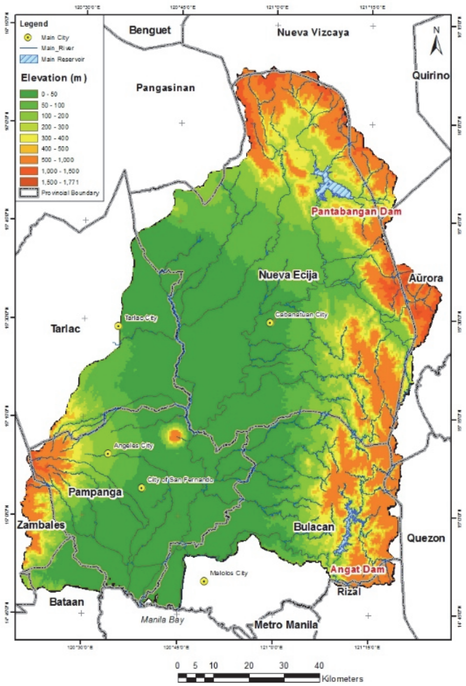
“SOUSEI” is a Japanese word which means “generation” or “creation”.

SOUSEI Program for Risk Information on Climate Change
気候変動リスク情報創生プログラム

Flood/Drought Risk Assessment under Climate Change in Asia



Pampanga River Version

International Centre for Water Hazard and Risk Management under the auspices of UNESCO (ICHARM),

Public Works Research Institute (PWRI), Japan

United Nations Educational, Scientific and Cultural Organization

Contents

1. Background

SOUSEI Program for Risk Information on Climate Change
気候変動リスク情報創生プログラム

Three Key Global Agendas in 2015

Understanding | Governance | Investment | EW/BBB

- March 2015 — Sendai Framework on Disaster Risk Reduction
- September 2015 — Sustainable Development Goals
- December 2015 — Paris Agreement (COP 21)

Concerted Action is Required

- Reducing Current Risk
- Preventing Future Risk
- Adaptation & Recovery

Building Resilience

Sustainable Development

1. Background

SOUSEI Program for Risk Information on Climate Change
気候変動リスク情報創生プログラム

CMIP5 (Coupled Model Intercomparison Project Phase 5)

http://cmip-pcmdi.llnl.gov/cmip5/

- At a September 2008 meeting involving 20 climate modeling groups around the world agreed to promote a new set of coordinated climate model experiments.
- These experiments comprise the fifth phase of the Coupled Model Intercomparison Project (CMIP5).
- More than 50 General Circulation Model (GCM) datasets for IPCC AR5 studies.

Intergovernmental Panel on Climate Change (IPCC) 5th Assessment Report (AR5) (2013)

✓**RCP (Representative Concentration Pathway)**

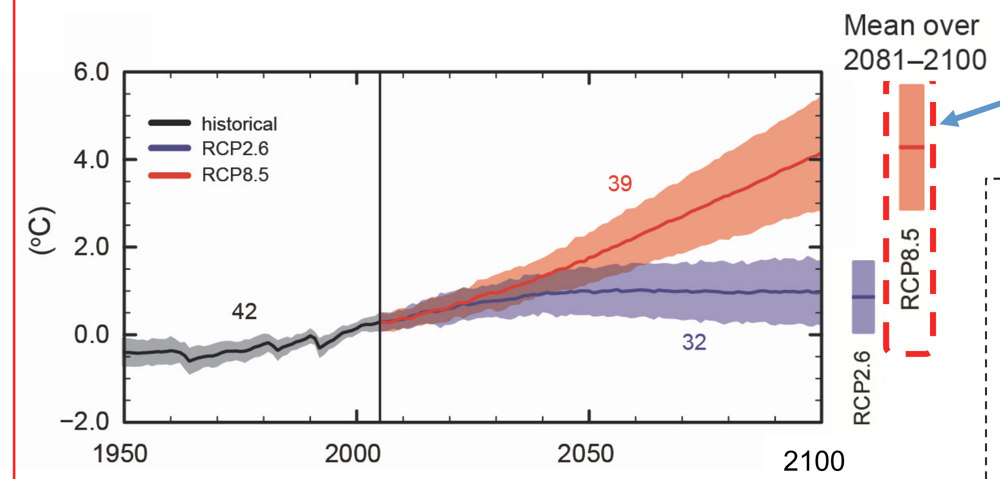


Fig. Global average surface temperature change (in AR5)

RCP8.5: Business as usual scenario with highest GHG emission in RCPs.

RCP 2.6:Global annual GHG emissions peak between 2010-2020, with emissions declining substantially thereafter.
RCP 4.5: GHG emissions peak around 2040, then decline
RCP 6 : GHG emissions peak around 2080, then decline
RCP 8.5, emissions continue to rise throughout the 21st century

2. Outline of SOUSEI Program (1/2)

SOUSEI Program for Risk Information on Climate Change
気候変動リスク情報創生プログラム

Objectives

To create new basic information required for managing water-related disaster risks resulting from climate change in the river basin scale.

Outline

- The program is a five-year (2012-2016) research program funded by MEXT (Ministry of Education, Culture, Sports, Science and Technology, Japan).
- Co-workers are Kyoto Univ., Yamanashi Univ., etc., and the research collaborators in relative governments.

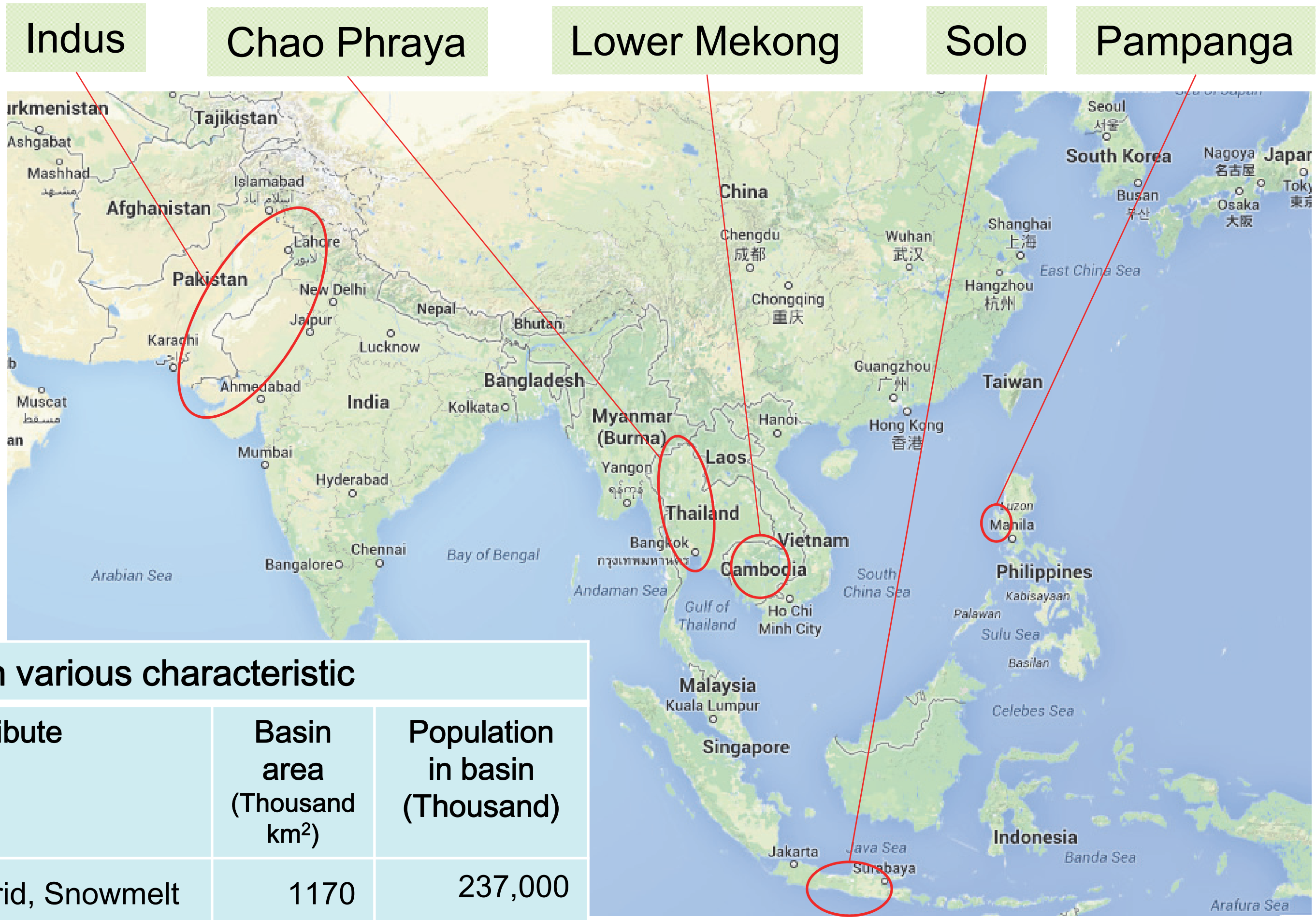
Basic technologies to develop

1. Prediction of the change of rainfall under the climate change,
2. Development of hydrological model,
3. Flood/Drought hazard analysis for future condition using hydrological model,
4. Flood/Drought risk assessment on socio-economic activities for future condition,
5. Promotion of adaptation measures against the climate change

2. Outline of SOUSEI Program (2/2)

SOUSEI Program for Risk Information on Climate Change 気候変動リスク情報創生プログラム

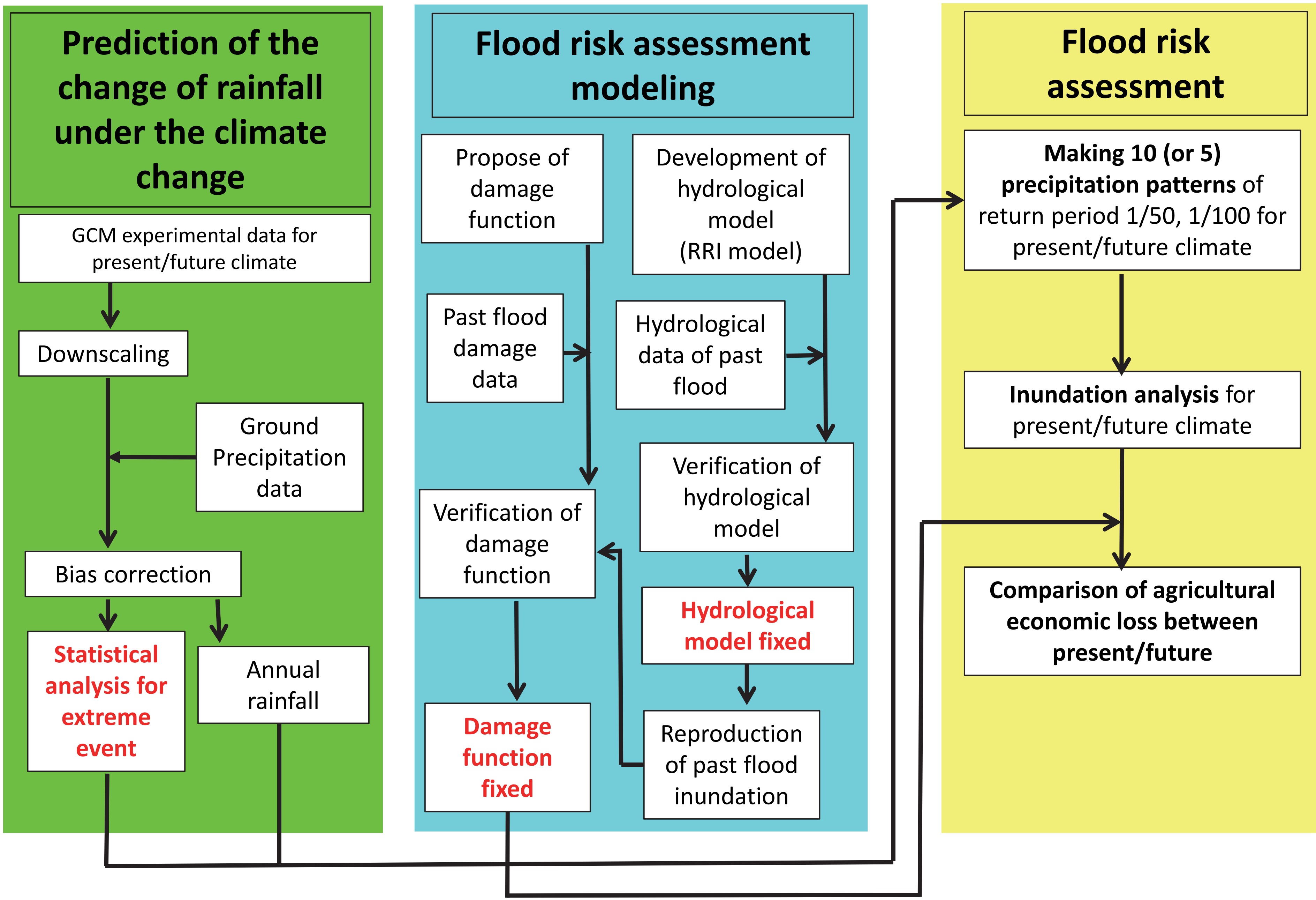
Target River Basins (5 basins)



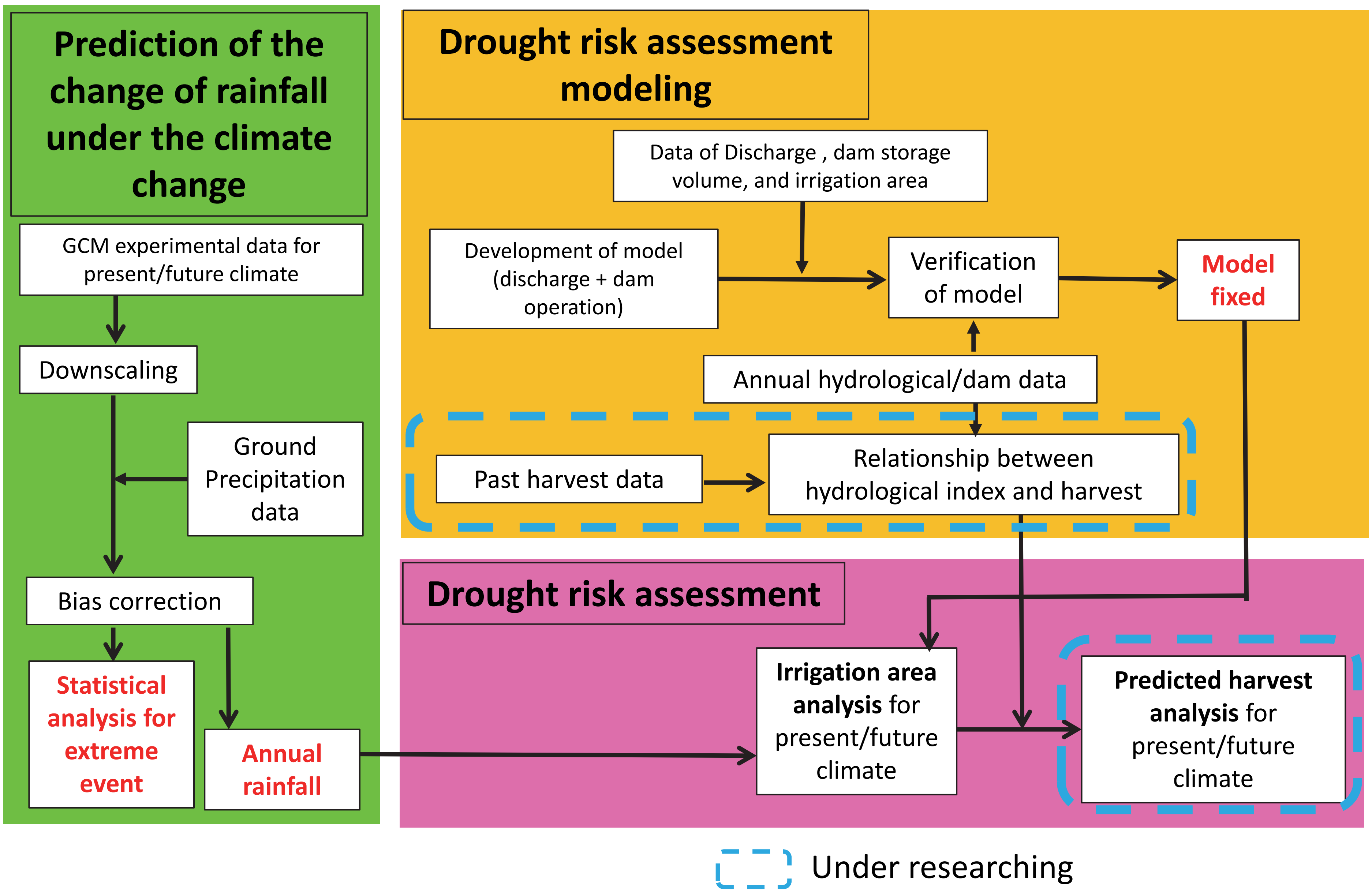
River basins with various characteristic			
River	Attribute	Basin area (Thousand km²)	Population in basin (Thousand)
Indus	Continent, Semi-Arid, Snowmelt	1170	237,000
Mekong	Continent, Monsoon, Dam	800	60,000
Chao Phraya	Continent, Monsoon, Dam	160	28,000
Solo	Islands, Volcano, No Typhoon	16	17,000
Pampanga	Islands, Volcano, Typhoon	11	5,800

3. Research Methodology (1/2)

SOUSEI Program for Risk Information on Climate Change
気候変動リスク情報創生プログラム



3. Research Methodology (2/2)



3. Research Methodology 3.1 Rainfall change assessment

SOUSEI Program for Risk Information on Climate Change
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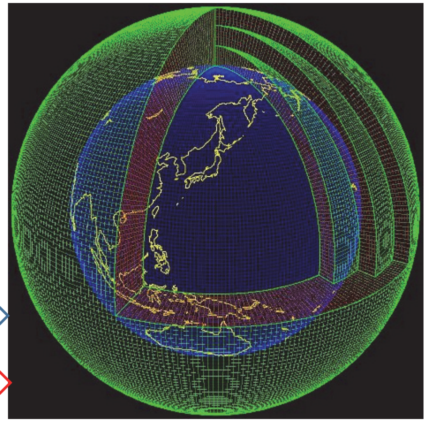
GCM experimental data for present/future climate

Input data:
CMIP5 dataset, etc.

