Estimation of damage area due to tropical cyclones using fragility curves for paddy rice in Japan

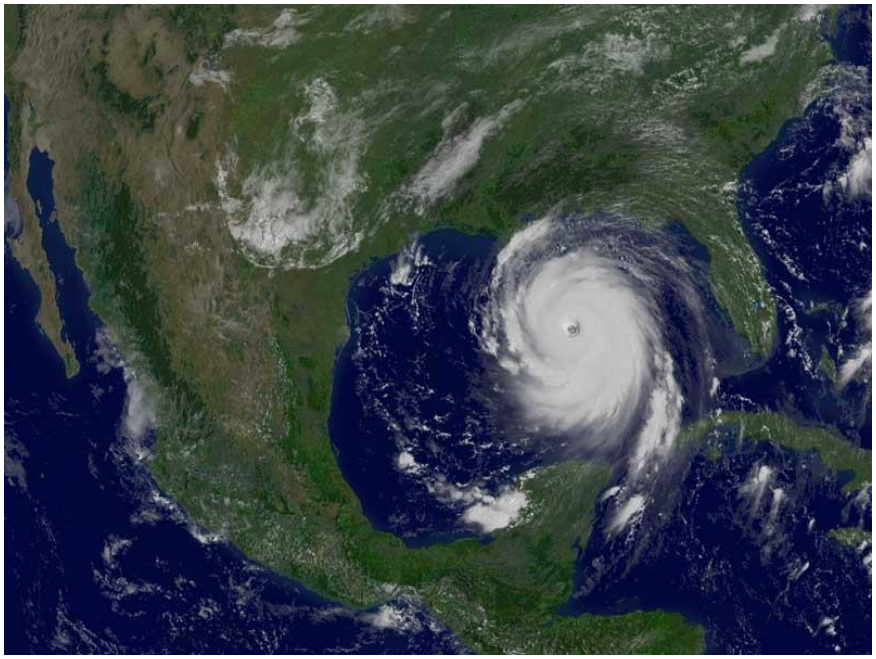
17th AIM international WS
Feb. 18, 2012

○Yuji Masutomi（CESS）
Toshichika Iizumi（NIAES）
Kiyoshi Takahashi (NIES)
Masayuki Yokozawa(NIAES)

This presentation is based on Masutomi et al., (2012) ERL (in press)

