DEVELOPMENT OF ASSESSMENT TOOLS FOR FLOOD DAMAGE RISK ON PADDIES AND ITS APPLICATION TO LOW-LYING AREAS IN JAPAN

ICID2015
26th ERC & 66th IEC

Hiroki Minakawa* and **Takao Masumoto***
*National Institute for Rural Engineering, NARO, JAPAN
E-mail: hmina@affrc.go.jp **Phone:** +81-29-838-7538 **Fax:** +81-29-838-7609

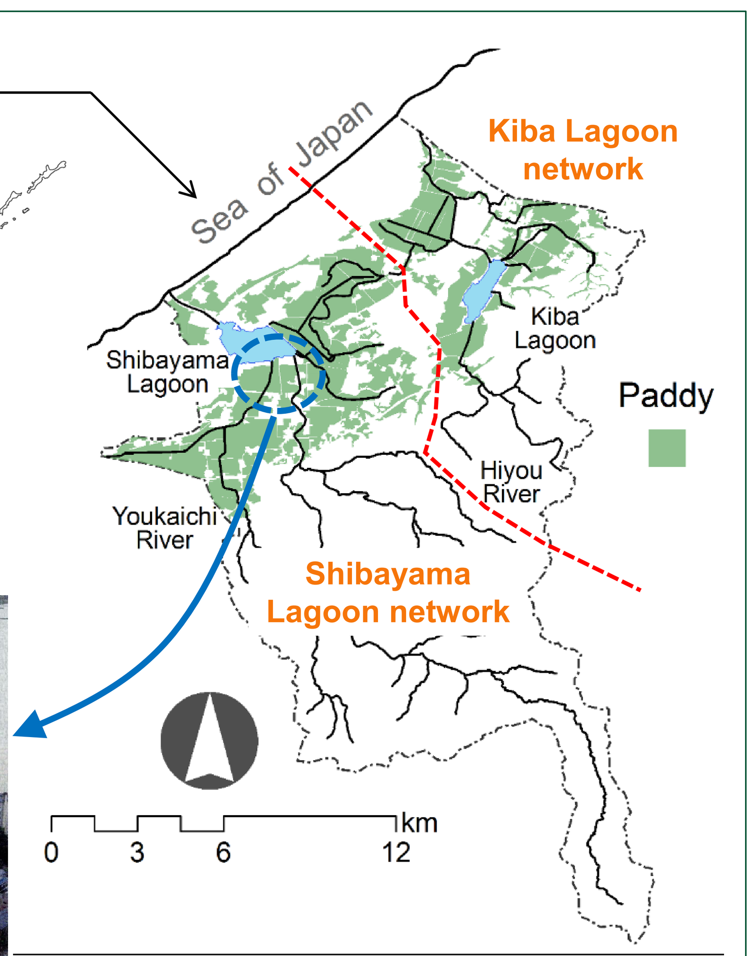
1. Background

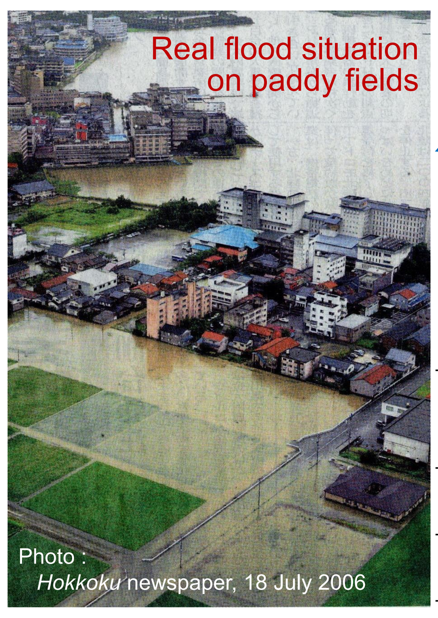
As a result of climate change, characteristics of heavy rainfall are predicted to change in future. Heavy rainfalls trigger flood disasters (**Figure 1**), especially in low-lying areas. In Asia monsoon area, **paddy fields** are typically expanded in low-lying area, and are important for food production (rice is main crop). There are often damaged by flooding with heavy rainfall.