Present Climate Experimental Data (1979-2003)
<u>1 pattern</u>
Initial/Boundary Conditions:
Green house gas (GHG), Sea surface temperature (SST), sea ice, etc.,
<u>based on the observation</u>

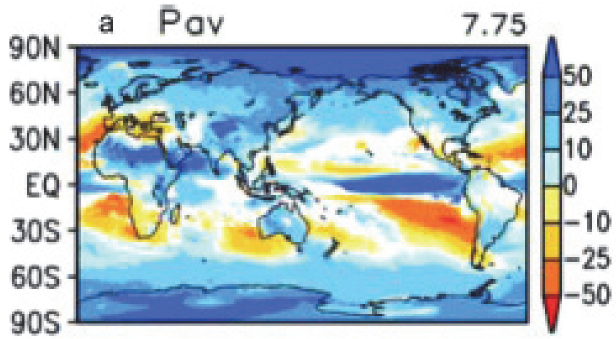
Future Climate Experimental Data (2075-2099)
<u>4 patterns</u> (MME, C1, C2, C3)
Initial/Boundary Conditions:
GHG (RCP8.5), etc.,
<u>4 types of SST & sea ice fields based on 28 GCMs in CMIP5 RCP8.5 experiment (MME, C1, C2, C3)</u>
[Refer next slide]

Atmospheric General Circulation Model:
MRI-AGCM 3.2S



Output:
Precipitation change

Hydrological Effect of Global Warming



(Kitoh & Endo, 2016 WCE)

<u>Merits of MRI-AGCM</u>:
✓Horizontal resolution is higher (20km) than those of coupled GCMs (CGCMs) in CMIP5 (100+km)
→ **<u>Better precipitation (topography, TCs, etc.)</u>**
✓Uncertainty in CGCMs can be separated:
➢Uncertainty of model physics
➢**<u>Uncertainty of SST distribution</u>**

Reference:
✓*Kitoh, A. and H. Endo (2016) Changes in precipitation extremes projected by a 20-km mesh global atmospheric model, Wea. and Clim. Extremes, 11, 41-51, DOI:10.1016/j.wace.2015.09.001.*
✓*Mizuta, R., H. Yoshimura, H. Murakami, M. Matsueda, H. Endo, T. Ose, K. Kamiguchi, M. Hosaka, M. Sugi, S. Yukimoto, S. Kusunoki and A. Kitoh (2012) Climate simulations using MRI-AGCM3.2 with 20-km grid, J. of Meteor. Soc. of Japan, 90A, 233-258, DOI:10.2151/jmsj.2012-A12.*
✓*Mizuta, R., O. Arakawa, T. Ose, S. Kusunoki, H. Endo and A. Kitoh (2014) Classification of CMIP5 future climate responses by the tropical sea surface temperature changes, SOLA, 10, 167-171, DOI:10.2151.sola.2014-035.*

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4 types of Sea Surface Temperature (SST) & sea ice fields based on 28 GCMs in CMIP5 RCP8.5 experiment (MME, C1, C2, C3)

Cluster 1 (C1):

8 MRI-AGCM3.2S models with nearly uniform warming in the both hemispheres

Cluster 2 (C2):

14 models with a larger warming over the central equatorial Pacific (so-called El Niño-like pattern)

Cluster 3 (C3):

6 models with a larger warming in the Northern Hemisphere than in the Southern Hemisphere.

The mean of these 28 CMIP5 models (MME):

a baseline future precipitation while C1, C2 and C3 cases represent climate change uncertainty.

Reference:
✓*Mizuta, R., O. Arakawa, T. Ose, S. Kusunoki, H. Endo and A. Kitoh (2014) Classification of CMIP5 future climate responses by the tropical sea surface temperature changes, SOLA, 10, 167-171, DOI:10.2151.sola.2014-035.*

3. Research Methodology

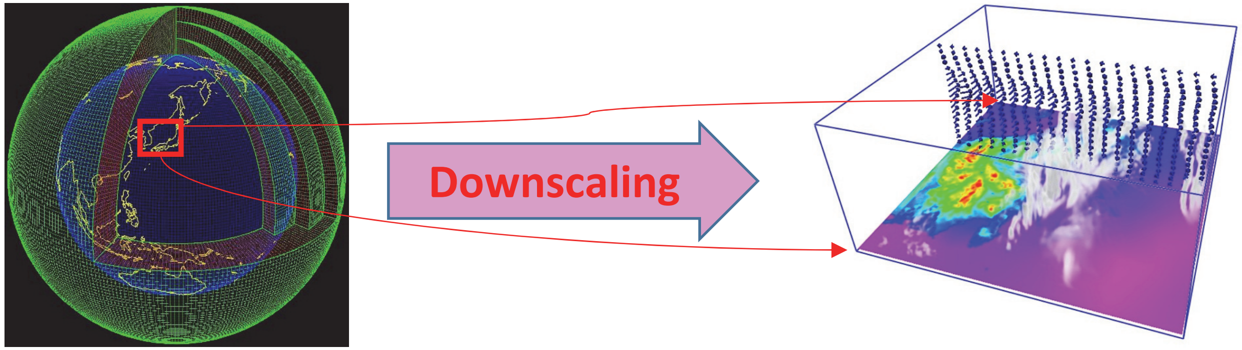
3.1 Rainfall change assessment

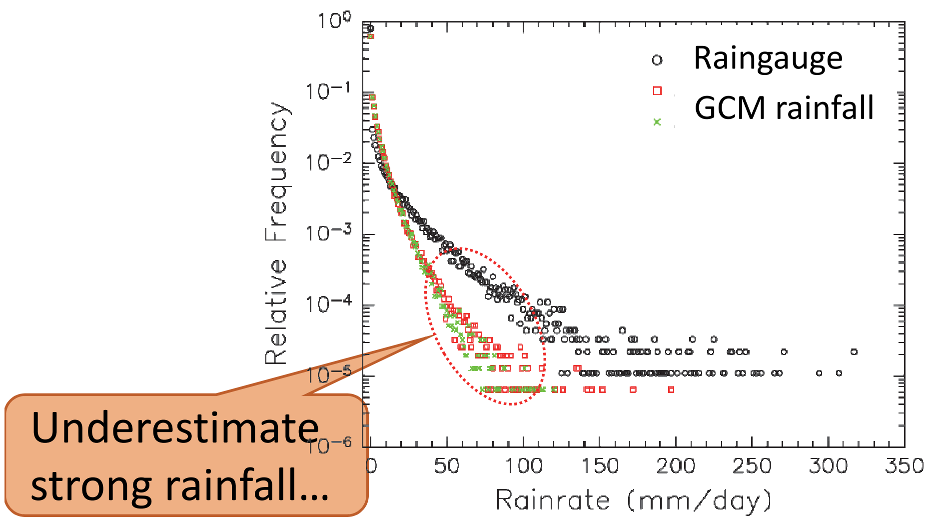
Dynamic downscaling

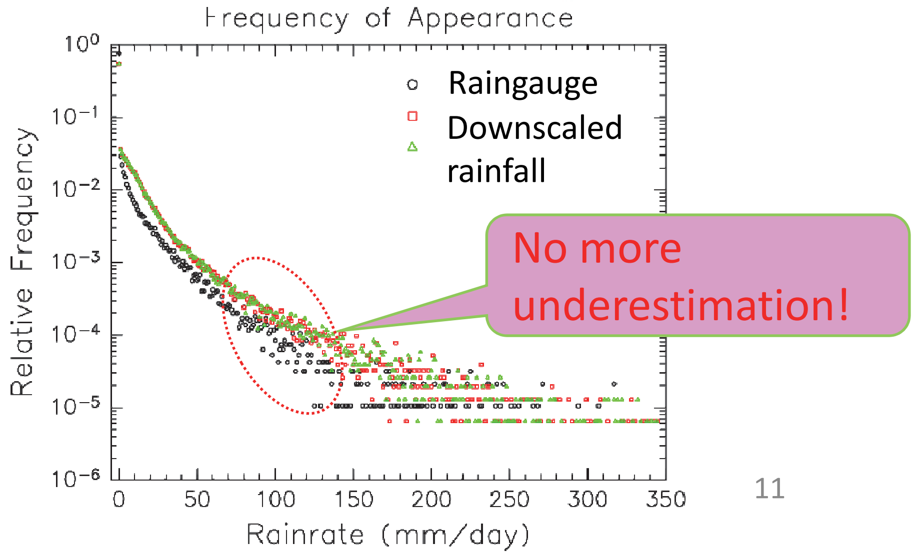
- General Circulation Model (GCM) is **too coarse** to compute precipitation processes in typically 20-30 km size clouds with the effect of complex terrains.
- Dynamic downscaling by a regional model reproduces **more accurate** rainfall via realistic representation with high resolution model in a limited area.

GCM

Regional model







3. Research Methodology

3.1 Rainfall change assessment

SOUSEI Program for Risk Information on Climate Change
気候変動リスク情報創生プログラム

Bias correction

✓ **Climate models exhibit systematic errors (biases) in their output.**

These errors can be due, among others, to:

- Limited spatial resolution (horizontal and vertical)
- Simplified physics and thermodynamic processes
- Numerical schemes
- Incomplete knowledge of climate system processes

- **Initial GCM result should be tuned to the observation data by bias correction.**
- **The ratio can be used to get bias corrected GCM future value.**

The main assumptions of bias correction methods are:

- Quality of the observations database limits the quality of the correction.
- It is assumed that the bias behaviour of the model does not change with time.
- Limitation: Temporal errors of major circulation systems can not be corrected.

Reference: IS-ENES project Web site *https://climate4impact.eu/impactportal/help/faq.jsp?q=bias_correction*

3. Research Methodology

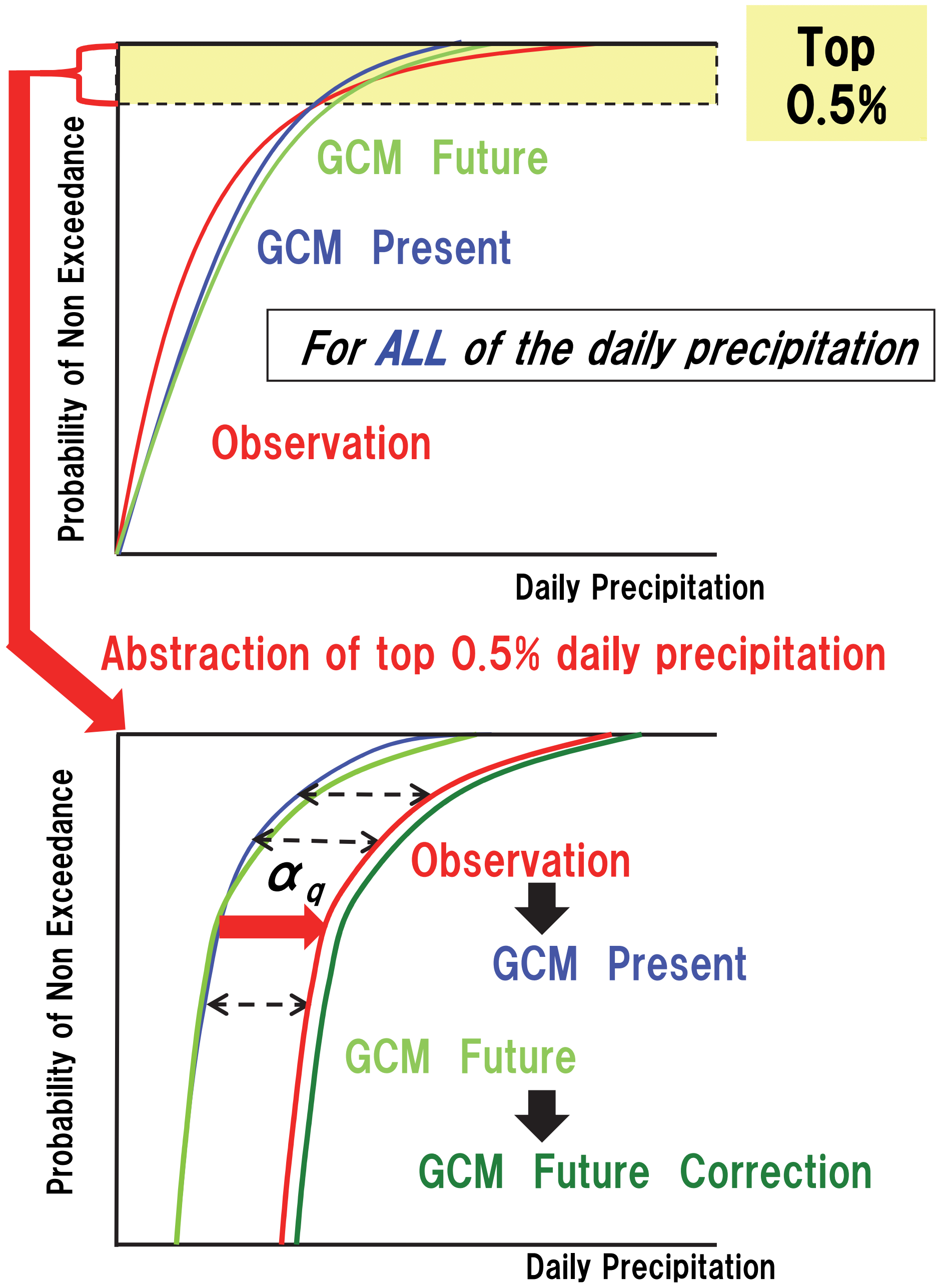
3.1 Rainfall change assessment

Concept of bias correction method for GCM -Hybrid Method- (1/2)

A) Extreme Value
⇒The samples in top 0.5% of prob. of non exceedance are considered.
B) Other value
⇒They are divided into each month.

①The samples in top 0.5% on probability of non exceedance for observation, GCM Present and GCM Future are abstracted.

②The ratio for each quantile (α_q) between observation (Red line) and GCM Present (Blue line) is estimated.
α_q is regarded as a correction coefficient for each quantile and multiplied to the value of GCM Future (Light Green line) of same quantile and corrected value (Dark green line) is obtained.

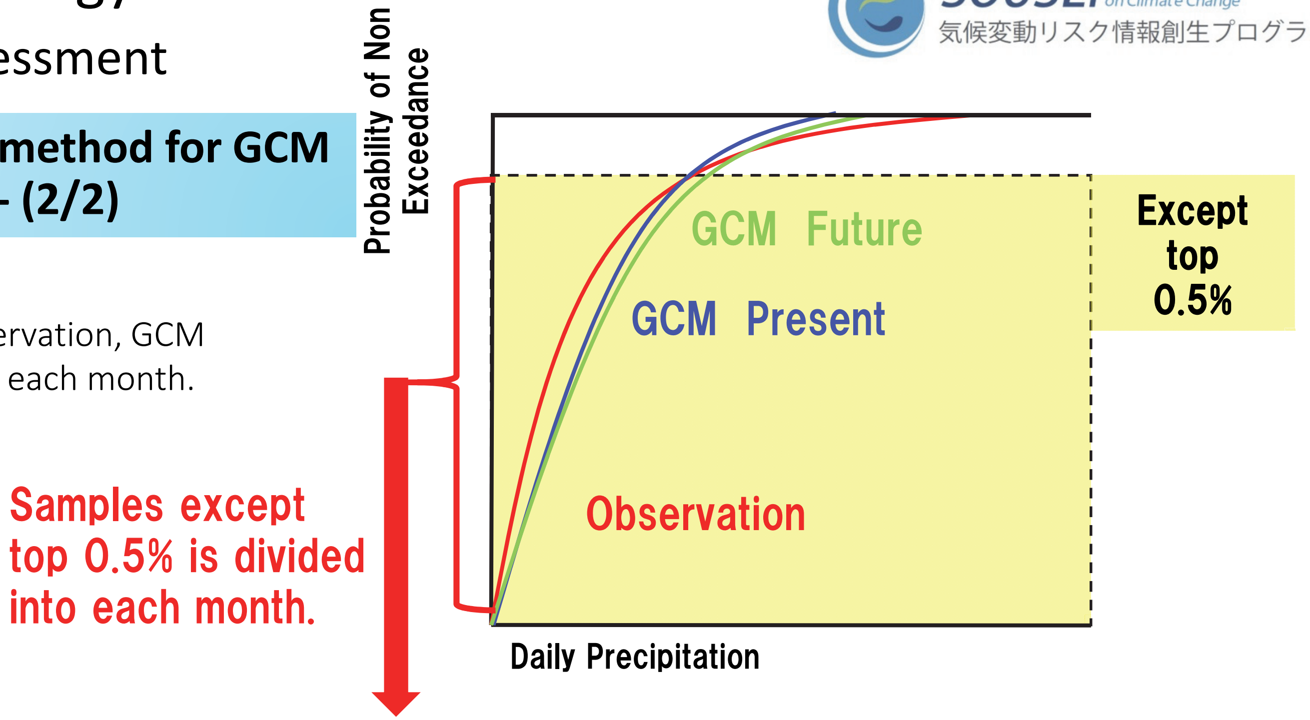


Reference:
Inomata, H., K. Takeuchi and K. Fukami (2011) Development of a statistical bias correction method for daily precipitation data of GCM20, J. of Japan Soc. of Civil Engineers, Ser. B1 (Hydraulic Engineering), 67, I_247-I_252, DOI:10.2208/jscejhe.67.I_247.

