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Original Article

# Quantifying the Direct Impacts of Climate Change on Flood Damage for Rice in Hung Nguyen District, Nghe An Province

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**Abstract:** A deep understanding of current and projected flood risk is need for effective flood risk management and better adaptation planning under climate change. This research aims to investigate the direct impacts of climate change on flood damage to rice under changes in water depth and flood extent induced by rainfall increase and sea-level rise. The Hung Nguyen district, a rural area in Nghe An province, the Ca river basin was selected as a case study. A rice-specific damage tool is employed to evaluate changes in flood damage to rice under climate change scenarios projected for the study area. We found that the rice damage of the historical flood event in October 2010 in the study area is approximately 34 billion VND, and the lowland area in the center of the study area is the highest risk region. Based on an ensemble of climate projections for the RCP4.5 scenario as recommended by the Ministry of Natural Resources and Environment for the study area, the current damage projects to increase by 61% under a 0.5 – 1.5 m flood depth increase. The results indicate that the damage increase due to climate change by approximately 20.9 billion VND under an RCP4.5 scenario without further adaptation. The commune-level flood damage maps are vital for better adaptation and mitigation of the negative impacts of flooding on rice.

*Keywords:* Climate change, flood, damage, rice, Ca river basin.

## 1. Introduction

Climatic factors, including rainfall and time of rainfall events, play a vital role in flood damage since it exerts on flood depth and flooded extents. Therefore, climate change will likely affect flood damage in the future [1-5]. Characterizing such changes is necessary to understand the impacts of global warming on

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rice damage to minimizing the damage of floods and enacting the measures in advance for effective disaster management and adaptation planning. However, the impact of climate change/global warming on rice damage is still in its infancy compared with other economic sectors [6-8].

Several studies confirmed that even under the current climate conditions, damage to agricultural production due to excess precipitation events or flood events is still substantial [7,9]. Few studies have shown that the production losses may double during the next thirty years under excess precipitation due to climate change [10]. Various studies have focused on the hazard assessment under climate change, but the damage assessment has not received much attention [6].

The goal of this study is to investigate the impacts of climate change and sea-level rise on rice damage. The agriculture-specific damage tool integrated the local damage function which developed from empirical damage data is employed [11]. The research hypothesizes that changes in other flood characteristics will be implicitly reflected in flood depth variable. The study is performed in Hung Nguyen at a sub-regional scale in Nghe An province, the Ca river basin.

## 2. Materials and methods

### *2.1. Model Description*

We use a damage model to predict the rice damage under climate change (Figure 1). The specific-rice damage model incorporates a non-linear damage function as the relationship of rice damage and the flooded depth [11]. The hydrodynamic model is employed to capture the impacts of climate change on flood conditions. The estimated flood conditions served as a key determinant for the rice impact in the damage model. The October 2010 flood event considers for the current simulation. The flood conditions projected according to climate change scenarios are employed to examine the flood damage.

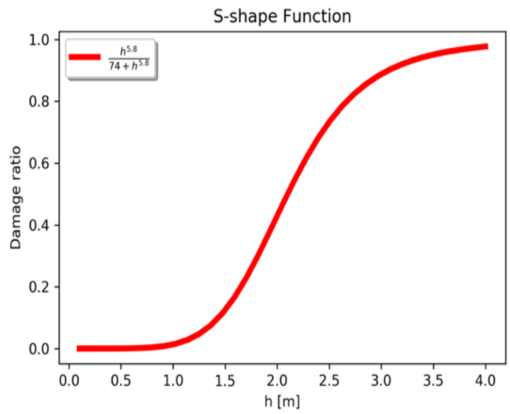


Figure 1. Damage function used in Damage model. h is water depth. (Source: [11])

The performance of the damage model based on the S-shape function in capturing the rice damage for the study area was confirmed in the study of Nguyen et al. (2017) [11] with a Nash value of around 0.7.

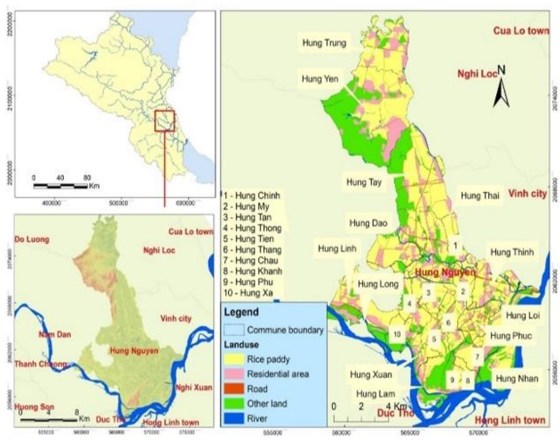


Figure 2. Map of study area in Hung Nguyen district, Nghe An Province, the Ca River Basin. (a) Administration map of the Ca River Basin showing Hung Nguyen in red region, the simulation is conducted over this area of 15,955.23 ha; (b) Map of elevation of Hung Nguyen district. The Hung Nguyen district is classified as one of the highest flood risk affected area in Nghe An province. Elevation data obtained from Vietnamese Department of Survey and Mapping (c) Landuse map of Hung Nguyen, Nghe An. Landuse data obtained from Hung Nguyen district people's committee.