To considering countermeasures for climate change impacts, **flood risks** should be estimated. However, the risks would be changed with **rainfall patterns** (= combination of total rainfall amount and shapes of hyetograph). Then we have to carry out the effect from difference of rainfall pattern.

This study discuss a method for evaluating a relationship between the risks of flood damage in low-lying paddy areas and the heavy rainfall patterns.

Figure 1 Outline of study area and flood situation in the basin





	Basin area (Total) (km²)	Paddy area in the basin (km²)	Note
Shibayama lagoon network	70.0	27.0	Discharge from montain area (100 km²) is flow into the lagoon
Kiba lagoon network	55.0	13.5	Considering runoff from urban areas (about12 km²)

2. Study area

The Kaga three-lagoon basin in Ishikawa Prefecture, Japan was chosen for a study area (Details are in **Figure 1**). The drainage system is topographically divided into two networks, one is the network which is going through the Shibayama lagoon (called **Shibayama lagoon network**), and another one is through Kiba lagoon (**Kiba lagoon network**). Here, the flood risks in the networks were evaluated individually.

3. Methodology and tools for flood risk assessment (Figure 2)

Step 1: Generation of many patterns of input rainfall data

A diurnal rainfall pattern generator (**Tool 1**, Minakawa, *et. al*., 2015) was used for creating short-term patterns of hyetograph. Total rainfall amount was fixed to 3-day rainfall with 2 to 200 year return periods, and generation number of hyetograph was set to 300 in each.

Step 2: Drainage analysis with all rainfall patterns

We already applied *a drainage analysis model* (**Tool 2**, Minakawa, *et. al*., 2013) to the study area. The model can calculate water level (depth) on all paddy fields, we got the results of the same number as input rainfall data (300 results with each rainfall amount).

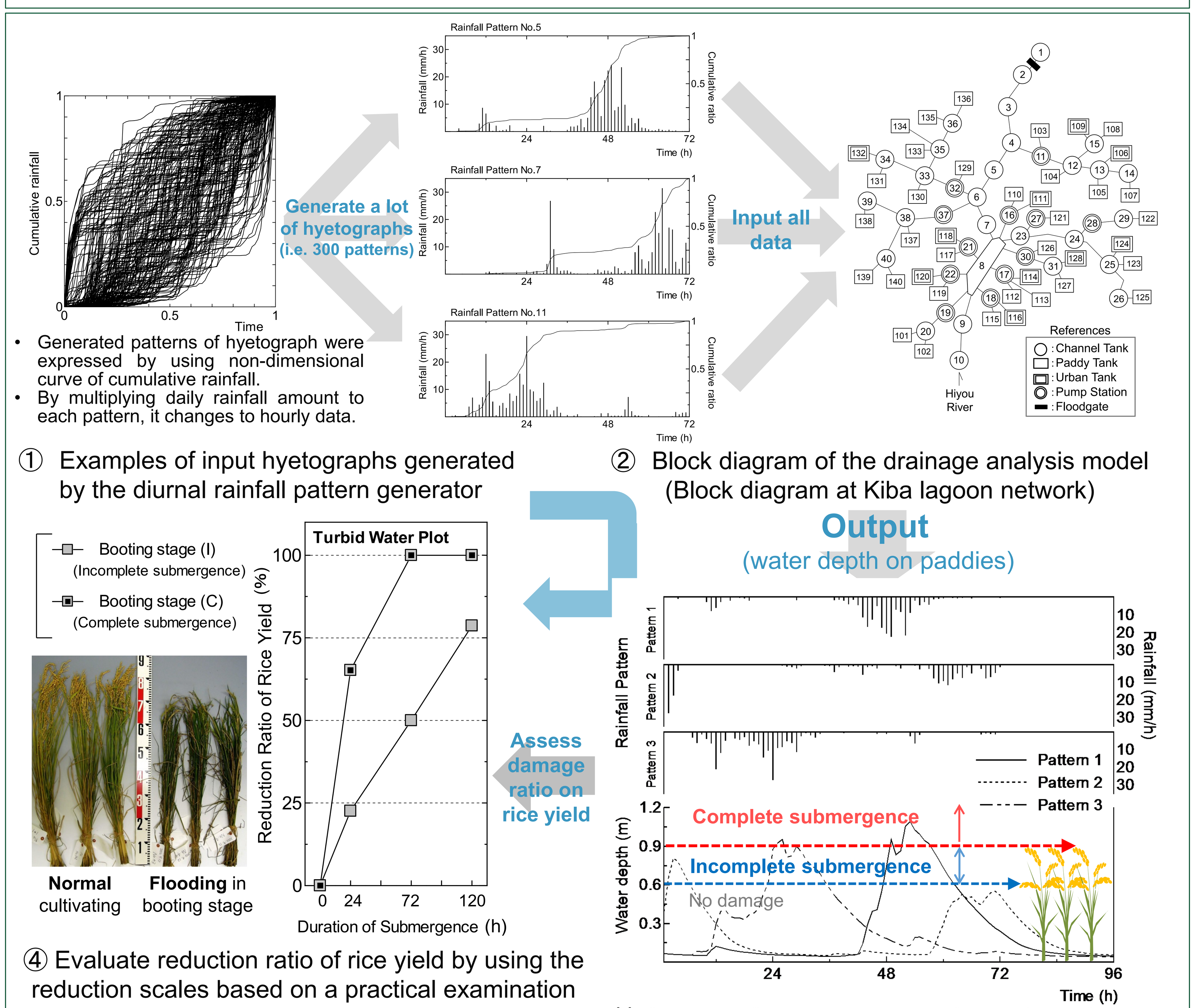
Step 3: Counting inundation duration on each paddy block