3. Research Methodology

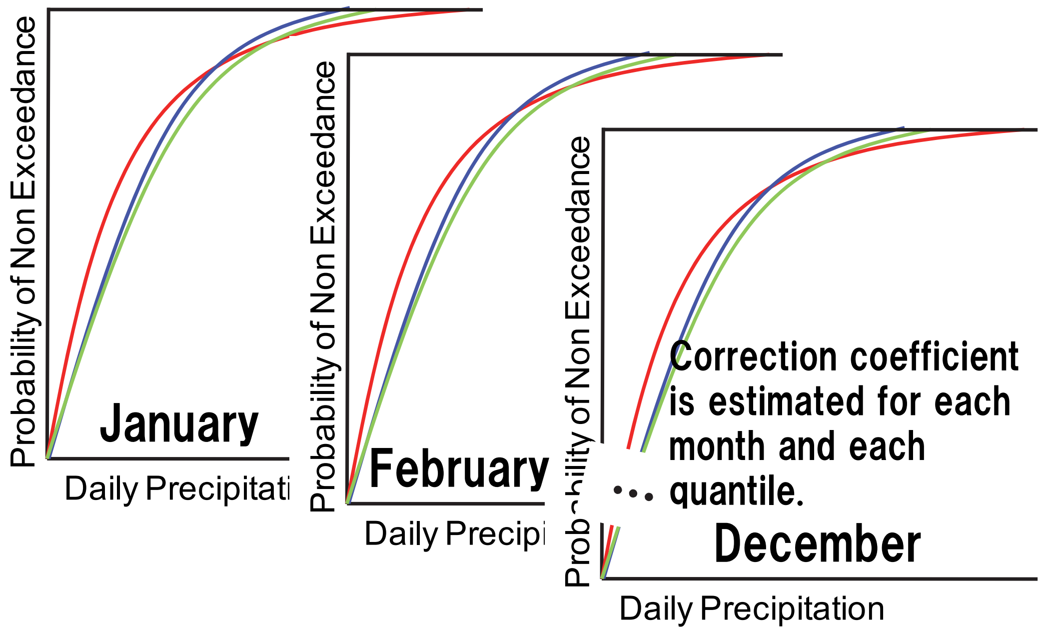
3.1 Rainfall change assessment

Concept of bias correction method for GCM -Hybrid Method- (2/2)



③Samples except top 0.5% on observation, GCM Present and Future are divided into each month.

④The ratio between observation (**Red line**) and GCM Present (**Blue line**) is estimated for each month and each quantile (α_{m_q}).
α_{m_q} is regarded as correction coefficient and multiplied to GCM Future of same month and same quantile (**Light Green line**) and corrected value is obtained.



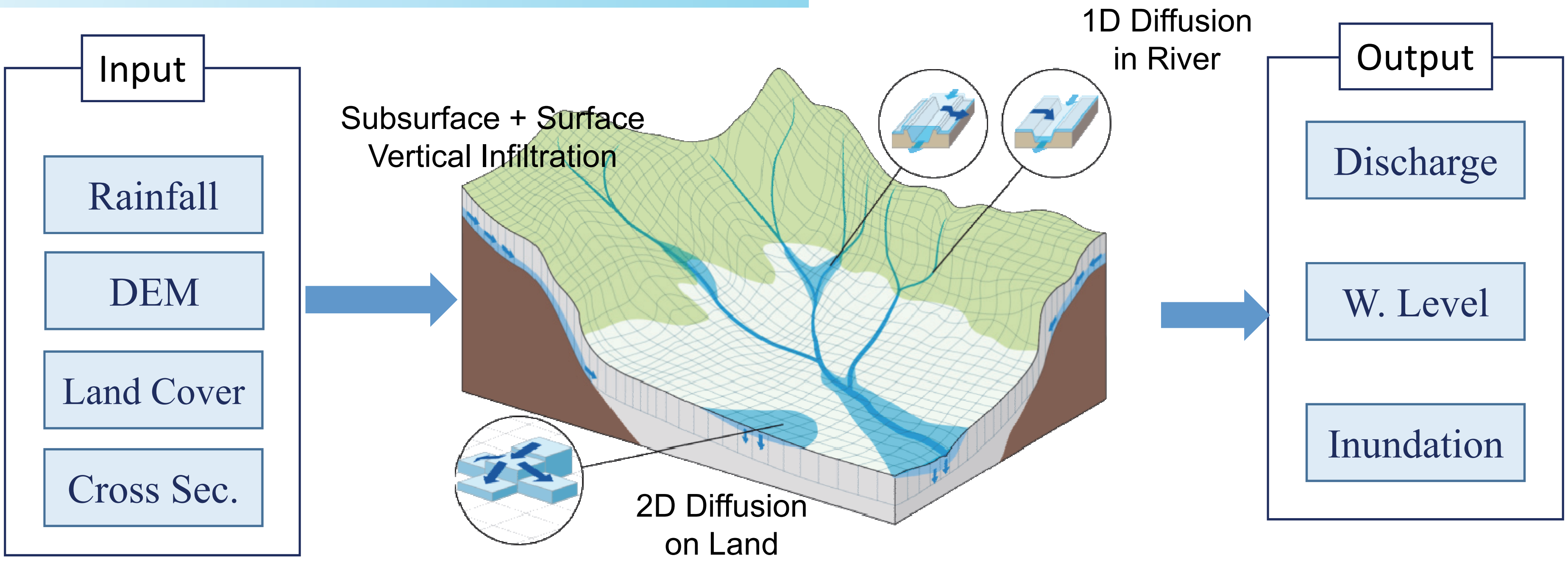
Reference:

Inomata, H., K. Takeuchi and K. Fukami (2011) Development of a statistical bias correction method for daily precipitation data of GCM20, J. of Japan Soc. of Civil Engineers, Ser. B1 (Hydraulic Engineering), 67, I_247-I_252, DOI:10.2208/jscejhe.67.I_247.

3. Research Methodology

3.2 Flood risk assessment

Rainfall-Runoff-Inundation Model (RRI model)



- Two-dimensional model capable of simulating rainfall-runoff and flood inundation simultaneously
- The model deals with slopes and river channels separately
- At a grid cell in which a river channel is located, the model assumes that both slope and river are positioned within the same grid cell

Reference:
Takahiro Sayama, Go Ozawa, Takahiro Kawakami, Seishi Nabesaka & Kazuhiko Fukami et al.: Rainfall-Runoff-Inundation Analysis of Pakistan Flood 2010 at the Kabul River Basin, Hydrological Sciences Journal, 57(2), pp. 298-312, 2012.

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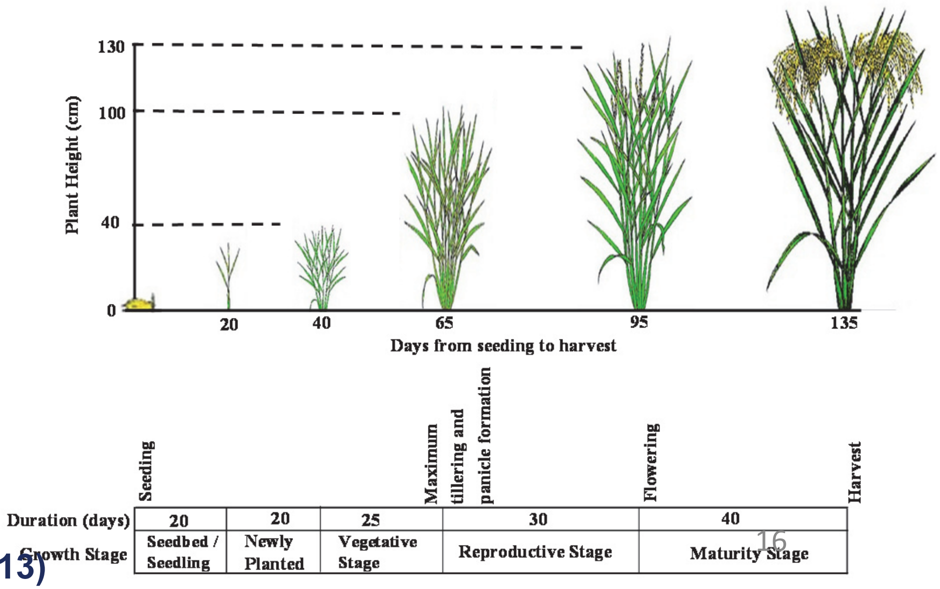
Process of Damage Assessment (Damage to Rice-Crops)

Growth Stage of Rice	Calculation Method
Seedbed / Seedling 20 days from palay germination	***Value of production losses*** = Area affected x Cost of input / hectare x yield loss
Newly Planted Stage 1-20 days after sowing	
Vegetative Stage (21-45 days)	
Reproductive Stage (46-75 days)	***Value of Production Losses*** = Volume of losses x most recent farm gate price ***Volume of losses*** = Most recent yield/hectare x area damaged x Yield loss
Maturing Stage (76-115 days)	

Flood damage matrix: Rice-crops Damage

Growth stage	Days of submerge			
	1-2	3-4	5-6	7
	Estimated yield loss (%)			
Vegetative stage: Minimum Tillering /Maximum Tillering	10-20	20-30	30-50	50-100
Reproductive Stage: Panicle Initiation/Booting Stage (Partially Inundated)	10-20	30-50	40-85	50-100
Reproductive Stage: Panicle Initiation/Booting Stage (Completely Inundated)	15-30	40-70	40-85	50-100
Maturity Stage: Flowering stage	15-30	40-70	50-90	60-100
Ripening Stage	5	10-20	15-30	15-30

Days and plant height of rice crops at its each stage



Source: Bureau of Agricultural Statistics, Philippines (2013)

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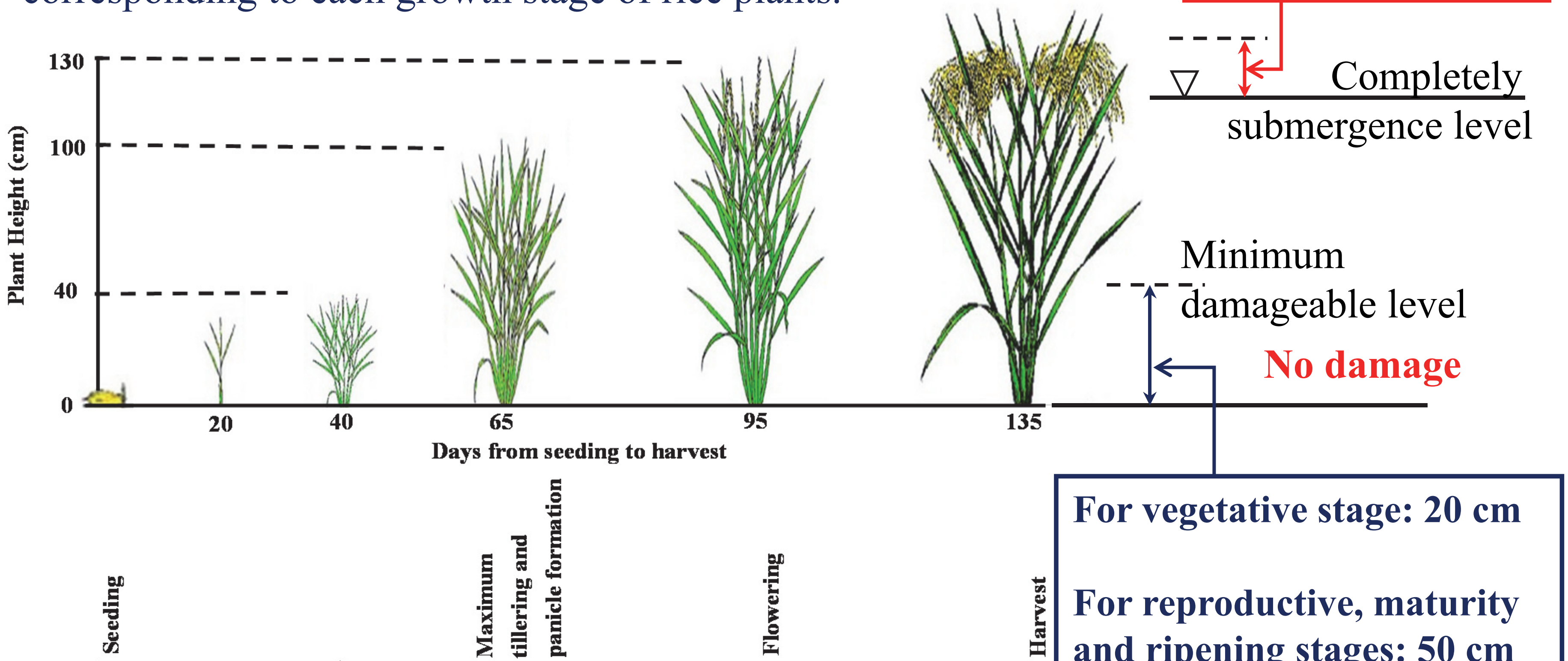
Development of Flood Damage Curves (Rice-Crops)

- Flood damage curves as a function of flood depth and duration are proposed based on linear interpolation of flood damage matrix data by introducing minimum damageable flood depth and by considering partial or complete submergence water surface levels corresponding to each growth stage of rice plants.



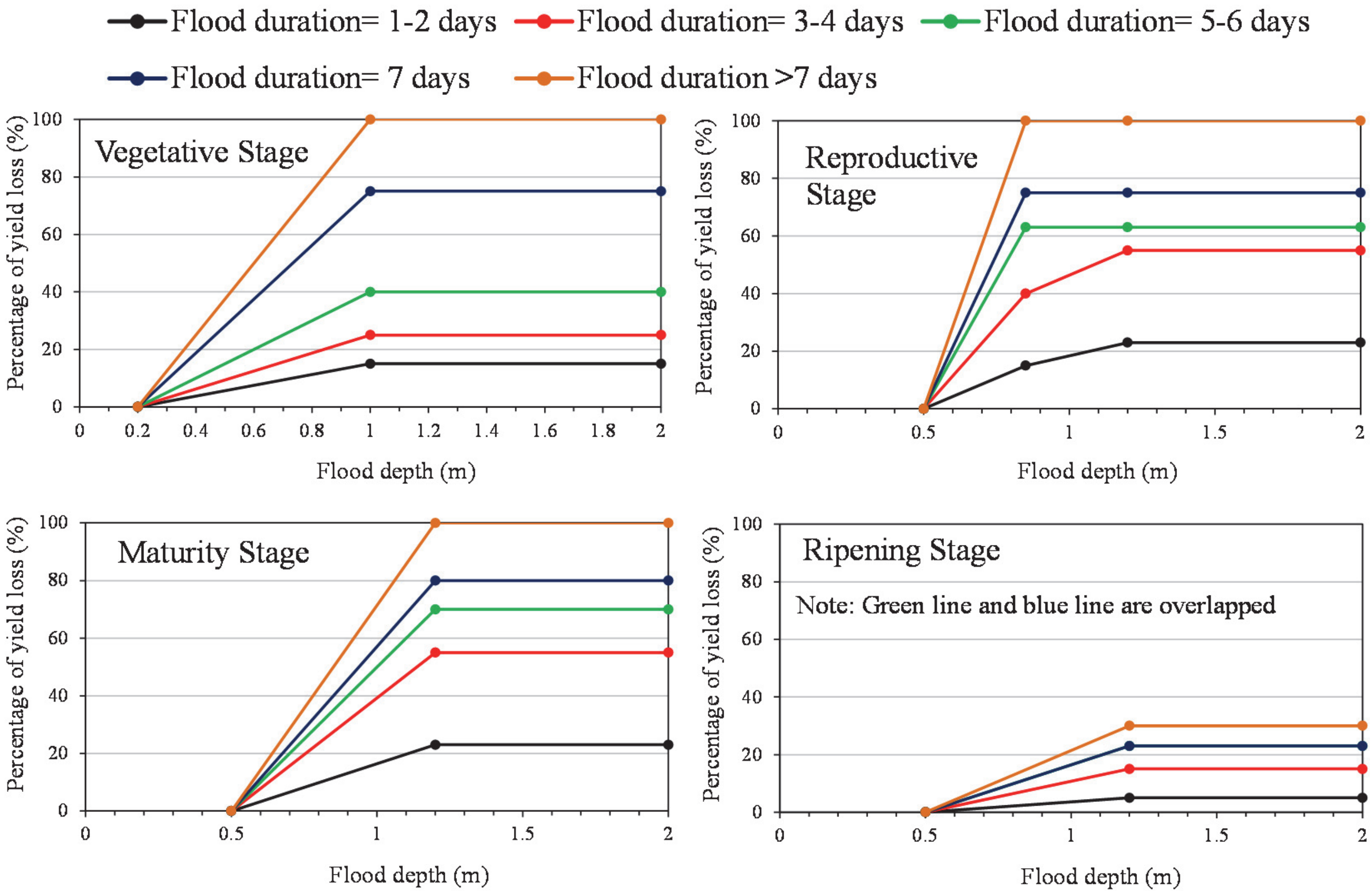
Duration (days)	20	20	25	30	40
Growth Stage	Seedbed / Seedling	Newly Planted	Vegetative Stage	Reproductive Stage	Maturity Stage

Source: International Rice Research Institute (IRRI, 2009)

Development of Flood Damage Curves (Rice-Crops) (Cont.)