Intro

Damages to crops due to Tropical cyclones

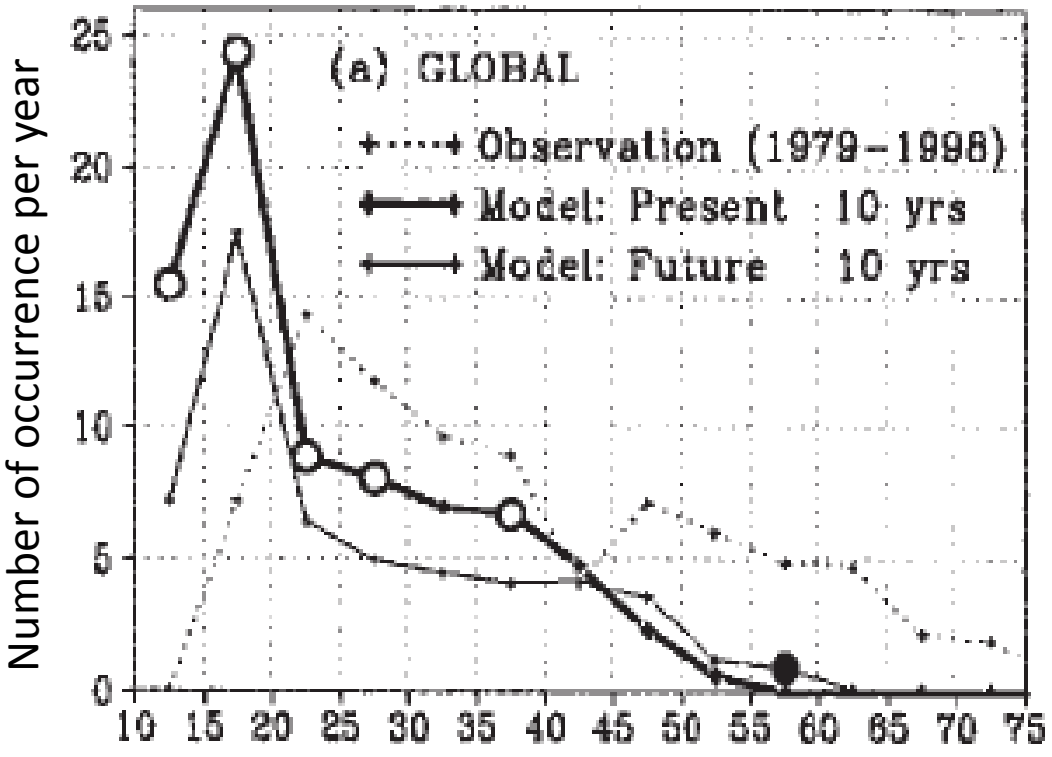


Hurricane Katrina, 2005 AUG. 29

- Hurricane Katrina in 2005 decreased sugarcane production in Louisiana by 8.7% (USDA 2005)
- Cyclone Sidr in 2008 decreased aman rice production in Bangladesh by approximately 15% (GoB 2008)

Tropical cyclones (TCs) have caused substantial damage to crops in parts of the world.

Future trend of TCs



Oouchi *et al* 2006

The number and intensity of TCs will change under the global warming condition.

Motivation and Objective

- We want to know whether crop damage increase or decrease due to the change in the number and intensity of TCs
- It is necessary to develop a model for estimating TCs' damages to crops.
- We propose a new method for estimating TC's damages to crops
  - We focus on the estimation of the area [ha] of crop damage, not the amount [t].

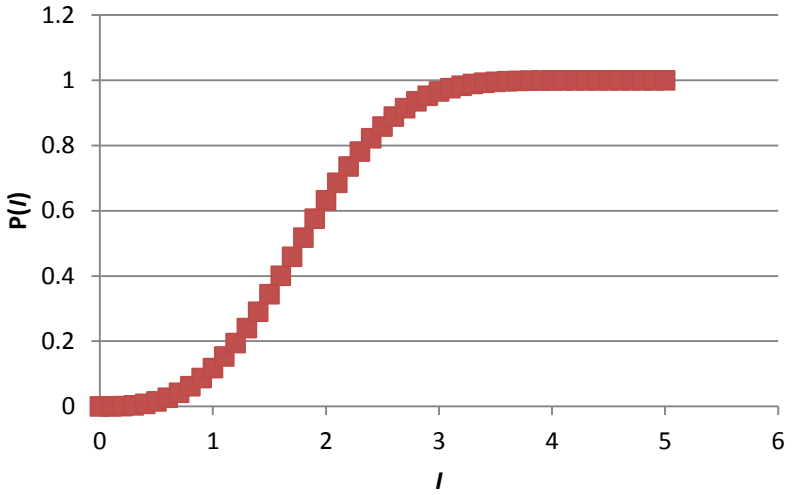
Study area and crop

- Study area
  - Japan
- Study crop
  - Paddy rice
    - Staple food in Japan

Method

Fragility curves

- FCs denote the relationship between the probability of damage and the intensity of external forces.



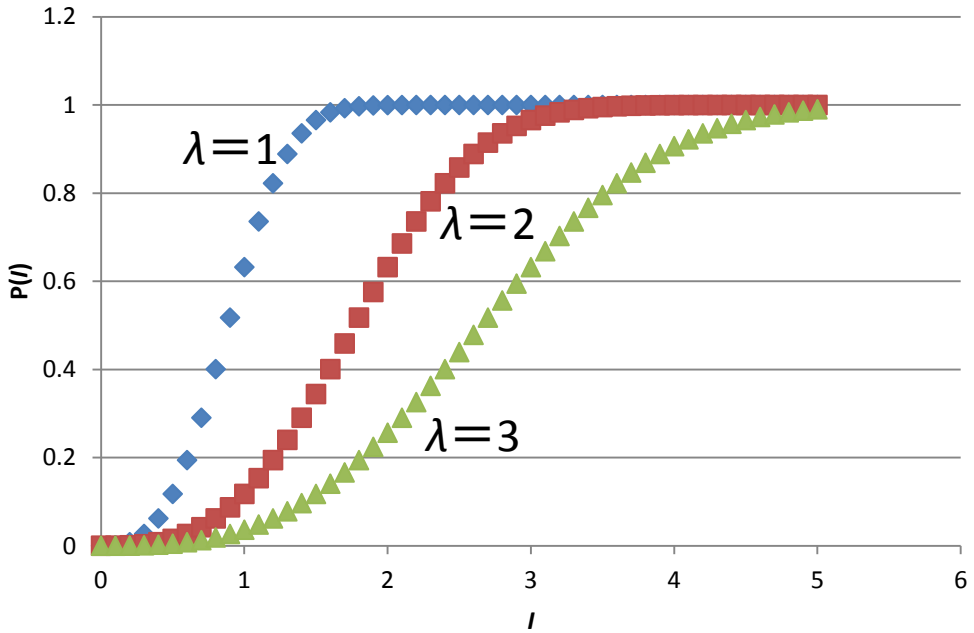
- FCs are widely used to assess damages to buildings due to typhoons, storms, earthquakes and other natural disasters.