### *2.2. Study Area*

The Hung Nguyen district, a rural area located southeast of the Nghe An province, the Ca river basin, is selected as a case study for flood damage evaluation (Figure 2). The region suffers a high level of flood risks. The damage in 21 years is around 3,300 billion VND [12]. The natural area of the study area is 15,955.23 ha, of which approximately 10,106.56 ha for the agriculture area; and 6,311.36 ha area for rice field. The dominant livelihood is subsistence farming, 77% of the population [13]. Here we only considered rice in evaluation, the dominant vegetation of the study area. The rice area is approximately 65% agriculture area, showing a slight decrease recently. The flooded season in the study area is from June to November. The highest flood months usually happens from September to November. The simulation domain covers the whole 10,106.56 ha agriculture area in district with a medium to high vegetation coverage (Figure 2).

### *2.3. Data*

Topography: 10 m × 10 m resolution topographic data was provided by the Department of Survey and Mapping Vietnam [14] for flood depth and flood extent simulation.

Land use data: Winter rice crops at 10 [m] spatial resolution is extracted from the land use maps for Hung Nguyen province provided by the Hung Nguyen district people's committee. Figure 2 shows the current distribution of rice crops in the study domain. At the sub-regional scale, we assume the rice area mobility is negligible or immobile for simulations as a result of the insignificant decrease in the rice crop area recently [15].

Flood variables: The hydrodynamic simulation provides the maximum flood depth and flood extent for baseline and climate change conditions. The inundation model performance to capture the inundation characteristics have been demonstrated in the work of Nguyen et al., (2014) [16] (Figure 3a). Both precipitation and sea-level rise under the climate change conditions are incorporated in the flood simulation. This integration provides the predictive capability to capture the impacts of climate changes on flood conditions. These data thus will be used directly to evaluate the alteration in flood damage.

Climate change scenarios. The flood condition for a typical flood in October 2010 as input of damage model provides a rice damage baseline condition (S0-baseline). S1 conditions are under a 50% rainfall increase and a 44 cm sea-level rise projected for 2100 according to the RCP4.5 scenario (recommended by the Ministry of Natural Resources and Environment [17]). No change in flood distribution compared with the 2010 flood event is assumed for the scenario (S1) in this study.

It is unlikely that S1 will be happening in the future with the same distribution as the previous one. However, scenario S1 allows us to analyze rice damage distribution associated with flood depth under an increasing of rainfall and sea level on rice damage which is critical to understand.

Rice properties: the study focused on winter rice, usually planted from May to July and harvested in the early winter from October to November in the study area [18]. The domestic rice price in Hung Nguyen is 4,500 VND/kg according to the Decision of Nghe An Province [19].

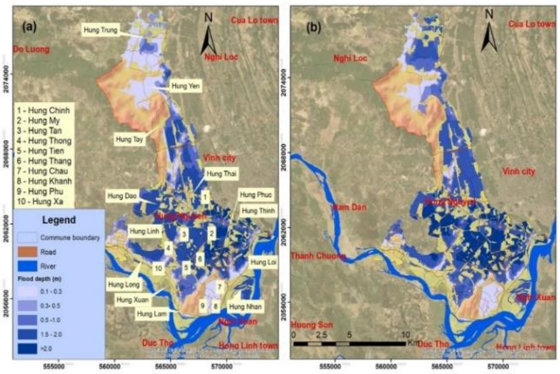


Figure 3. Inundation map for rice paddy area under (a) the flood event on October 2010 (Source data: [16]) and (b) the climate change and sea level rise projected for 2100 using the RCP4.5 scenario.

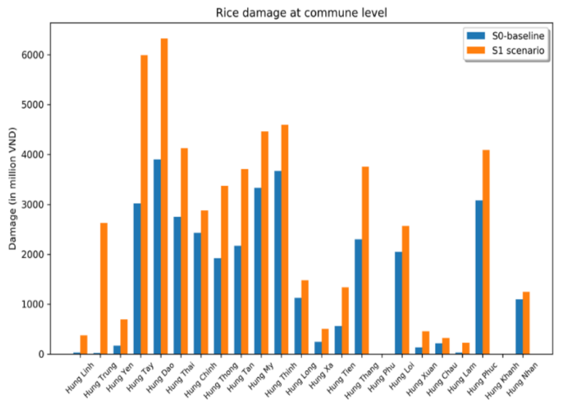


Figure 4. Mean rice damage at commune level obtained from model simulations for each climate scenario.

## 3. Results - Impacts of Climate Change on Rice Damage

### *3.1. Flood Simulation*

The flood depth used in S0 is approximately 1.5 m (Figure 3a). The flood depth increases from 0.5 m to 2.0 m in the case of the S1 scenario.