ICHARM's Damage Curve

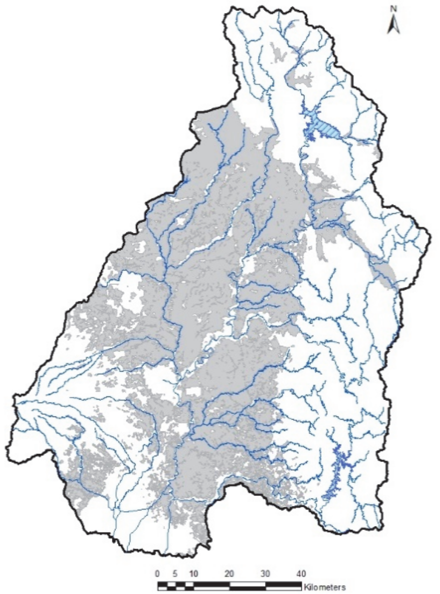
The damage curve can consider growth stage, flood depth, and flood duration.

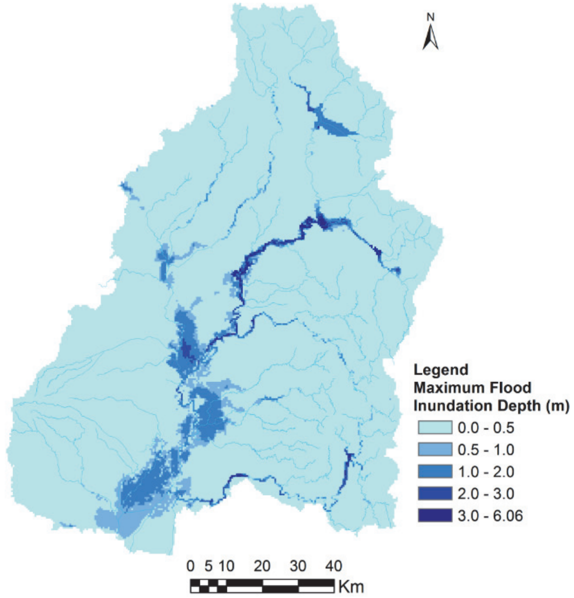


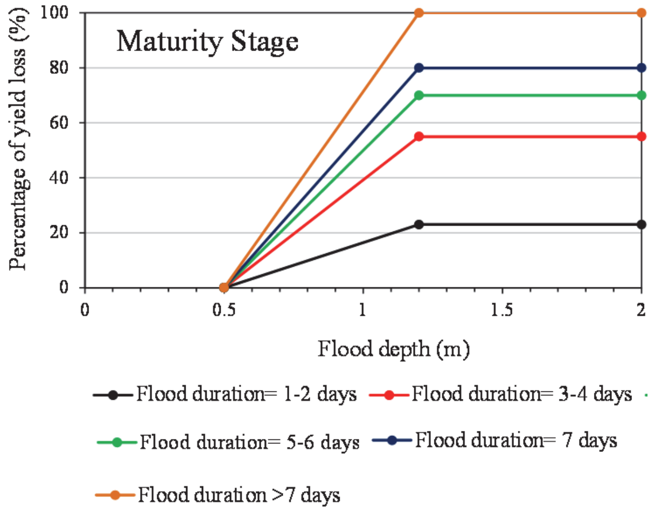
Reference: *Shrestha, B. B., Okazumi, T., Mamoru, M. and Sawano, H.: Flood damage assessment in the Pampanga river basin of the Philippines, Journal of Flood Risk Management, Vol. 9, No. 4, pp.355-369, 2016. DOI: 10.1111/jfr3.12174*

3.2 Flood risk assessment

Schematic of agricultural economic loss calculation (Rice production)







Paddy field area (Global data)

Inundation area, depth, duration by RRI model

Damage function for rice production

Value of farm gate price (17 Peso/kg)*

Rice yield (4360 kg/ha)**

Agricultural economic loss

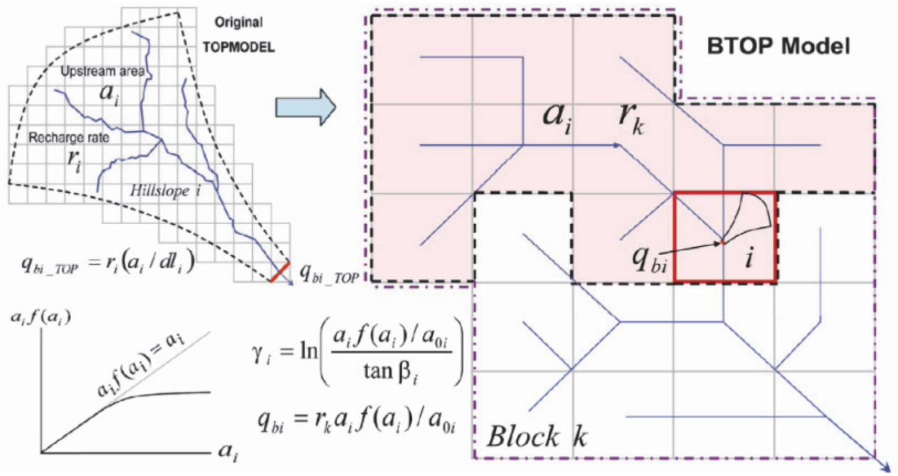
Sources:
**Bureau of Agricultural Statistics (BAS): Manual on damage assessment and reporting system, BAS, Philippines, 2013.*
***Bulacan Provincial Agricultural Office (BPAO: Final validation report for cereals, BPAO, Philippines, 2011.*

3. Research Methodology

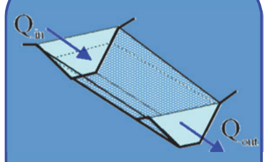
3.3 Drought risk assessment

Distributed hydrological model - BTOP

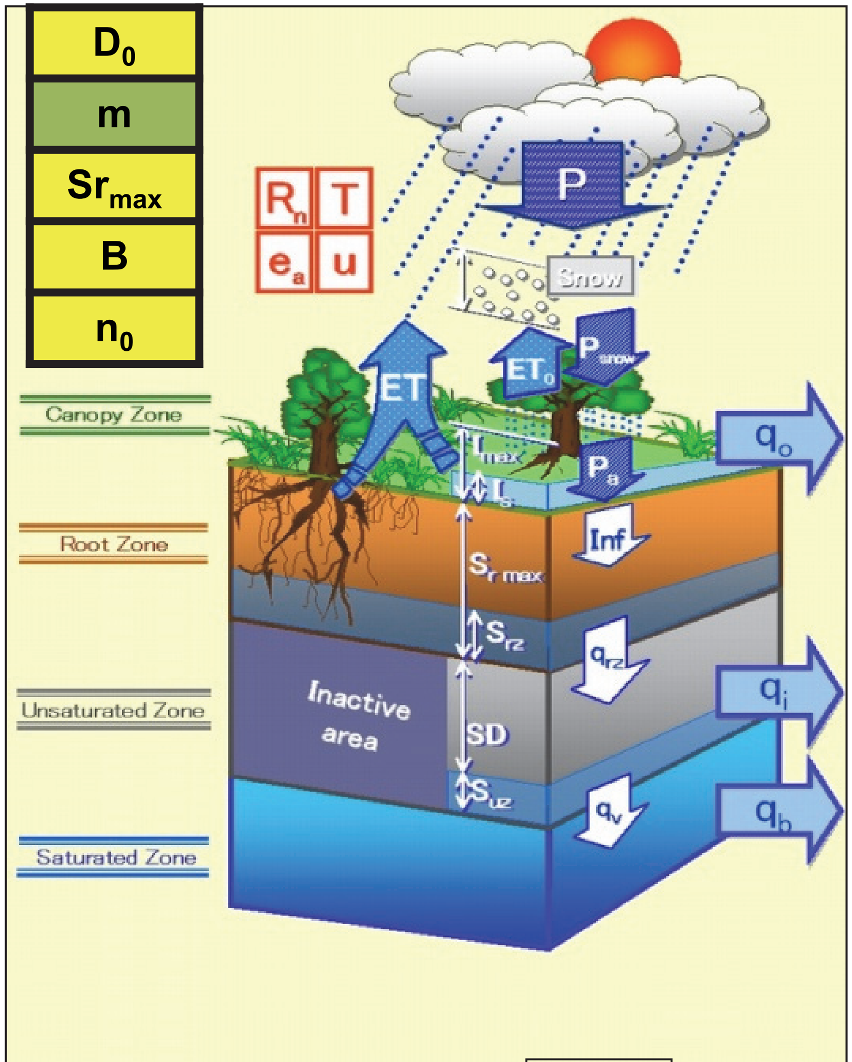
Runoff Generation and Flow Routing



River Flow Routing



Muskingum-Cunge(M-C)
Modified M-C



Reference: *Takeuchi K, Hapuarachchi P, Zhou M, Ishidaira H, Magome J, A BTOP model to extend TOPMODEL for distributed hydrological simulation of large basins, Hydrological Processes, 22, 2008*

4. Research Result

4.1 Rainfall change assessment

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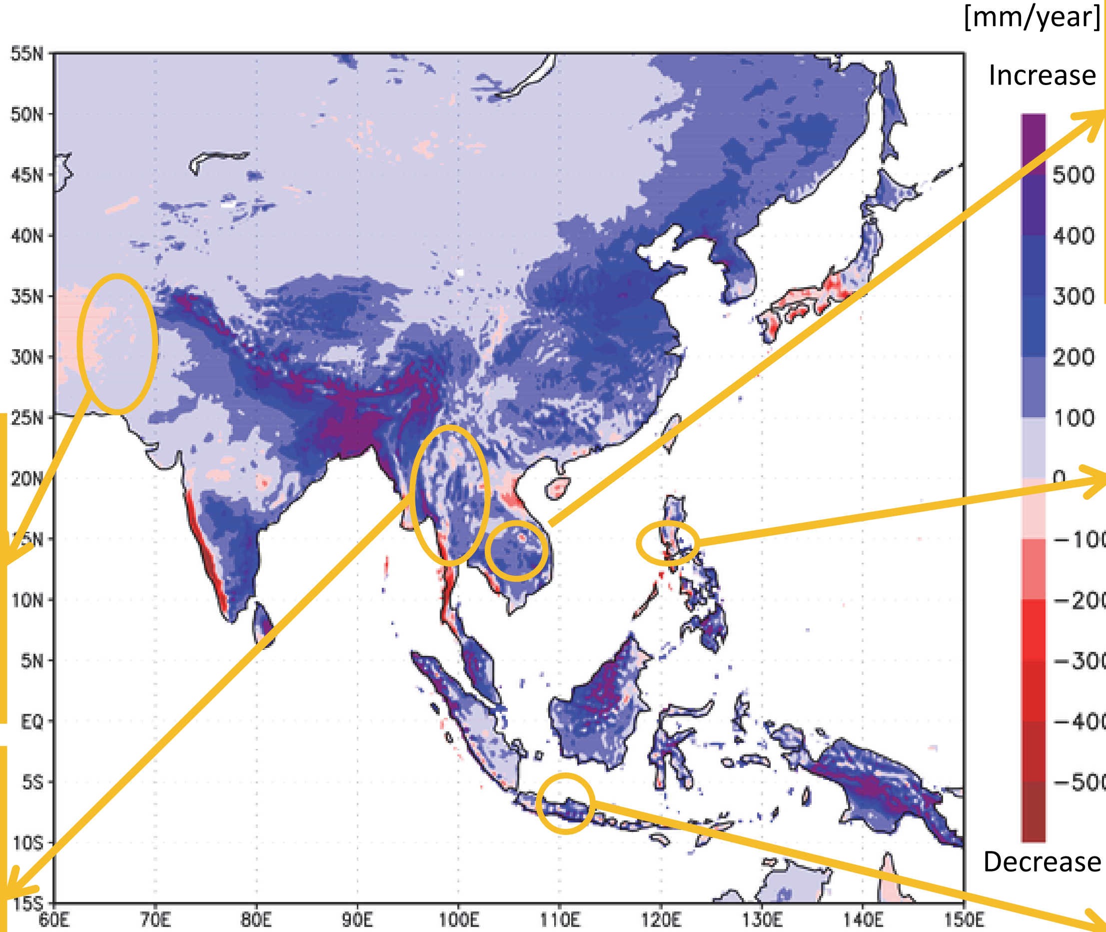
気候変動リスク情報創生プログラム

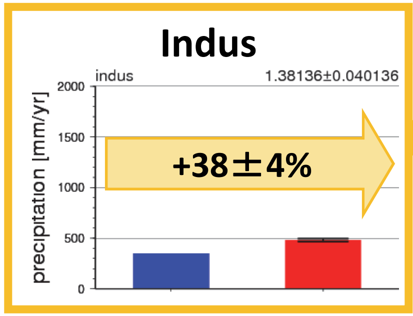
Analysis result –Comparison of 5 river basin- (1/2)

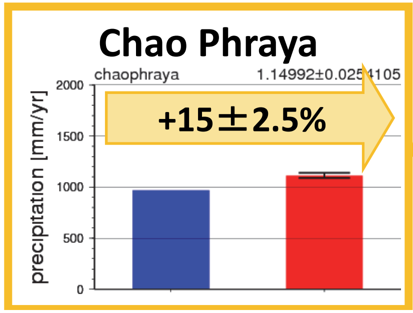
Difference in <u>average yearly precipitation</u> between present and future climate for 4 Sea Surface Temperature (SST) patterns (MME, C1, C2, and C3)

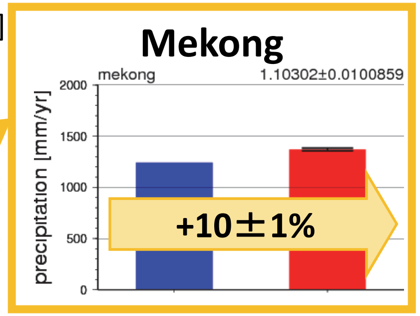
Basin average yearly precipitation
- **Present Climate (1979-2003)**
- **Future Climate (2075-2099)**

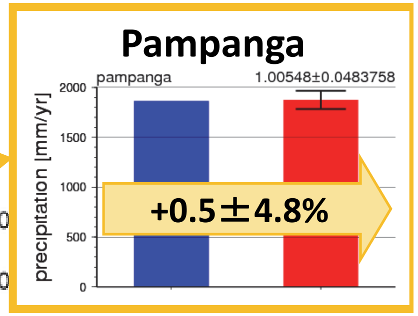
Average and standard deviation in 4 SSTs

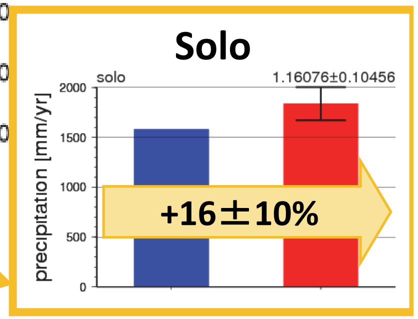












4. Research Result

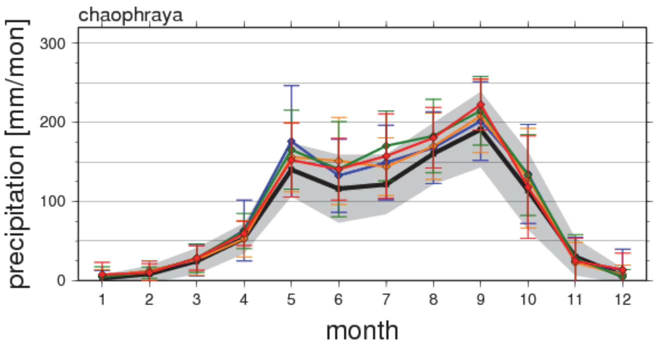
4.1 Rainfall change assessment

SOUSEI Program for Risk Information on Climate Change
気候変動リスク情報創生プログラム

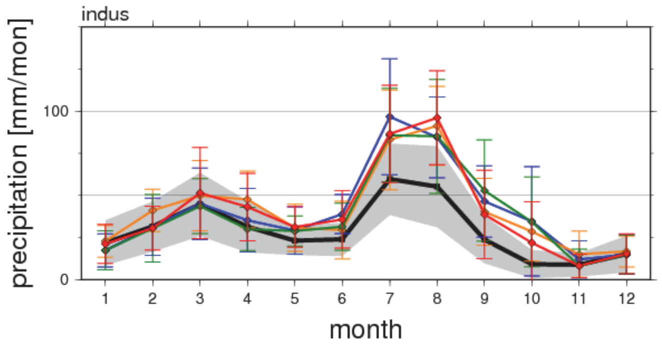
Analysis result –Comparison of 5 river basin- (2/2)

Comparison of <u>average monthly precipitation</u> between present and future climate or 4 SST patterns (MME, C1, C2, and C3)