Inundation duration on paddy fields were counted in each result. In this study, the flood situation with water depth of over 0.6 m was assumed as a cause of rice damage.

Step 4:Estimation of the damage ratio on rice yields

Damage ratio on rice was estimated by applying a *reduction scales on rice yield* (**Tool 3**, Minakawa, *et. al*., 2014) to the results of inundation duration. By using the ratio, the damage amount of rice was evaluated as eq.(1).

Figure 2 Flowchart of flood risk assessment in low-lying areas (how to evaluate damage amount on rice yield)



$$D = R \times A \times Yn \quad \cdots \quad (1)$$

D: Damage amount of rice yields (ton) *R*: Reduction ratio (%)
A: Area of paddy (ha) *Yn*: Yields in normal year (here, 5.3 ton/ha)

・Between 0.6 m to 0.9 m: incomplete submergence
・Over 0.9 m : Complete submergence

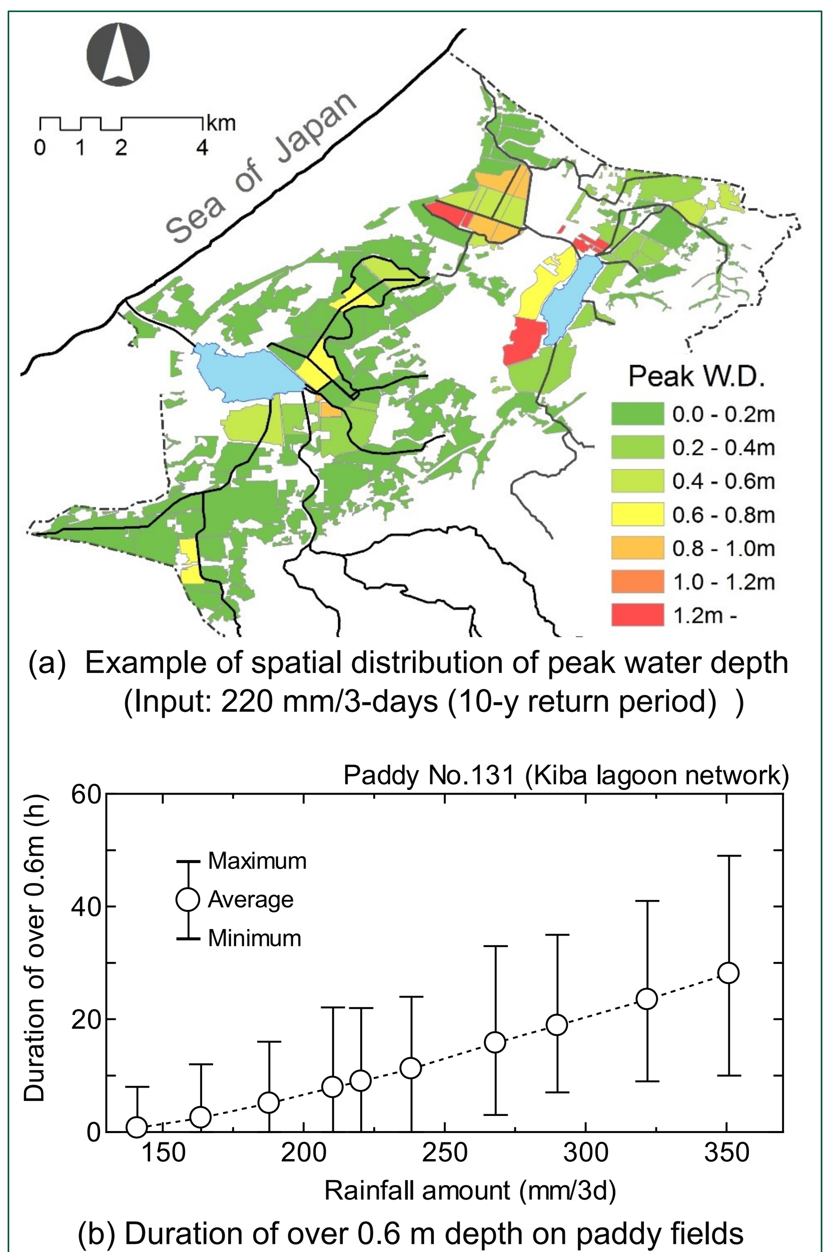
4. Result and discussion

4.1 Inundation duration on paddies

Figure 3(a) showed distribution of peak water depth on paddy field. The result indicated that the paddies in the Kiba network were relatively vulnerable for heavy rainfall, comparing with paddies in the Shibayama one.

At the same time, **Figure 3(b)** was showed the result of averaged, maximum and minimum inundation duration (over 0.6 m) from 300 outputs in each rainfall amount. There were big range between maximum to minimum duration, even if the total amount of input data were same. These differences were seen to an effect of rainfall pattern.

Figure 3 Examples of result of the drainage analysis