- Cumulative distribution function of Weibull distribution is used for FCs in this study

$$P(I) = 1 - \exp(-(I/\lambda)^k)$$

Characteristics of Weibull distribution

$$P(I) = 1 - \exp(-(I/\lambda)^k)$$



- λ indicate the resistance to external forces.
  - Large λ implies a low probability of damage (low vulnerability).
  - Small λ implies a high probability of damage(high vulnerability).
- k is a shape parameter.

Modification of FCs for crops

- Resistance of paddy rice to TCs vary with the growth stage (Tsuboi, 1961; Yamada, 1959; Funaba *et al*., 1992)

$$I = aT^2 + bT + c$$

T: Growth stage
a, *b*, and *c*: Parameters

$$P(I) = 1 - \exp(-(I / I)^k)$$

$$P(I) = 1 - \exp(-(I / (aT^2 + bT + c))^k)$$

-TC intensity-

- We assumed that TC intensity is expressed by a linear combination of maximum wind speed and accumulated rainfall

$$I = W + mR$$

W: maximum wind speed.

(※We used normalized wind speed)

R: accumulated rainfall

m: parameter

$$P(I) = 1 - \exp(-(I/(aT^2 + bT + c))^k)$$

$$P(W,R) = 1 - \exp(-((W + mR)/(aT^2 + bT + c))^k)$$

Estimation of damage area

- We applied a FC to each prefecture in Japan.