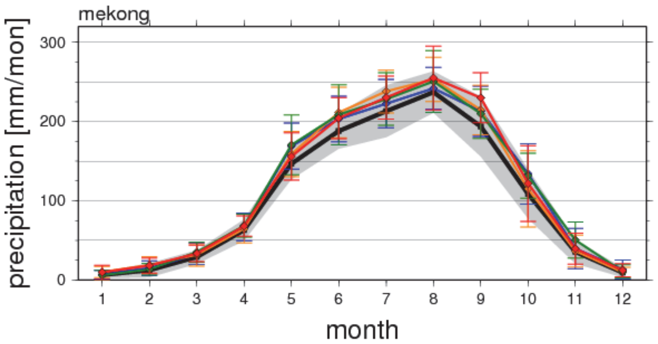
Chao Phraya



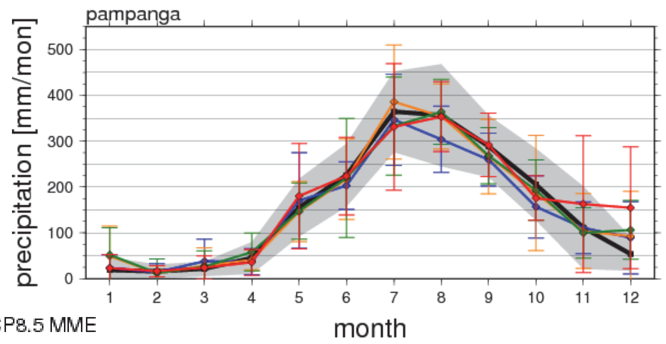
Indus



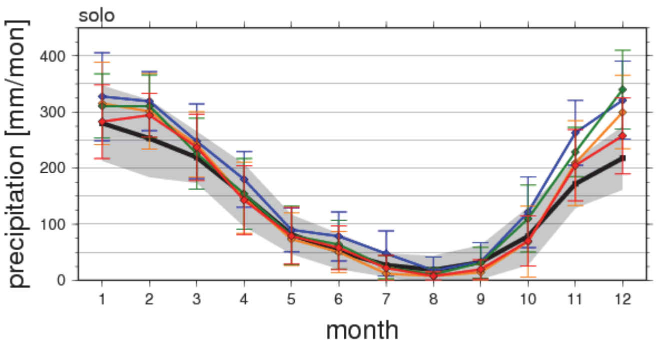
Mekong

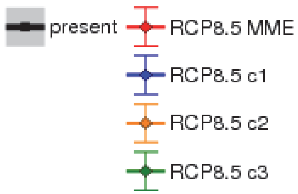


Pampanga



Solo



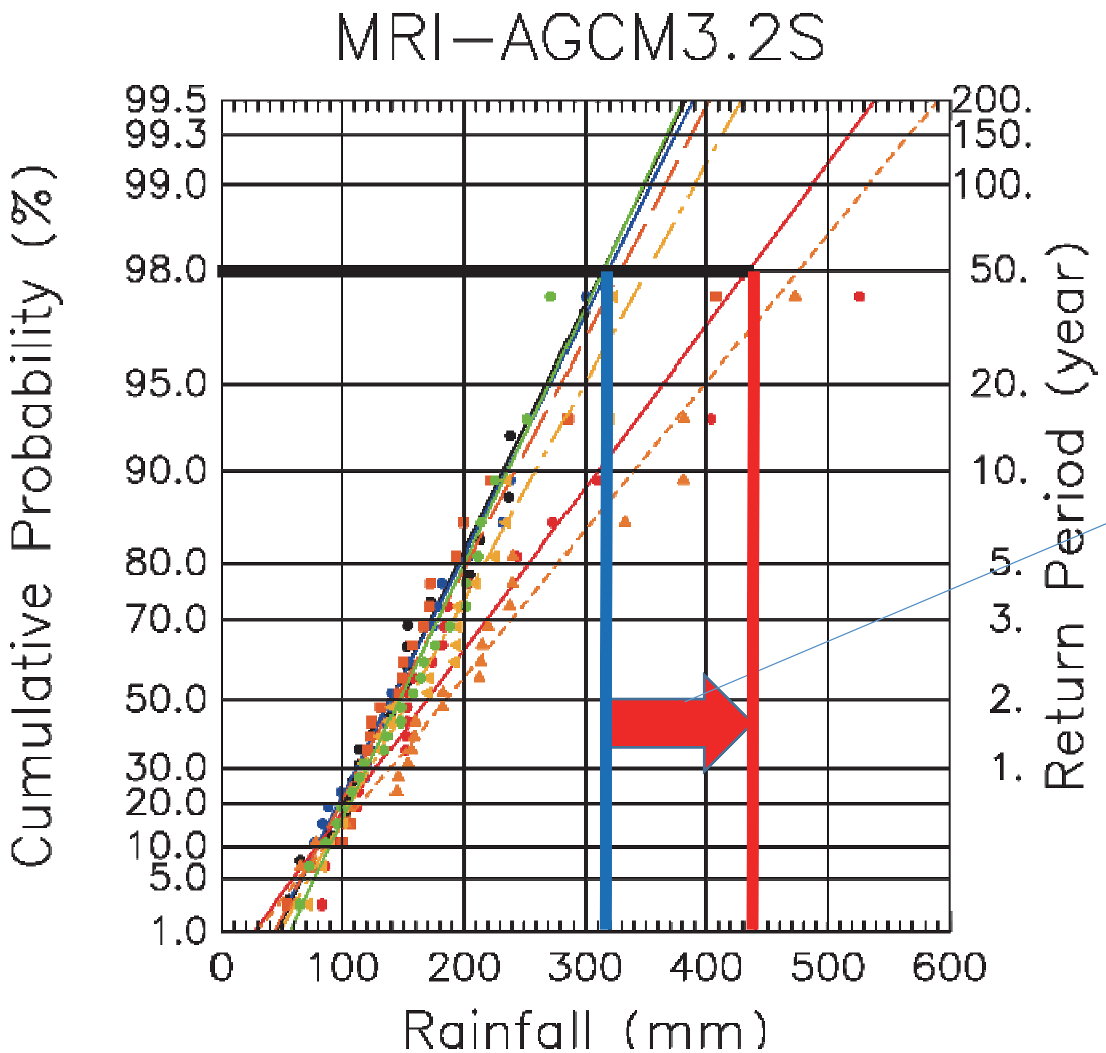


Reference: *Iwami et al, Comparative study on climate change impact on precipitation and flood in the Asian river basins (2016), HRL*

4. Research Result

4.1 Rainfall change assessment

Statistical analysis for extreme event



Example of statistical analysis of annual maximum 48-hour precipitation in MRI-AGCM3.2S

(Present) 320->
(Future（RCP8.5 MME)) 440
for 50-year return period

4. Research Result

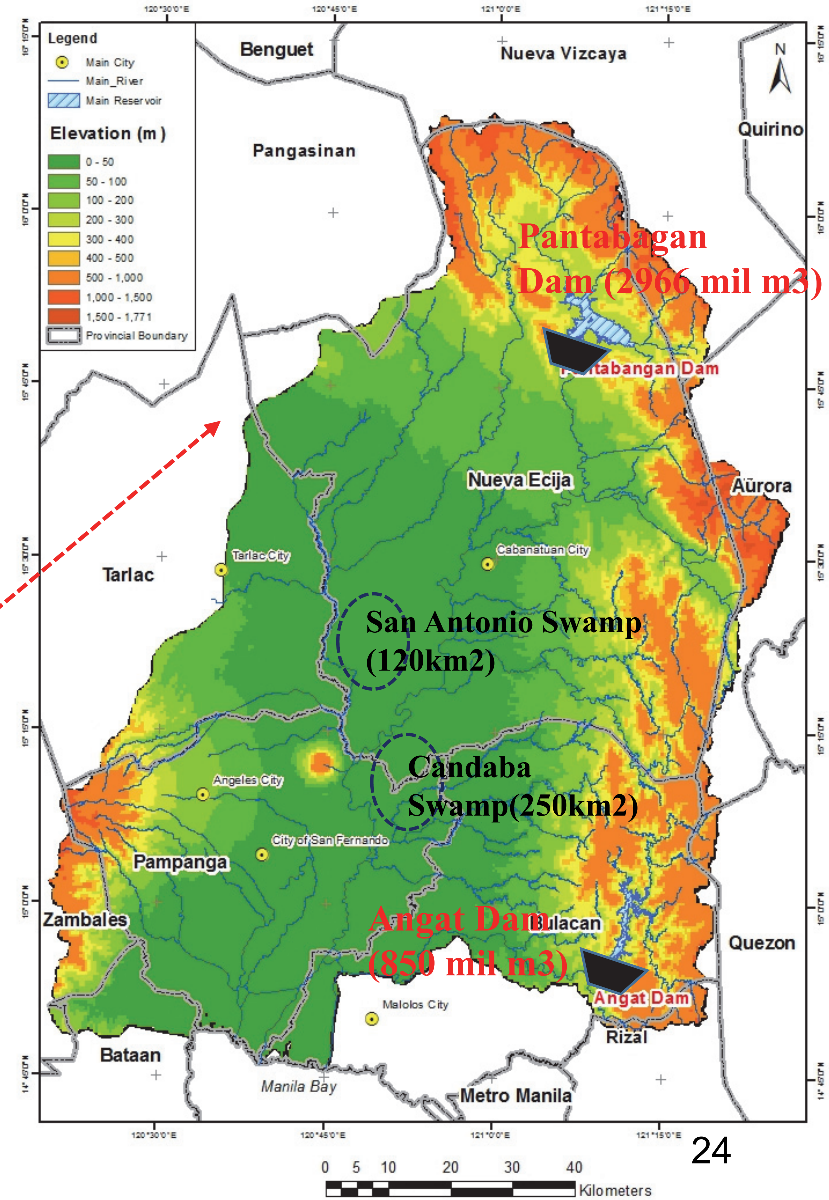
4.2 Flood risk assessment

SOUSEI Program for Risk Information on Climate Change
気候変動リスク情報創生プログラム

Pampanga River Basin: General Features

Forth largest river basin in the Philippines

- **Catchment Area: 10,434 km²**
- **River Length: 260 km**
- **Average annual rainfall: 2155mm/year**
- **Population: 6.58 million** (based on national statistic 2010)
- **Population Density: 630 persons / km²**



4. Research Result

4.2 Flood risk assessment

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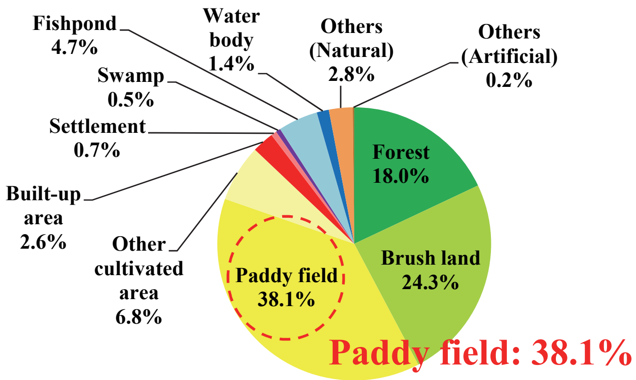
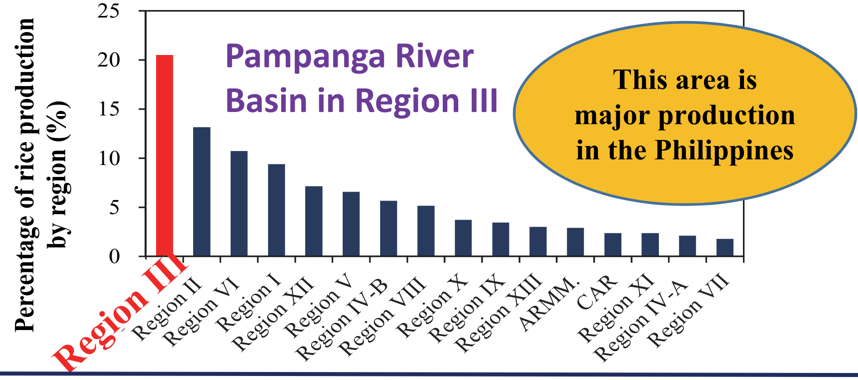
Pampanga River Basin: Agricultural production and damage

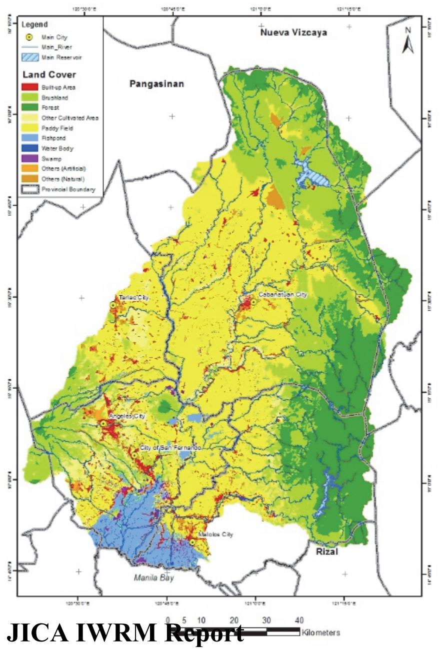
Land Cover in Percentage



Rice Production in Percentage as of 2014 data

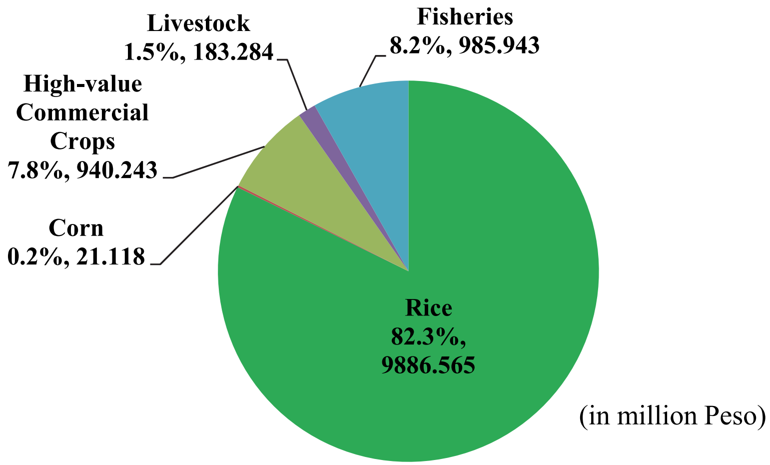


Land Cover Map



Source: JICA IWRM Report

Estimated value of Agricultural damages due to flood during September 24-26 ,2011



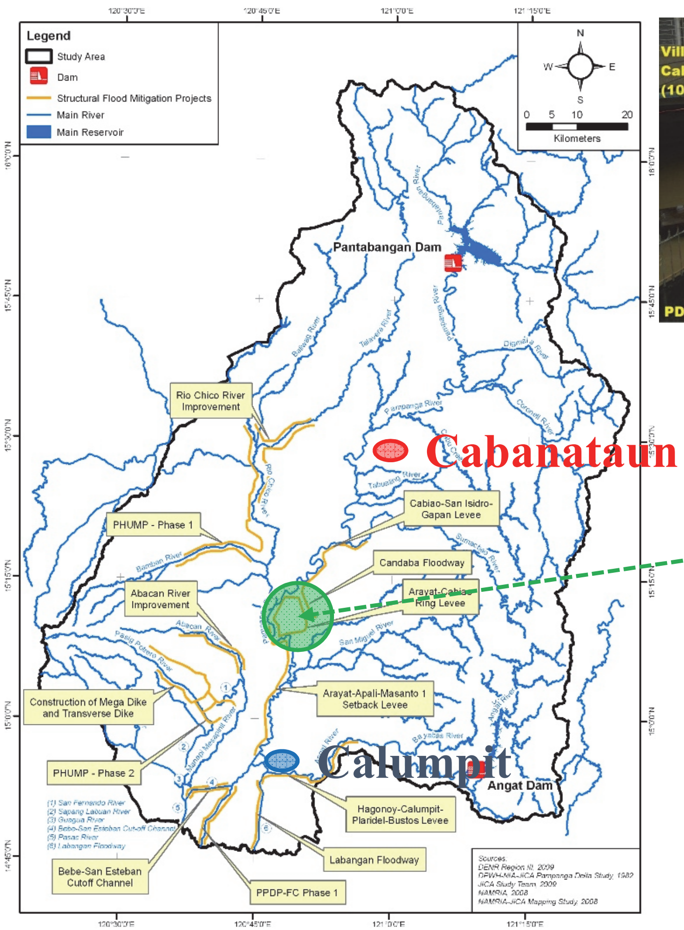
Source: Office of Civil Defense Region III

