# EXTREME FLOOD IMPACT EVALUATION ON CROP YIELD LOSS

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## INTRODUCTION

In term of food security, floods, droughts, and tropical storms affect the agriculture sector most showing a severe impact of climate-related disasters (FAO, 2015). However, the impact of the flood was not as well understood as drought and other related disasters (Aggarwal, 2009). Therefore, the study to investigate the flood impact on agriculture is needed. This study is aimed to evaluate the impact of an extreme flood event on crop yield loss. An extreme flood event was chosen from the latest biggest flood event according to the historical data. The crop yield loss was assumed due to the direct instantaneous impact during the period of and just after extreme flooding.

## MATERIAL AND METHOD

### Case Study and Flood Event

Paddy crop field along solo river basin Indonesia (Figure 1) was selected as a case study to investigate flood impact on crop yield loss. There are approximately 526,000 ha paddy crop cultivated in the basin or 26% of the total basin area. Total paddy field area in this basin accounts 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.

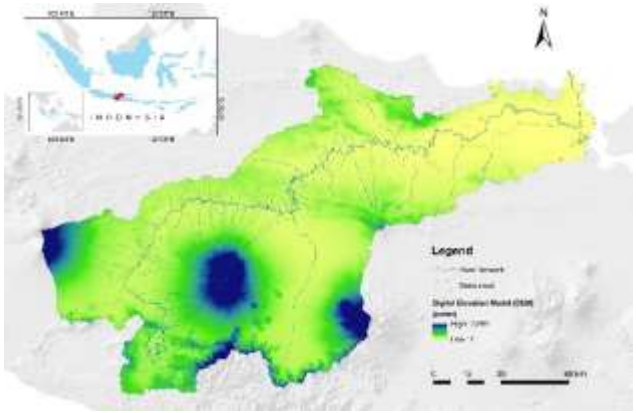



*Figure 1 Solo River Basin Elevation Model*

From the 25th December 2007 to 10th 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, 2016). In this study, we modeled the flood events in 2007 in Solo river basin by examining the following study framework.

### Methodology

#### *Crop Yield Model*

Vegetation indices (NDVI and EVI) and yield statistic (ton/ha) were used to develop a statistical crop yield model to estimate crop yield as well as to evaluate crop yield loss due to flood.

The regression model derived in this study as follows:

$$y = \sum_{i=1}^{m}\sum_{j=c}^{n} a_{ij} \times x_{ij} + b_0$$

where y is the crop yield, x is vegetation indices within time of flood event, i represents the vegetation indices index, j represents the targeted month from c to n (12 months), a is regression slopes and $b_0$ is the model intercept.

#### *Flood Propagation Model*

Rainfall-Runoff-Inundation (RRI) model developed by Sayama (2012) was used to simulate the inundation and flood characteristic. The model uses the mass balance and the momentum equations under the diffusion wave approximation.

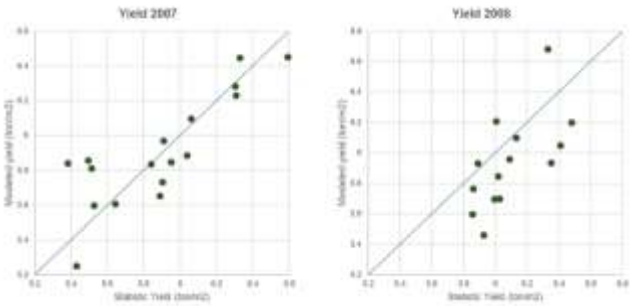
#### *Analysis of Flood Impact on Crop Yield Loss*

Flood simulation result would be a necessary information for predicting the crop area which is affected by the flood. Crop yield loss map obtained from the remote sensing-based regression model would be used for evaluating the damage with the reference of the simulated flood inundation.

## RESULT AND DISCUSION

### Crop Yield Model

Crop **yi**eld regression model was obtained shown in Figure 2. It shows the actual yield from statistic data and the model prediction for 2007 as a flood-affected year and 2008 assumed as a normal year.




Y = 3.588 – 11.207*EVIfeb – 4.0604*NDVIfeb

Y = 4.825 – 10.614*NDVIsep + 20.711 *EVIsep

*Figure 2 Actual and modeled yield*

***Keywords: crop, yield, loss, flood, damage***
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Satisfactory reliability of the model could be achieved for the 2007 model with the coefficient of determinant by 0.68. While for 2008 model the coefficient shows lower value by 0.36. According to that, the crop yield model may potentially lead some error of each yield and the yield loss value. Therefore, it should be noted that the improvement of the accuracy of the model prediction is highly needed by taking other consideration such as classification of cropping system (single, double, and tripple cropping) and applying different regression equation for each cropping system instead of assuming that all of the field has the same cropping stage.