(a) Example of spatial distribution of peak water depth (Input: 220 mm/3-days (10-y return period))

(b) Duration of over 0.6 m depth on paddy fields Example of paddy No.131 in Kiba network)

4.2 Damage estimation in the basin

Table 1 indicated total damage ratio in the basin with each rainfall amount. The results with heavy rainfalls of 10-year return period (the standard scale of design rainfall for drainage planning) showed that a percentage of damage amount to total amount of rice yields in the basin varied from 0.0 % to 1.0% in the Shibayama network (mean value was 0.2%). On the other hand, the ratio in Kiba network varied from 8.4 % to 13.8% (mean 11.2 %).

We found that the risk increased according to the increment of rainfall amounts, but also depended on hyetograph patterns for the input amounts of rainfalls. In addition, the result indicated that the Kiba-network was more vulnerable to heavy rainfalls comparing with the Shibayama network.

Table 2 Relationship between rainfall amount and damage ratio on rice yield in each basin (Average, Maximum, and Minimum value)

Return period (y)	Rainfall amount (mm/3d)	Estimated damage ratio on rice yields in the basin: Shibayama lagoon network Average (%)	Max (%)	Min (%)	Kiba lagoon network Average (%)	Max (%)	Min (%)
2	141.0	0.0	0.1	0.0	5.8	6.3	3.6
3	163.6	0.0	0.2	0.0	6.5	8.4	5.1
5	187.8	0.1	0.2	0.0	8.0	9.4	6.0
8	210.4	0.2	0.8	0.0	9.9	13.0	7.8
10	220.4	0.2	1.0	0.0	11.2	13.8	8.4
15	238.2	0.2	1.2	0.0	12.7	15.5	9.0
30	268.1	0.4	1.8	0.2	13.1	17.8	8.8
50	290.0	0.7	3.9	0.2	15.8	20.0	8.9
100	321.9	2.3	5.5	0.4	19.0	22.5	10.2
200	350.9	3.4	5.9	1.5	20.3	24.3	13.4