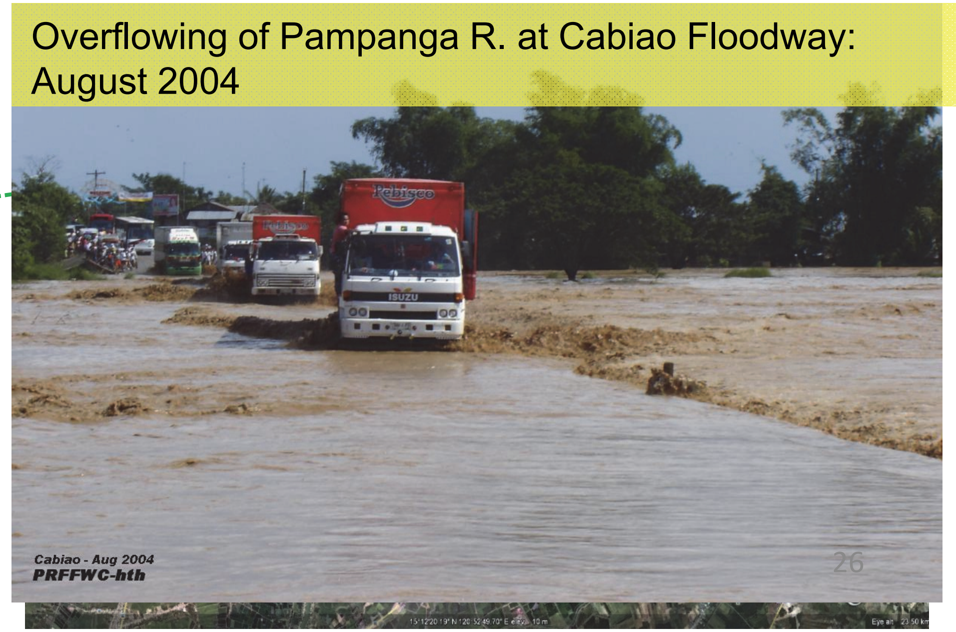
4. Research Result

4.2 Flood risk assessment

Pampanga River Basin: Recent Floods

- 2015 Oct & Dec : Typhoon Lando and Nona
- 2012 August: Monsoon Rainfall
- 2011 September: Typhoon Pedring, Quiel
- 2009 September: Typhoon Ondoy, Pepeng





4. Research Result

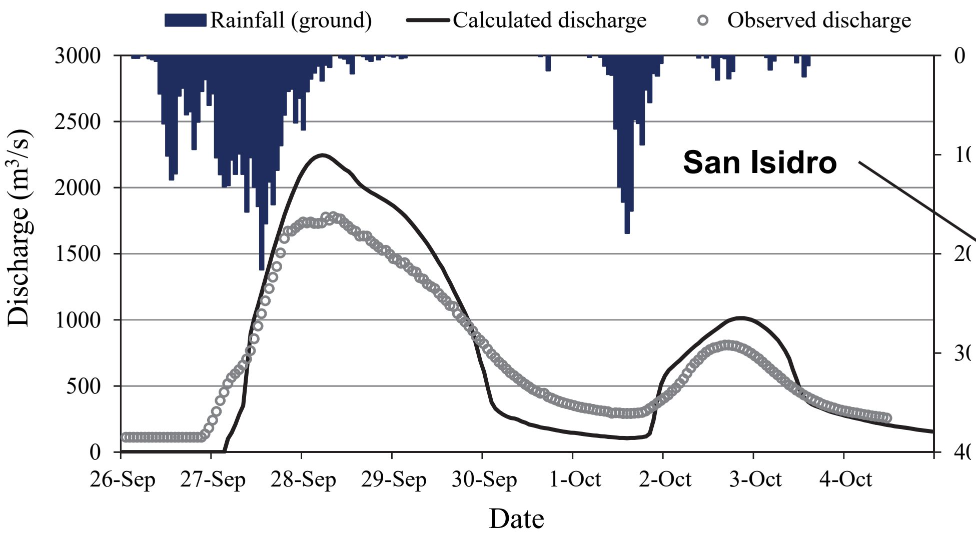
4.2 Flood risk assessment

SOUSEI Program for Risk Information on Climate Change
気候変動リスク情報創生プログラム

Verification of reproduction of past flood inundation by RRI Model

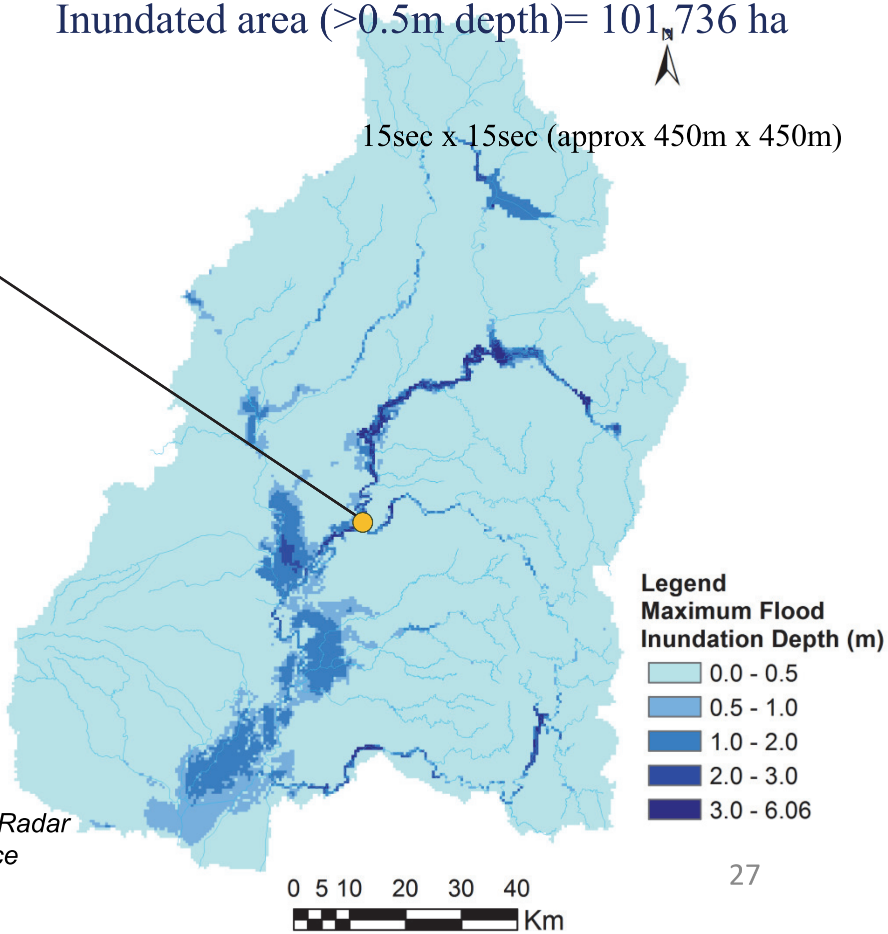
Flood event: 26 September to 4 October 2011 (Largest Recorded Flood Event)

Comparison of calculated and observed discharge at San Isidro Station



Maximum flood inundation depth calculated by RRI Model

Inundated area (>0.5m depth)= 101,736 ha

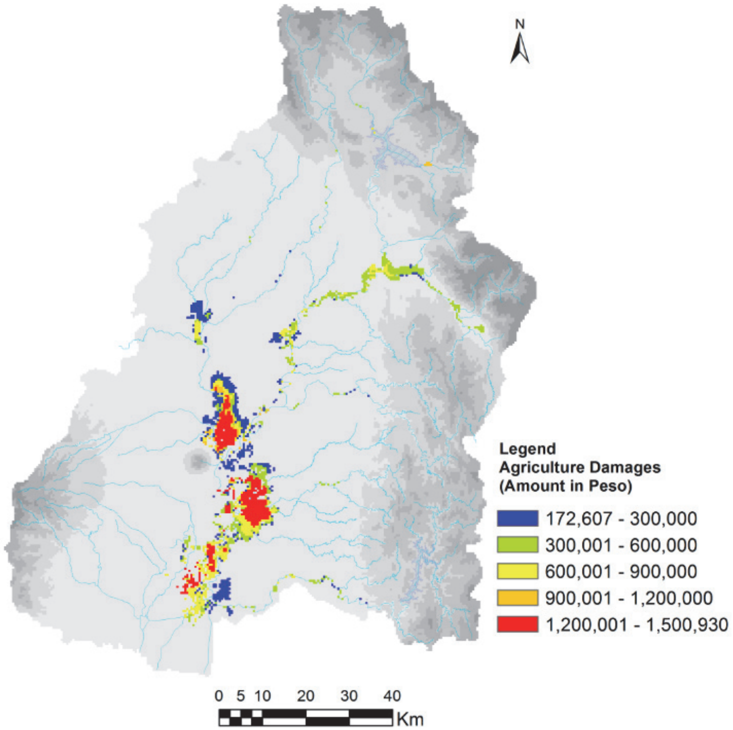


DEM: Intermap's airborne Interferometric Synthetic Aperture Radar (IfSAR) data was Provided by National Mapping and Resource Information Authority

4. Research Result

4.2 Flood risk assessment

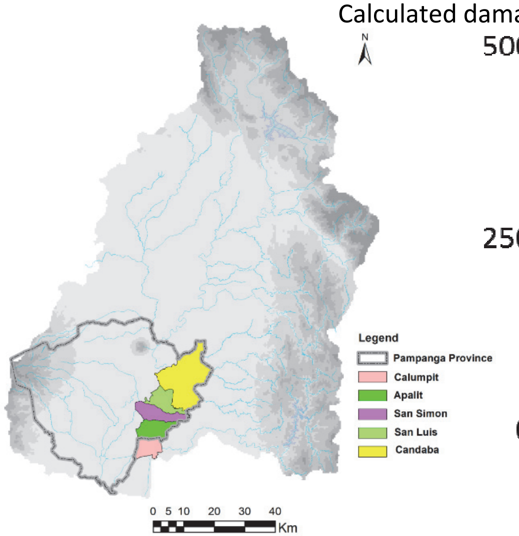
Verification of the damage function by ICHARM
(Application for past flood event: September 2011 Flood)

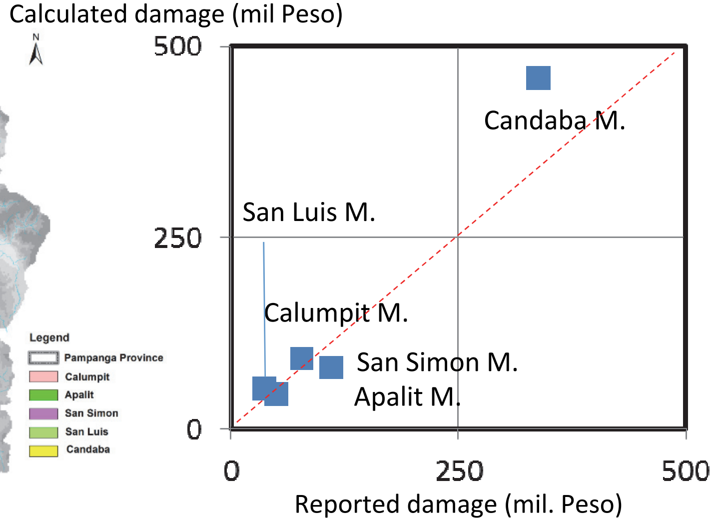


Calculated agricultural economic loss in Pampanga Province: 821 million Peso

Reported agricultural economic loss:1376 million Peso
The deference of the loss may be caused by other damage factors (wind, etc.)

Comparison of agricultural economic loss between reported and calculated in areas where the main cause of the disaster was flood





Province/ Municipality	Reported	Calculated (using IfSAR DEM)	
	Damage (mil. Peso)	Damage (mil. eso)	Area affected (ha)
Pampanga Province	1376	821.59	19318
Calumpit M.	37	53.69	2308
San Luis M.	114.88 (50.29*)	46	1923
Apalit M.	109.69	80.04	2349
San Simon M.	78.08	92.05	1944
Candaba M.	337.5	457.6	8808.75

** Estimated damage in inundated area by using proportion of inundation area and total paddy area in the municipality (Inundated area=1923.75ha, Total Paddy Area=4394.25ha).*

4. Research Result 4.2 Flood risk assessment

Methodology of flood risk assessment considering various precipitation patterns for present/ future climate

Step 1: Reproduction of daily (or hourly) precipitation pattern for present/future 25 years.

Step 2: Calculation of accumulated rainfall volume for fixed flood period (Panpamga: 48 hours, Solo: 4 days, Chao Phraya: 6 months, etc.) according to the reproduced precipitation by Step 1.

Step 3-1: Abstraction of 10 (or 5) precipitation patters with 10 (or 5) highest rainfall volume among the reproduced precipitation by Step1.

Step 3-2: Calculation of the accumulated rainfall volume for 50-year and 100- year return period.

Step 4: Extension of the each 10 (or 5) abstracted precipitation patterns to the level which rainfall amount is equal to the calculated ones by Step 3-2.

Step 5: Inundation analysis by RRI model for each extended rainfall patterns.
(for 50-year and 100-year return period, for present and future (totally 40 patterns)

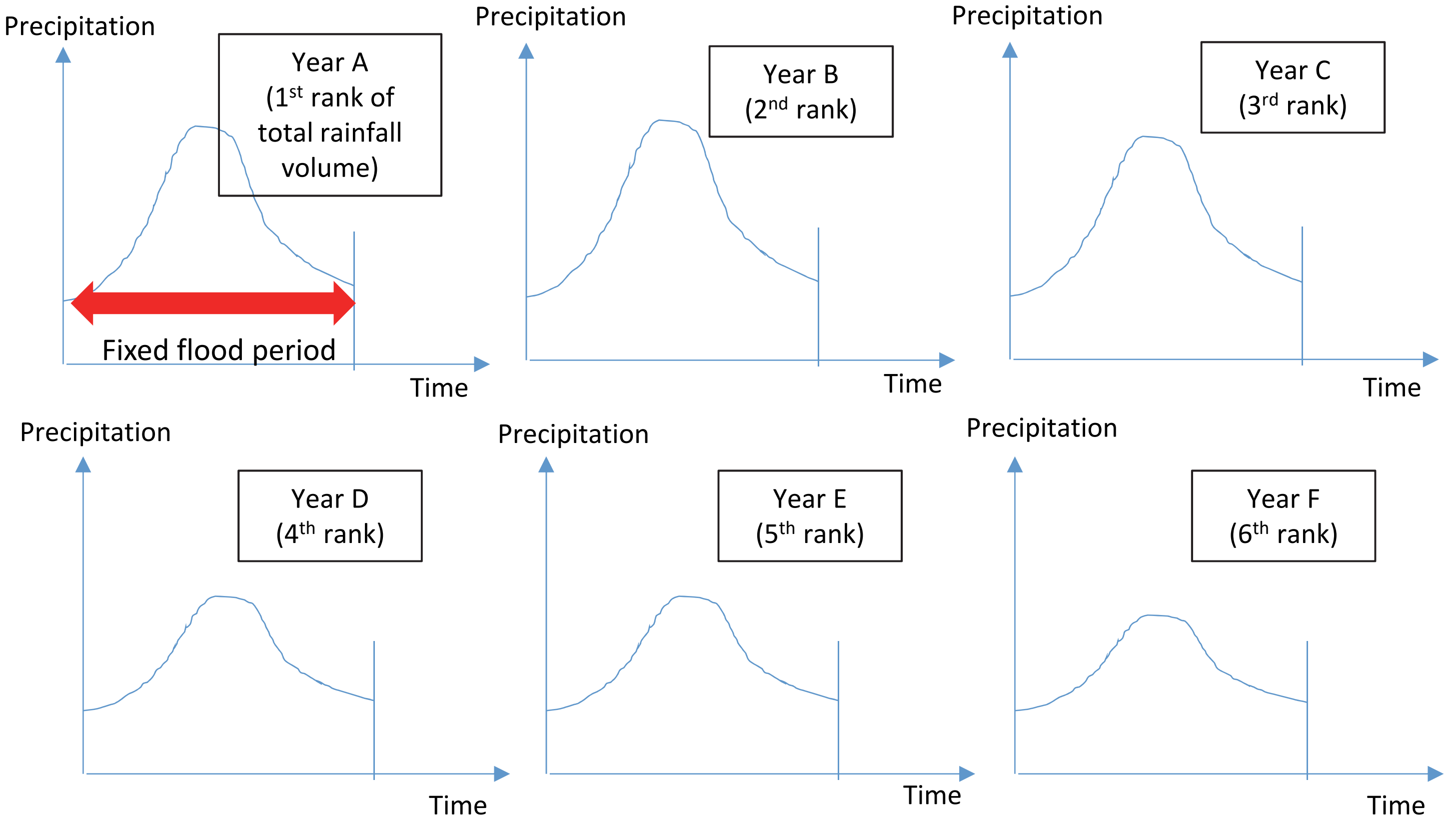
Step 6: Calculation of damaged agricultural areas and agricultural economic loss considering each maximum inundation areas.