$$P(W,R) = 1 - \exp(-((W + mR)/(aT^2 + bT + c))^k)$$

- We estimate damage area over Japan

$$EA = \sum_{\text{Pref}} P(W,R) * PA$$

EA: Estimated damage area
PA: Reported plating area

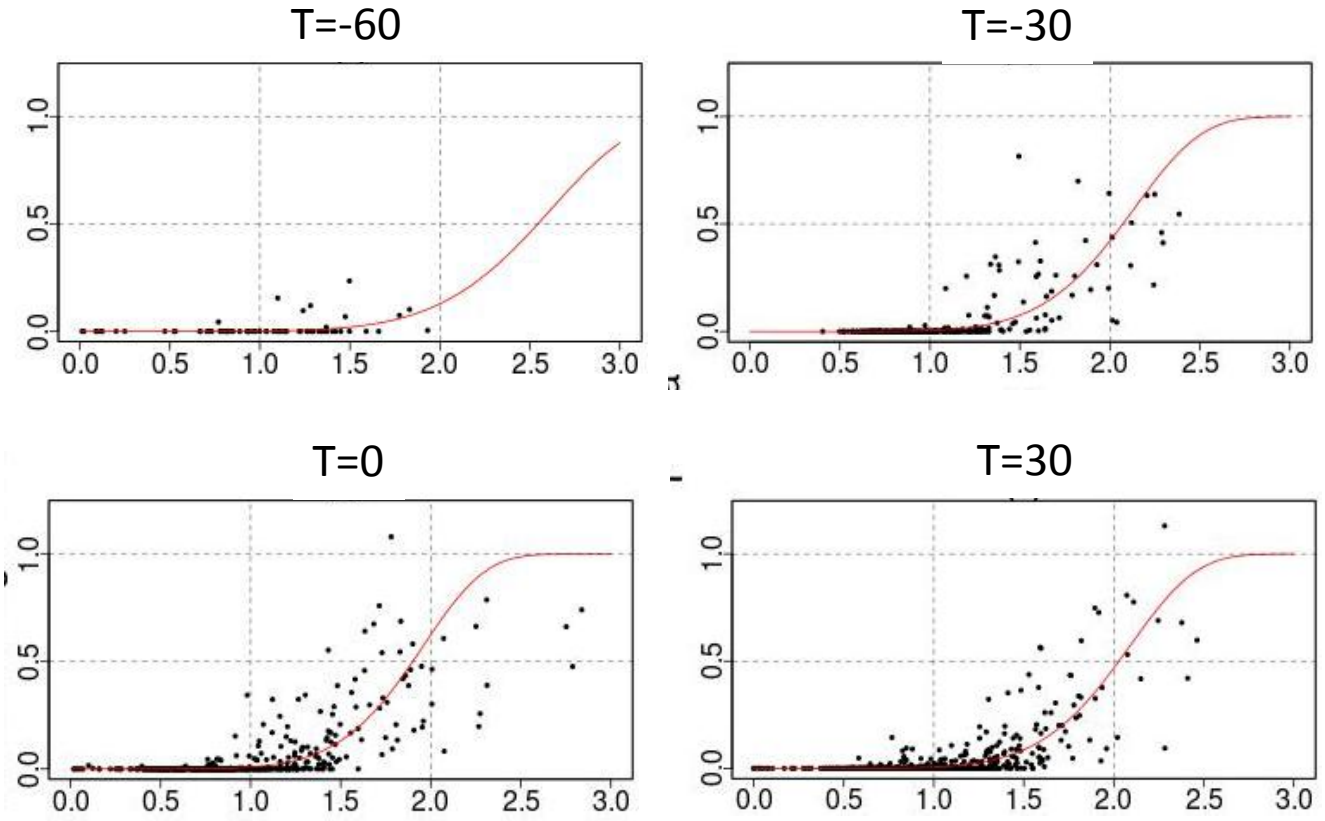
Parameter selection

- The parameters a, b, c, m and k were statistically selected.
- By minimizing the difference between estimated and reported damage areas.
- The downhill simplex method was used
- We used 42 typhoons which caused damage to paddy rice in Japan from 1991 to 2007 .

Validation

Validation –FCs-

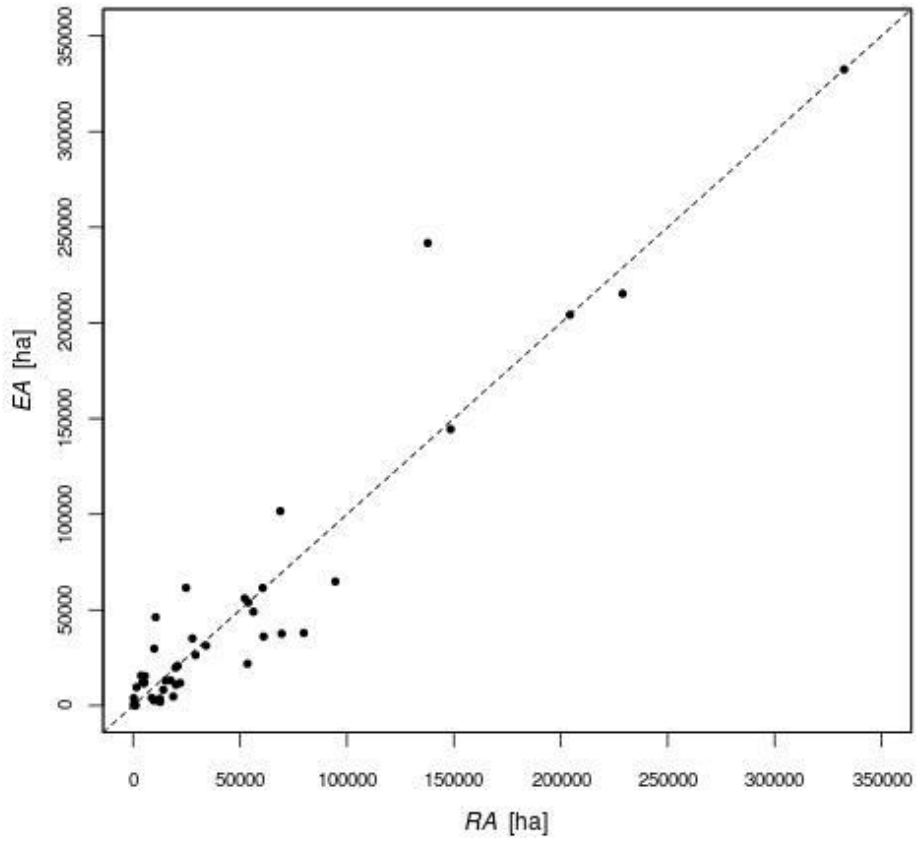
- Comparison between observation and the derived FCs