4.3 Risk curve related to damage expenses of rice yield reduction

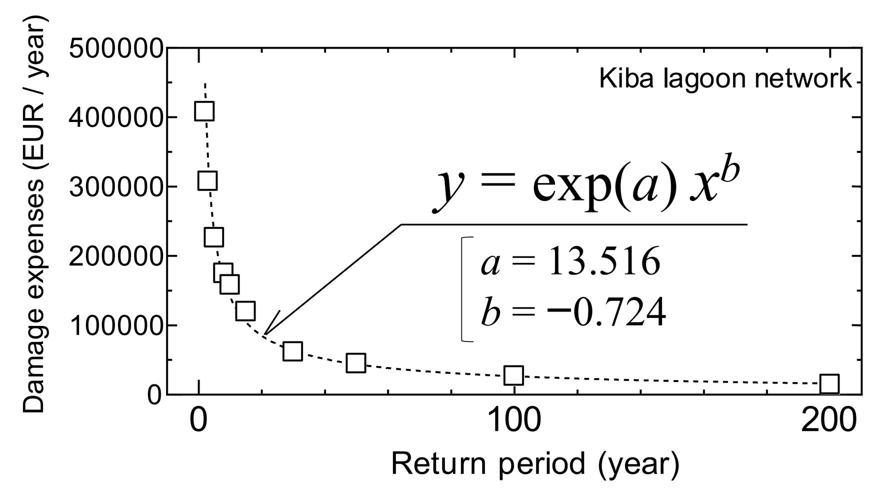
Damage expenses of rice yield reduction (*DE*) are estimated by using eq.(2) as the flood risk in the basin. Rainfall amount, return period (*RT*) and averaged damage amount calculated by eq.(1) (*D*) were available for formulating a risk curve. Here, we formulated a risk curve as **Figure 4**. The curve would be useful to calculate of the damage cost by flooding, and to estimate effects of countermeasures.

Figure 4 Formulation of a risk curve for flooding damage (example of the Kiba network)

$$DE = (D \times P) / RT \quad \cdots (2)$$

DE: Damage expenses (EUR/year)
D: Damage amount of rice yields (ton)
P: Purchase price (EUR/ton)
RT: Return period of input rainfall (year)

* 1 EUR = 135 Yen, P = 1975 (EUR/ton)



$$y = \exp(a)\,x^b \qquad a = 13.516,\; b = -0.724$$

5. Conclusions

We developed three tools for flood risk assessment. The rainfall pattern generator was proposed to generate many patterns of heavy rainfall. 300 patterns of internal structure of rainfall with 10 kinds of rainfall amounts were prepared as input data to the drainage analysis model. The flood risks on the paddy fields were assessed by using reduction scales for rice yields.

The result showed that the risks were depended on the rainfall pattern, even if the total amount were same. Comparing results of two networks, Kiba network was estimated more vulnerable to flooding. Expected damage on rice yields with rainfall of 10-year return period was evaluated more than 11.2 % in the basin. Furthermore, the risk curve depending on damage expenses was formulated. Advancement of these study could be expected to contribute to consider countermeasures against climate change impacts.

References:

1) Minakawa *et. al*., (2015): ESTIMATION OF CLIMATE CHANGE IMPACTS ON FLOODING IN LOW-LYING PADDY AREAS IN JAPAN, USCID 8th International Conference on Irrigation and Drainage "Sustainable Basin Water Management — Challenges of Supply and Demand Management at the Basin Scale", 79-94
2) Minakawa *et. al*., (2013): Variability in Intensity of Heavy Rainfall due to Climate Change and its Impact on Paddy Inundation in Low-lying Areas of Japan, Irrigation and Drainage 62(5), 679-686, DOI: 10.1002/ird.1762
3) Minakawa *et. al*., (2014): ESTIMATION OF DAMAGE TO RICE YIELDS BY FLOODING DUE TO HEAVY RAINFALL, 22th International Congress on Irrigation and Drainage Q.58.3, CD-ROM