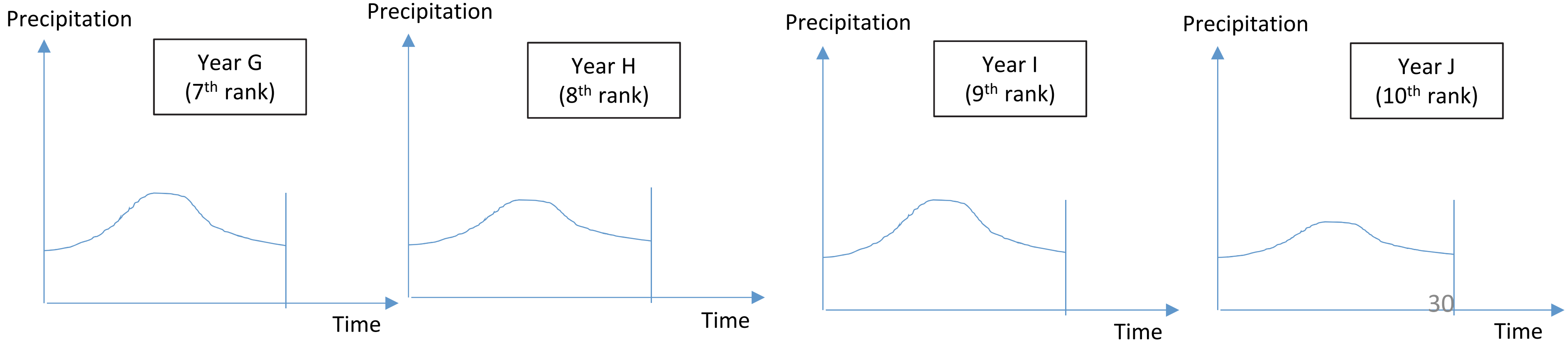
4. Research Result 4.2 Flood risk assessment

Methodology of flood risk assessment considering various precipitation patterns for present/ future climate

Step 3-1:
Abstraction of 10 (or 5) precipitation patters with 10 (or 5) highest rainfall volume

10 original precipitation patterns



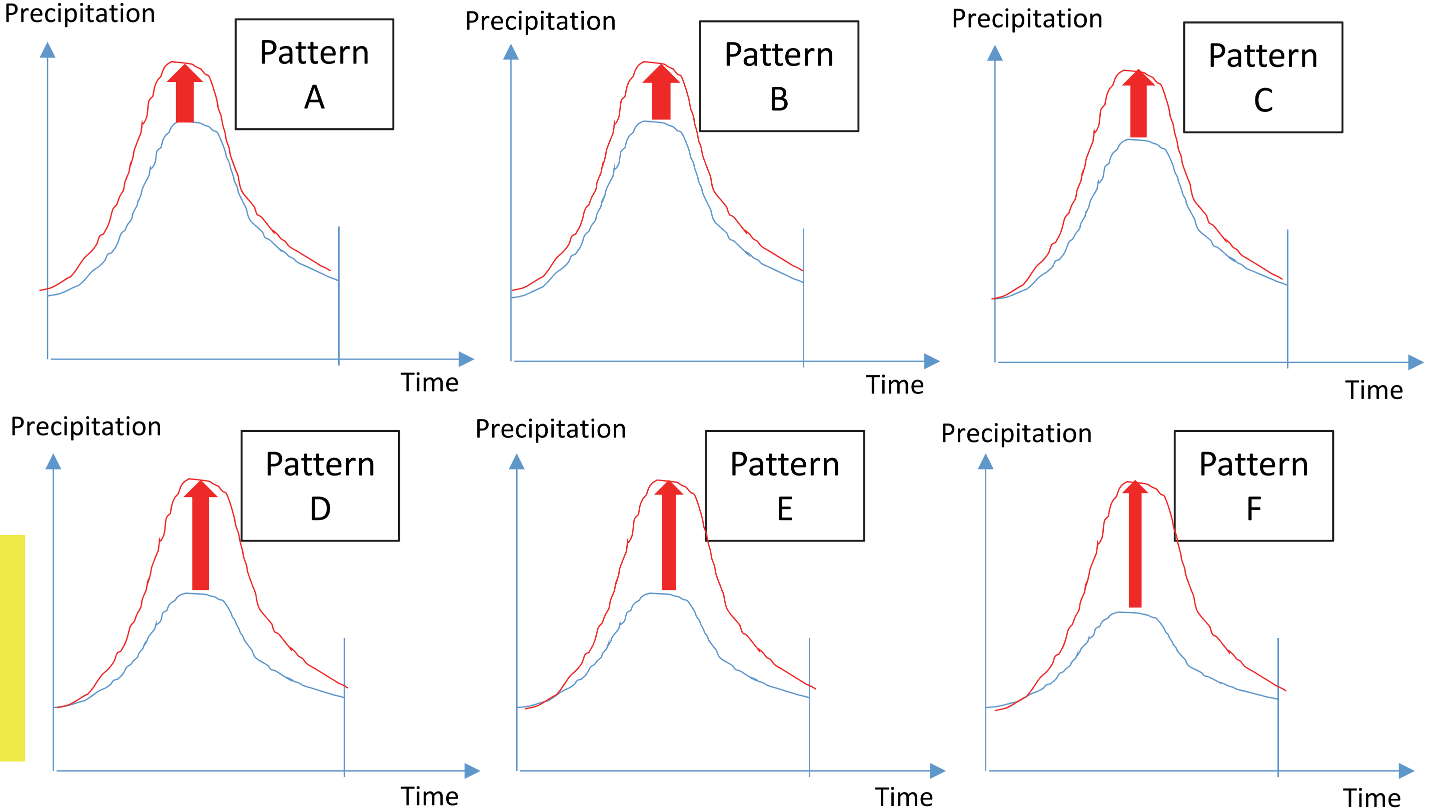


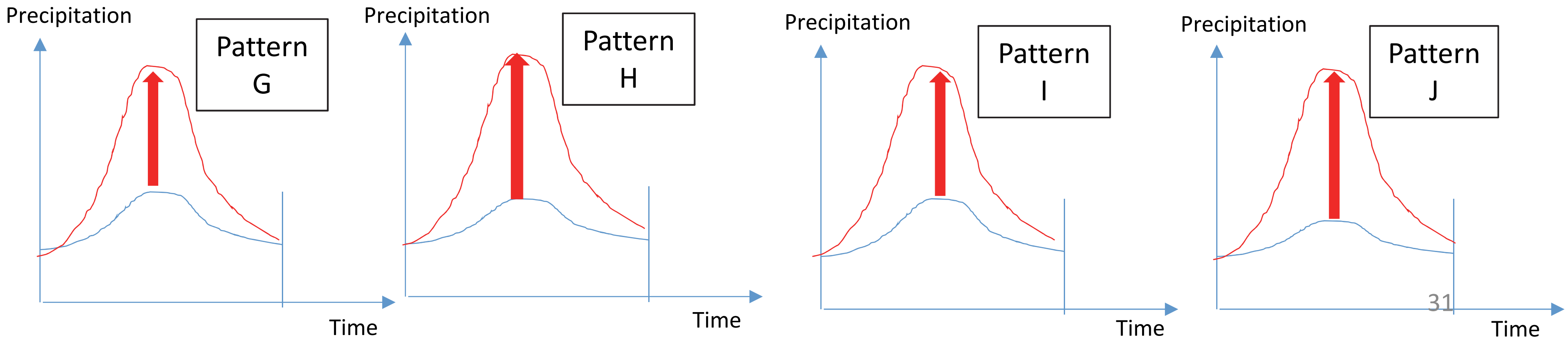
4. Research Result 4.2 Flood risk assessment

Methodology of flood risk assessment considering various precipitation patterns for present/ future climate

Step 4:
Extension of the each 10 (or 5) abstracted precipitation patterns to the level which rainfall amount is equal to the calculated ones by Step 3-2

Different 10 precipitation patterns corresponding to same rainfall volume





4. Research Result

4.2 Flood risk assessment

SOUSEI Program for Risk Information on Climate Change 気候変動リスク情報創生プログラム

Agricultural economic loss assessment: with 10 different rainfall patterns chosen from each climate (Original Rainfall)

Present Climate: (1979-2003)

Rainfall pattern	48-hour rainfall value (mm)	Damaged agricultural area (ha)	Agricultural economic loss (million Peso)
A	300.9	147,177.0	6434.3
B	252.7	139,097.3	5928.4
C	238.5	157,686.8	5867.6
D	232.6	**172,854.0**	7260.9
E	203.3	143,775.0	7494.5
F	181.9	110,119.5	3492.0
G	178.2	123,585.8	5733.1
H	174.5	119,738.3	5798.0
I	157.7	82,235.3	3082.9
J	154.8	88,512.8	2895.1
Average	207.5	128,478.2	5,398.6

Future Climate: (2075-2099)

Rainfall pattern	48-hour rainfall value (mm)	Damaged agricultural area (ha)	Agricultural economic loss (million Peso)
A	526.4	**204,160.5**	7859.0
B	309.3	98,658.0	4532.5
C	273.8	172,833.8	7482.8
D	244.7	154,507.5	5618.1
E	204.1	138,064.5	6345.9
F	186.9	99,751.5	4315.5
G	184.0	115,101.0	4514.3
H	182.3	143,005.5	5688.6
I	174.7	132,495.8	7457.2
J	171.6	133,548.8	6199.7
Average	245.8	139,212.7	6,001.3

4. Research Result

SOUSEI Program for Risk Information on Climate Change
気候変動リスク情報創生プログラム

4.2 Flood risk assessment

Agricultural damage assessment: with 10 different rainfall patterns chosen from each climate (50-Year Flood)

Present Climate: (1979-2003)

Rainfall pattern	Extended 48-hour rainfall value (mm)	Damaged agricultural area (ha)	Agricultural economic loss (million Peso)
A	311.7	150,963.7	6559.2
B		155,580.7	6468.1
C		187,150.5	6847.0
D		**200,434.5**	8109.4
E		177,207.7	8573.9
F		169,816.5	5827.1
G		171,659.2	7316.4
H		146,448	7277.1
I		154,163.2	6129.8
J		151,449.7	5644.6
Average		166,487.4	6,875.2

Future Climate: (2075-2099)

Rainfall pattern	Extended 48-hour rainfall value (mm)	Damaged agricultural area (ha)	Agricultural economic loss (million Peso)
A	450.3	188,345.25	7284.7
B		129,640.5	5733.1
C		205,821	8796.2
D		217,424.25	7836.6
E		190,431	8274.2
F		177,066	7277.7
G		220,158	8057.2
H		**224,370**	8405.7
I		187,312.5	9243.9
J		208,271.25	8593.9
Average		194,884.0	7,950.3

4. Research Result

SOUSEI Program for Risk Information on Climate Change
気候変動リスク情報創生プログラム

4.2 Flood risk assessment

Agricultural damage assessment: with 10 different rainfall patterns chosen from each climate (100-Year Flood)

Present Climate: MRI AGCM3.2S SPA (**1979-2003)**

Rainfall pattern	Extended 48-hour rainfall value (mm)	Damaged agricultural area (ha)	Agricultural economic loss (million Peso)
A	344.8	161,676	6912.5
B		163,397.25	6769.5
C		196,890.75	7212.0
D		**209,790**	8412.2
E		185,976	8837.0
F		180,690.75	6255.5
G		180,589.5	7623.2
H		151,368.75	7523.9
I		166,070.25	6584.5
J		163,478.25	6074.2
Average		175,992.8	7,220.4

Future Climate: MRI AGCM3.2S SFA rcp8.5 **(2075-2099)**

Rainfall pattern	Extended 48-hour rainfall value (mm)	Damaged agricultural area (ha)	Agricultural economic loss (million Peso)
A	556.5	208,777.5	8031.0
B		147,237.75	6376.3
C		218,112.75	9262.6
D		237,836.25	8545.9
E		200,738.25	8766.9
F		200,616.75	8069.3
G		**243,101.25**	8756.7
H		236,641.5	8836.5
I		195,696	9607.2
J		222,162.75	9094.9
Average		211,092.1	8,534.73

4. Research Result

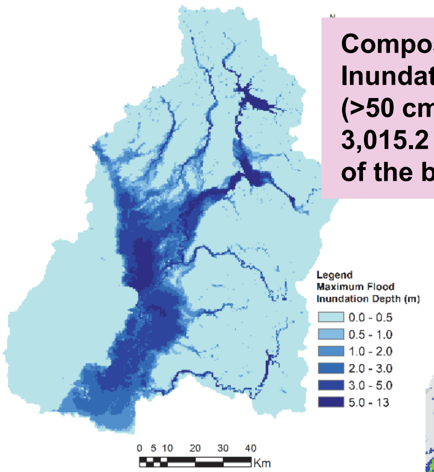
4.2 Flood risk assessment

Comparison of Rice Crop Damage under Present/future Climate

Worst Cases in terms of Agricultural Damage Area: Original Rainfall

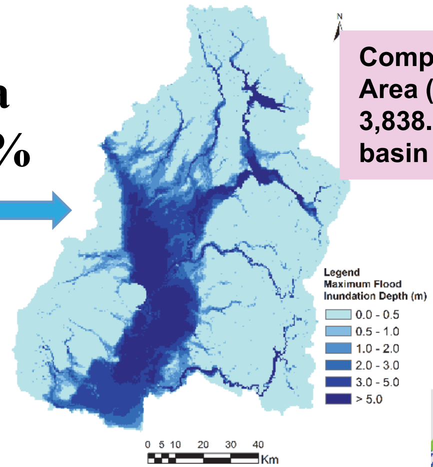
Present Climate: (1979-2003)

Future Climate: MRI AGCM3.2S SFA rcp8.5 (2075-2099)

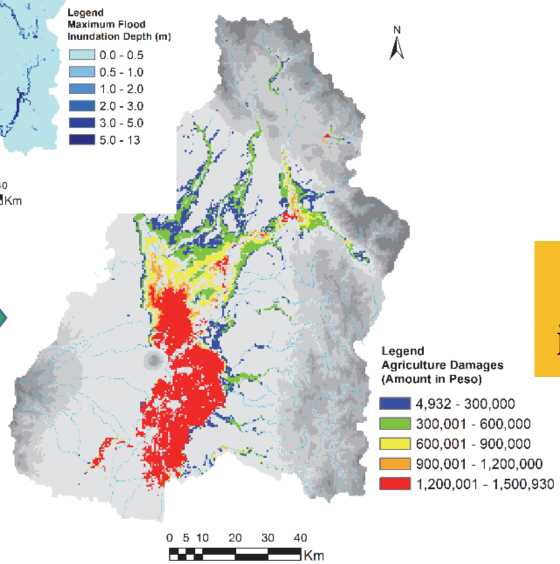


Composite of Inundation Area (>50 cm depth)= 3,015.2 km² (29.15% of the basin area)

Inundation area increased by 27 %

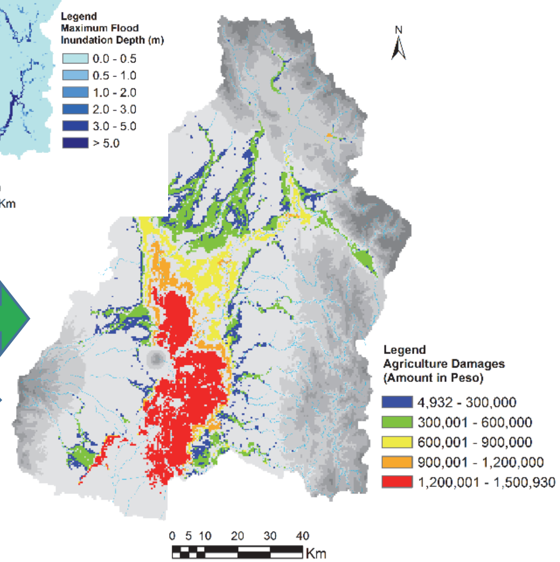


Composite of Inundation Area (>50 cm depth)= 3,838.9 km² (37.1% of the basin area)



Damage area increased by 18 %

Economic loss increased by 8 %



Damage area= 172,854 ha
Agricultural economic loss= 7,260.9 million Peso

Damage area= 204160.5 ha
Agricultural economic loss = 7,858.9 million Peso

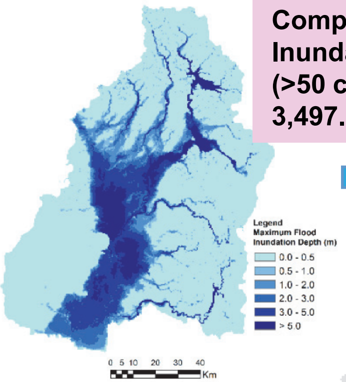
4. Research Result

4.2 Flood risk assessment

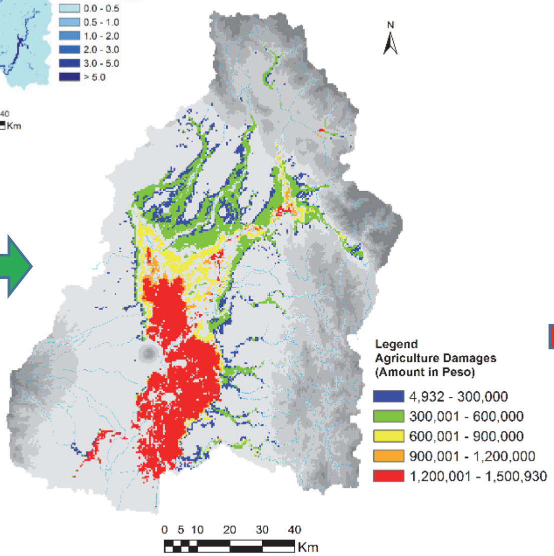
Comparison of Rice Crop Damage under Present/future Climate