## Flood Propagation Model

RRI model was able to simulate the 2007 flood event to understand how flood affect the crop field in the basin. The depth, velocity and duration were main parameters obtained from the model. The maximum depth within all inundated grids is 4.03 m and the maximum velocity is 0.26 m/s. While maximum accumulative duration for > 1 m depth is 13 days. The simulated inundation area in this study is in agreement with the observed inundation and the previous study (see Shresta, 2016).

As shown in Figure 3 (only flood duration map is shown here), I, II, and III annotation shows three main major inundation area which is located in the upstream, confluence, and the downstream of the river, respectively. A significant large extent inundation is located in the downstream area which is mostly paddy crop field.

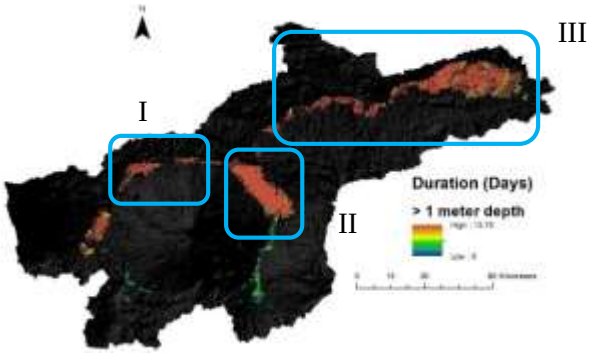


*Figure 3 Maximum Duration (>1meter depth)*

## Crop Yield Loss

The 2007 yield loss map was obtained by subtracting the modeled yield of 2008 and 2007. As shown in Figure 4, the yield loss map shows that there is a significant yield loss mostly located in surrounding river channel shown by the red line shape. While blue line shape shows the location of major inundation simulated by the flood model (see Figure 3). Based on the visual comparison of simulated inundation area and significant crop yield loss grids, however, it seems that there is no strong relation between potential flood affected area and its associated damage area. Since the flood inundation will derive a damage to the crop, the grids indicating losses should be within or surrounding the inundation area.

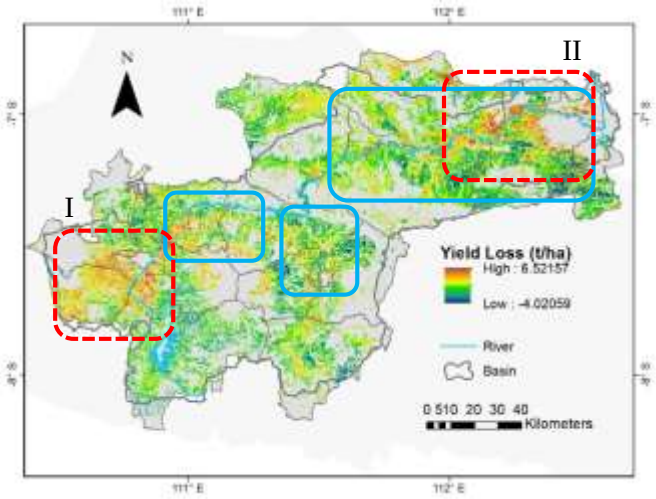


*Figure 4 Yield Loss Map*

## Total Damaged Paddy Field Area

In order to evaluate the total paddy field area damaged by the flood, we applied a threshold to detect the grid containing a significant yield loss. We set the threshold by 1 ton/ha, meaning that the grids which have yield loss value greater than one were used for calculating the total damaged area. While the rest of grids having low loss value were assumed as a normal anomaly and were not significantly damaged due to the flood. Table 1 shows the total damaged area by applying other various different threshold as a comparison. By applying such threshold, the total affected area based on the model is close to the observed damaged area reported by Shresta (2016).

*Table 1 Total Flood-affected Area by Applying Threshold*

| Loss (t/ha) | Simulated Affected Area (ha) | Observed Affected Area (ha) |
|---|---|---|
| > 3 | 262 ha | |
| > 2 | 5049 ha | |
| ***> 1*** | ***69,401 ha*** | ***60,630 ha*** |
| > 0 | 359,944 ha | |

## CONCLUSION

An extreme flood impact evaluation on crop yield loss was presented using remote sensing data and flood simulation. The crop yield model and flood propagation model can be elaborated as a tool to understand the impact of flood on crop. With some degree of accuracy, regression crop yield model was able to predict crop yield loss spatially. By the information resulted from flood simulation, an understanding on how flood affect crop can be concluded.

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