averaged to obtain city level NDVI and EVI value of each city. Crop statistic data in the wet cropping season (Januari - April) was used as independent variables based on the cities in the basin (n=14). Then selection of the variables and models based on the statistical parameter such as R^2 and p-value was determined. Selected models were then used to represent the spatial distribution of crop change in 2007 flood year due to flood.

Flood propagation model

Rainfall-Runoff-Inundation (RRI) model developed by Sayama et al. (2012) was used to simulate the inundation and flood characteristics. The model used several physical parameters obtained by the calibrated model, rainfall data during the 2007 flood event, and topography data derived from HYDROSHEDS Digital Elevation Model that was upscaled to 250 m resolution as MODIS provided. In this study, the outcomes of the flood model are maximum depth (m), velocity (m/s), and duration accumulation (days) during the simulation time window.

Analysis of flood impact on crop yield change

Crop yield loss map obtained from the remote sensing-based regression model was overlayed with the simulated flood inundation map to get the relationship. In this study, the grid value of flood parameters value (depth, velocity, and duration) are averaged every 0.01 yield change.

Keywords: crop, damage, flood, loss, yield
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RESULT AND DISCUSION

Crop yield loss

The yield change map obtained from the ratio between 2007 and 2014 year based on the regression models is shown in Fig.2. The grids where ratio value ranging from 0 to 1 are considered as ‘loss’, indicating yield in 2007 was lower than the benchmark year. The ratio above 1 indicate yield ‘benefit’, where yield in the flood year was higher than the benchmark. Figure 2 shows a robust signal of flooding stress in rice crop in the flood-prone area, which lies in the downstream of the river that is more vulnerable to flood attack.

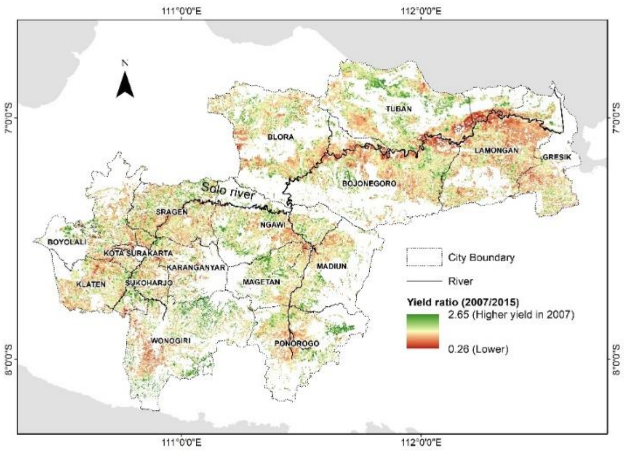

Figure 2 Yield change map

Simulated flood parameters

The depth, velocity, and duration were the main parameters obtained from the model (Fig. 3). The maximum depth obtained from the model within all inundated grids is 4 m, and the maximum velocity is 0.26 m/s. While the maximum accumulative duration is 14 days. The simulated inundation area in this study is in agreement with the observed inundation and the previous study by Shresta et al. (2016).

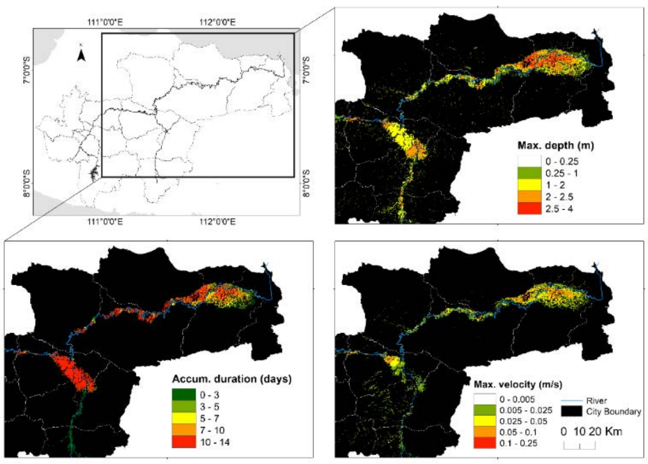

Figure 3 Flood simulation output

Flood-loss relationship

Based on the two models, we obtained flood-crop yield change relationship. In this study, we present the loss impact associated with the flood event despite yield benefit. Therefore, we obstructed the yield loss by obtaining the value of the 0-1 ratio.

Among the flood parameters, depth and velocity relationship show a robust relationship. We obtained the empirical curve damage using a logaritmic regression line, and got the best fit equation, as shown in Fig.4. The R^2 shows high value in both equations that indicate the good fitness for predicting yield loss using these equations.

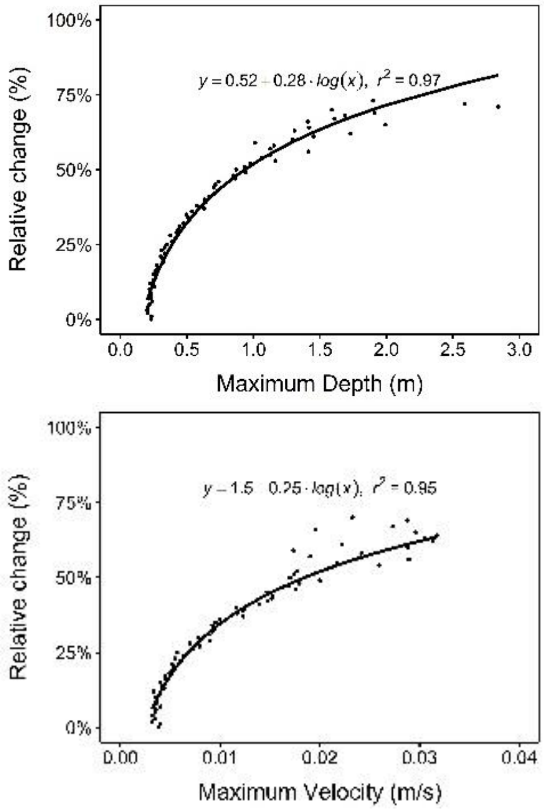

Figure 4 Relationship of crop yield change and flood parameters

CONCLUSION

This study presents an alternative approach to derive a flood-loss relationship curve using remote sensing and hydrodynamic model. However, since it relies on the empirical models, some elaboration from experimentation and historical damage data are still needed to verify the flood-loss relationship curve. Nevertheless, the utilization of the curve to the other damage assessment is also a worth further applications.

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