The flood extent with the depth from 0.3 to 2.0 m reduces significantly, around 17%, compared with the baseline scenario. This feature can be seen clearly in the northern part of Hung Nguyen (Hung Trung and Hung Yen communes). Adversely, it shows a dramatic increase in the flood extent with above 2 m flood depth under the projected climate change scenario. However, the extended inundation area is mainly located in non-agriculture land. Figure 3 displays the changes in flood conditions, the higher water depth, non-linearly expanding the flood extent.

### *3.2. Damage for the Climate Change Scenarios*

We compared the rice damage of the study area for the baseline condition (S0) with the increase of inundation characteristic conditions (S1).

Figure 4 shows the variation of rice damage at the commune level for all scenarios obtained from model simulations. The variation of damage is highly spatial dependent as a result of lowland features and agricultural land in the commune. The Hung Tay, Hung Dao, Hung My, Hung Thinh, Hung Phuc communes are the highest suffered damage communes, above 3 billion VND loss. But the paddy fields at highest risk is scattered mainly in Hung Phuc and small part in Hung Thinh. These are possibly the result of having large area of paddy fields in those communes.

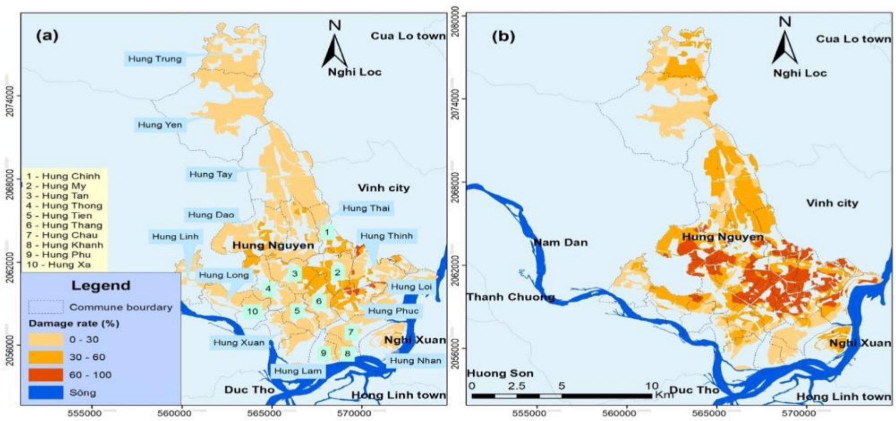


Figure 5. Flood damage map to rice for (a) flood event on October 2010 and (b) under the climate change and sea level rise projected for 2100 using the RCP4.5 scenario.

In Hung Trung and Hung Tay, the rice damage shows a dramatic increase. This increase is due to a low change in flood depth but over the large flood area, 2.6 and 2.9 billion VND respectively. In Hung Dao, the rice damage also shows a dramatic increase but under the effect of high flood depth increase over the small area, 2.4 billion VND (Figure 4).

Even under the impact of climate change, the rice damage in several communes has not been affected, such as in Hung Phu and Hung Khanh, with no change in flood damage. This result is probably because the climate changes do not cause the change in flood depth for these areas.

The mean rice damage found in the baseline condition S0 is 34.24 billion VND for the whole Hung Nguyen district. The small paddy field area in the district center lowland is at the highest risk. Under the climate projection, the damage projects to increase 61% (corresponding with 20.9 billion VND increase) under the S1 condition, 55.1 billion VND loss on average.

The highest increase in risk observes in the central area of the study site. The highest risk happens in the same paddy field as the baseline condition but expands broadly under projected climate conditions (Figure 5). The Hung Tay is the highest suffered region. The damage in the Hung Tay commune is nearly double under the impact of climate change, increase from 3.0 billion VND to 5.9 billion VND. In many communes located on the outer side of the Hung Nguyen (Hung Trung, Hung Yen in northern part, Hung Xa, Hung Tien, Hung Xuan, Hung Lam in southern part), the damage is insignificant under the baseline scenario but increase dramatically under the S1 scenario. For example, the loss in Hung Trung under S0 scenario is 16.9 million VND while it reaches 2.6 billion under the S1 scenario. This is because of the significant change in the flood depth of these regions.

The effects of flood extent are not much stronger than the impacts of higher flood depth since almost the whole area of Hung Nguyen district is being flooded even under the baseline condition.

## 4. Conclusion

This study provides a picture of projected flood damage under climate change. The results demonstrate that the proposed model can be useful to investigate the impacts of the nonlinear changes in water depth and flood extent on the rice damage. In conclusion, it should notify several limitations of this study. The impacts of the flood on rice damage caused by multi factors do not consider in this study. Although water depth is the main factor in many studies, rice damage is affected by growth periods, duration, rice type, coping capacity, flooding time, and harvesting time. Therefore, considering only water depth and flooded extent in rice damage assessment limits the applicability of the proposed model in estimating the rice damage. Further work should incorporate the dynamics of other factors for better study the rice damage under the impact of the flood.

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