FCs can reproduce the trend of the probability of damage.

Validation -Estimation of damage area-

- Comparison of damage area



The estimated damage areas generally show good agreement with the reported ones.

Validation -Estimation of damage area-

- Estimation errors for different range of damage area

Range of *RA* [ha]	Average error [%]
<5000	327.9
5000−10000	126.5
10000–20000	81.3
20000–50000	40.6
50000–100000	29.9
>100000	16.8

The model has a high ability of damage estimation for large typhoons

Summary and future work

- We proposed a method to estimate the crop damage area due to TCs by using fragility curves.
- The method has a high ability to estimate damage areas for large TCs

- Combining typhoon simulations with the method, future impact under the global warming condition will be assessed.

Thank you for your attention

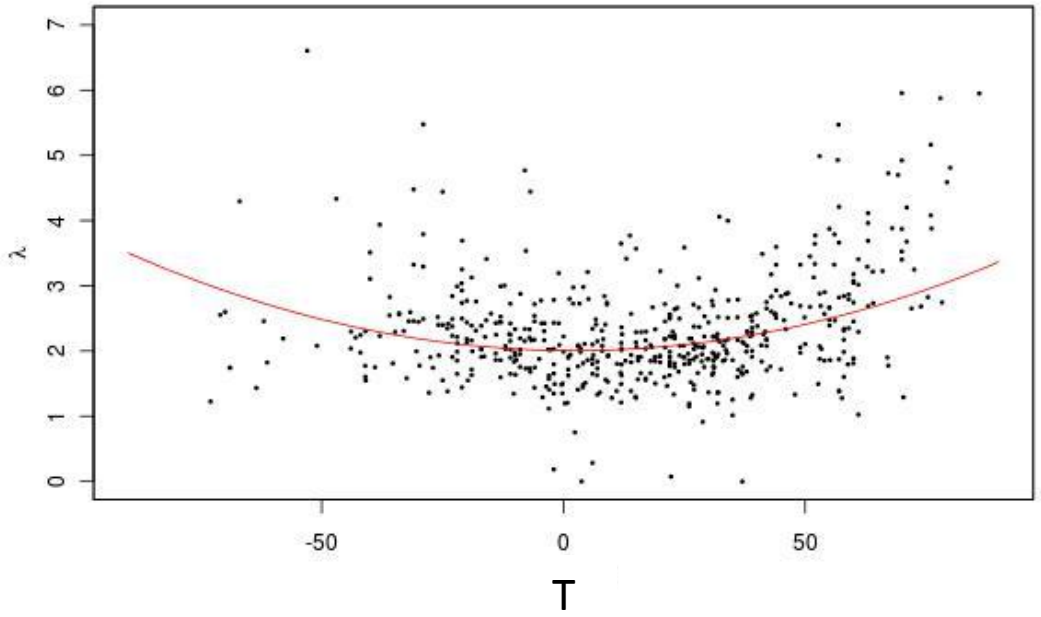
Acknowledgement:

This research was supported by the Environment Research and Technology Development Fund (S-8) of the Ministry of the Environment, Japan.

This presentation is based on Masutomi et al., (2012) ERL (in press)

Resistance of paddy rice

- λ : Resistance to TCs



The heading stage (T=0) is the most vulnerable stage against TCs

It is possible to reduce the damages if we displace the heading stage from TCs season by adjusting variety and/or planting date (Adaptation!)