Worst Cases in terms of Agricultural Damage Area: 50-Year Flood

Present Climate



Composite of Inundation Area (>50 cm depth)= 3,497.3 km²

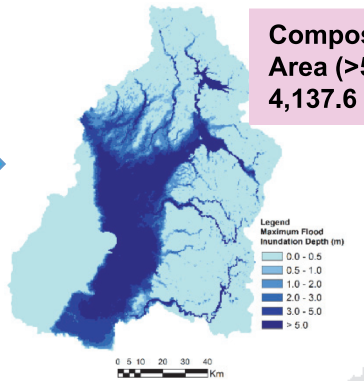


Inundation area increased by 18 %

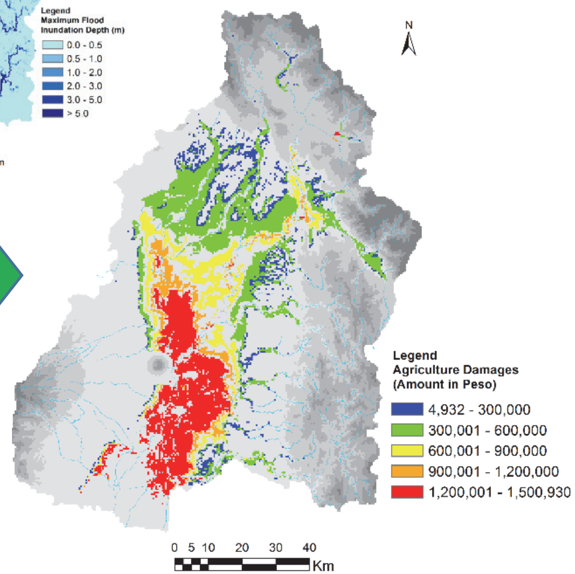
Damage area increased by 12 %

Economic loss increased by 4 %

Future Climate



Composite of Inundation Area (>50 cm depth)= 4,137.6 km²



Damage area= 200,434.5 ha
Agricultural economic loss = 8,109.4 million Peso

Damage area= 224,370 ha
Agricultural economic loss = 8,405.7 million Peso

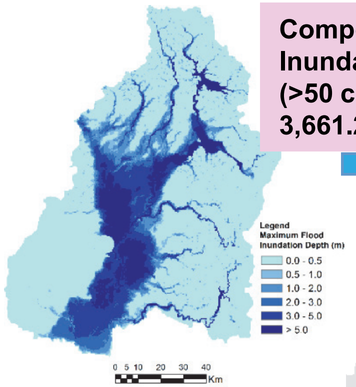
4. Research Result

4.2 Flood risk assessment

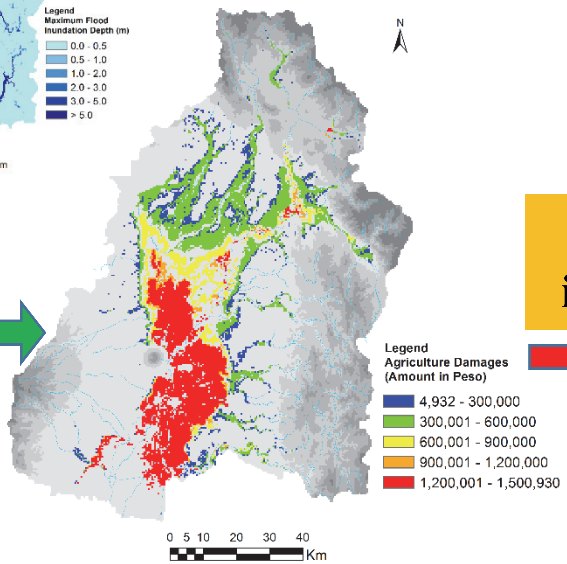
Comparison of Rice Crop Damage under Present/future Climate

Worst Cases in terms of Agricultural Damage Area: 100-Year Flood

Present Climate



Composite of Inundation Area (>50 cm depth)= 3,661.2 km2



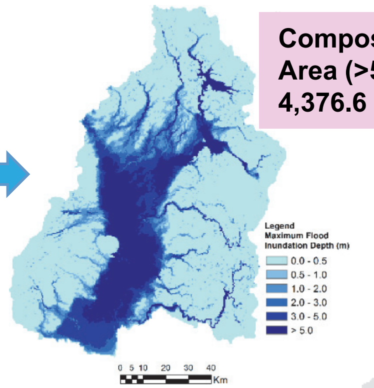
Damage area= 209,790 ha
Agricultural economic loss = 8,412.1 million Peso

Inundation area increased by 20 %

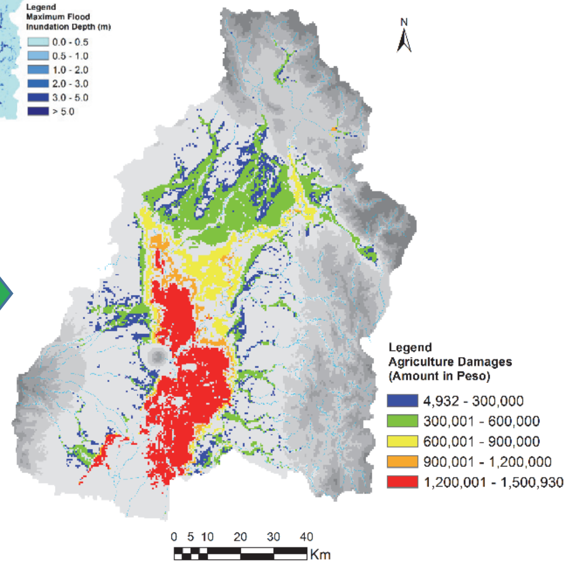
Damage area increased by 16 %

Economic loss increased by 4 %

Future Climate



Composite of Inundation Area (>50 cm depth)= 4,376.6 km2



Damage area= 243,101.25 ha
Agricultural economic loss = 8,756.7 million Peso

4. Research Result

4.2 Flood risk assessment

Comparison of Rice Crop Damage under Present/future Climate

Summary : Comparison with worst damage area case

Rainfall Conditions	Present Climate		Future Climate		% Increased	
	Agricultural damage area (ha)	Agricultural economic loss (mil. Peso)	Agricultural damage area (ha)	Agricultural economic loss (mil. Peso)	Agricultural damage area	Agricultural economic loss
Original	172,854	7260.9	204,161	7859.0	18	8
50-Year Return Period	200,435	8109.4	224,370	8405.7	12	4
100-Year Return Period	209,790	8412.2	243,101	8756.7	16	4

4. Research Result

4.2 Flood risk assessment

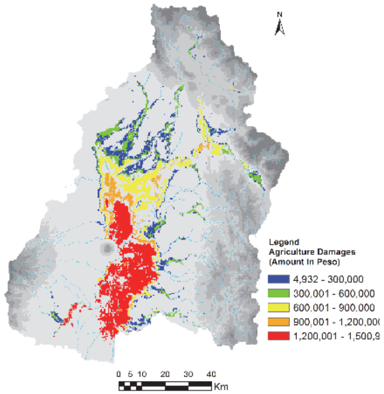
Agricultural damage assessment by conducting hazard analysis using 10 different precipitation patterns with rainfall amount of 50 year return period

50-Year Flood **(1/2)**

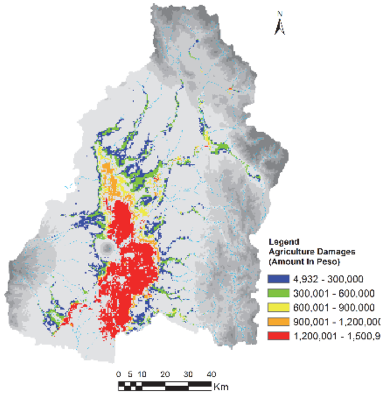
Under Present Climate (1979-2003): SPA

Maximum damaged agricultural area

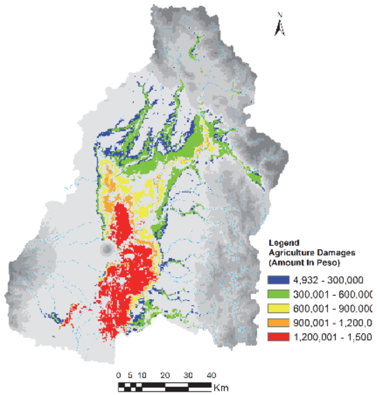
Pattern A



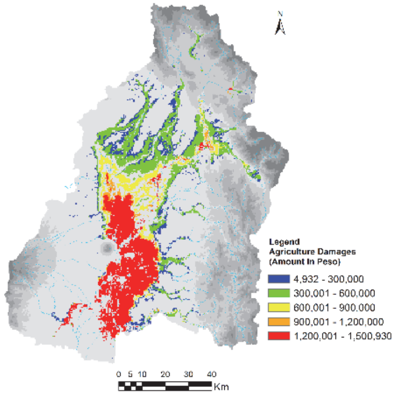
Pattern B



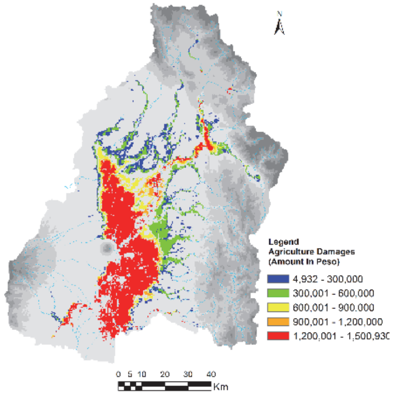
Pattern C



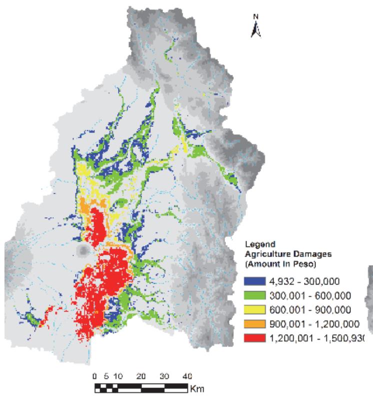
Pattern D



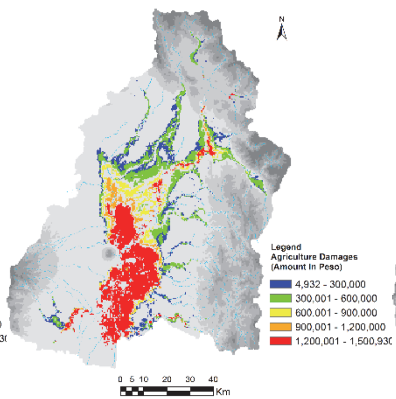
Pattern E



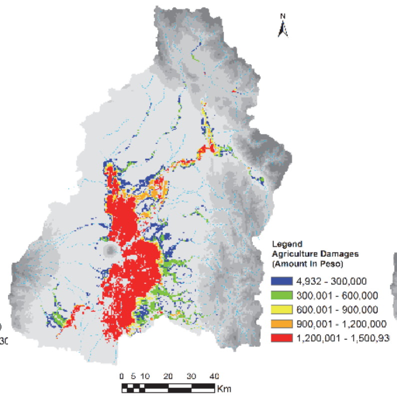
Pattern F



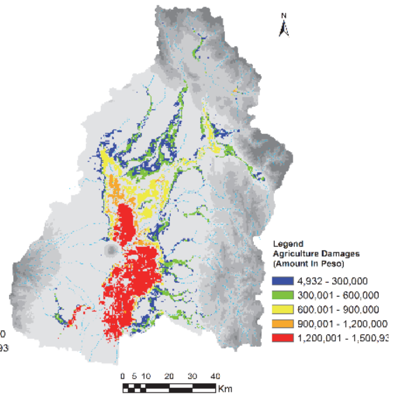
Pattern G



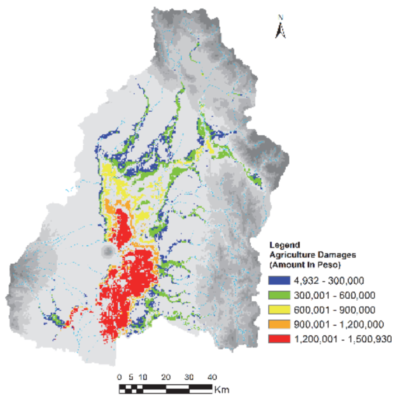
Pattern H



Pattern I



Pattern J



4. Research Result

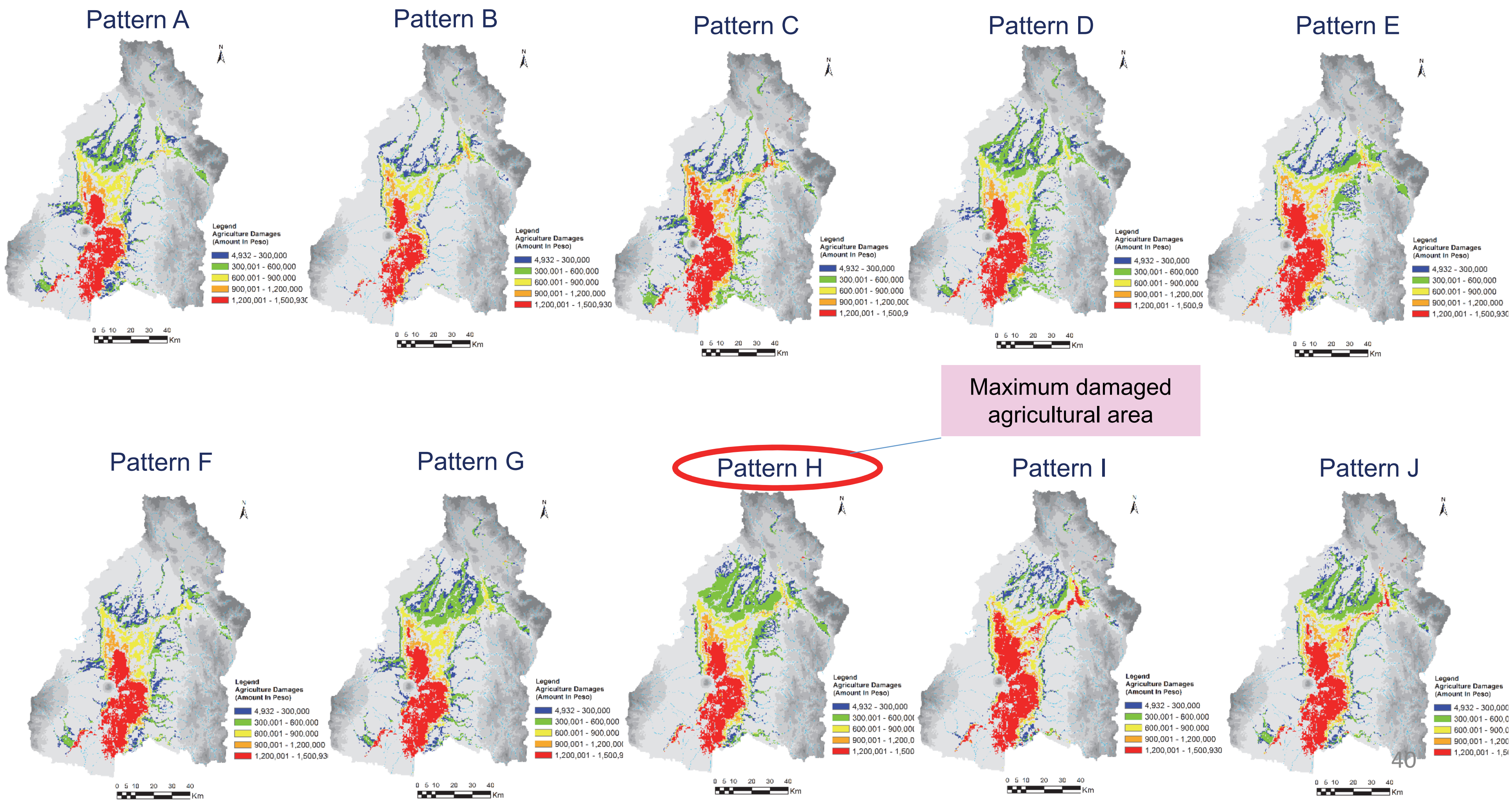
4.2 Flood risk assessment

SOUSEI Program for Risk Information on Climate Change
気候変動リスク情報創生プログラム

Agricultural damage assessment by conducting hazard analysis using 10 different precipitation patterns with rainfall amount of 50 year return period

50-Year Flood **(2/2)**

Under Future Climate (2075-2099): SFA rcp8.5



4. Research Result

SOUSEI Program for Risk Information on Climate Change
気候変動リスク情報創生プログラム

4.2 Flood risk assessment

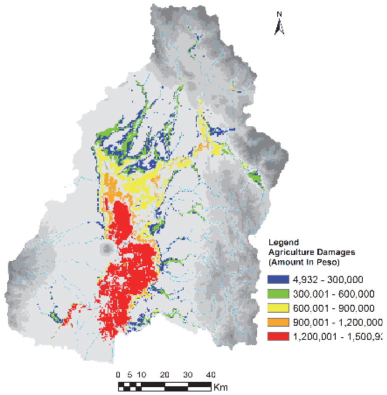
Agricultural damage assessment by conducting hazard analysis using 10 different precipitation patterns with rainfall amount of 100 year return period

100-Year Flood **(1/2)**

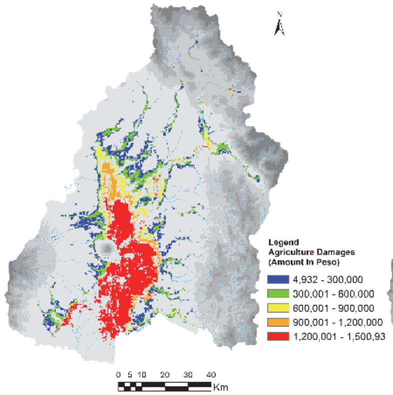
Under Present Climate (1979-2003): SPA

Maximum damaged agricultural area

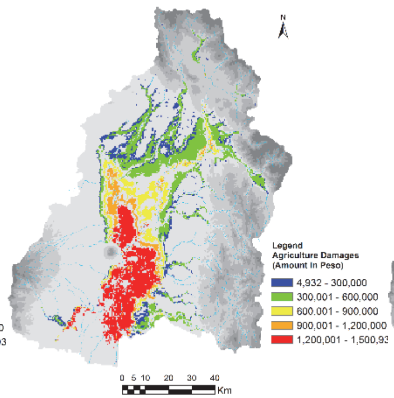
Pattern A



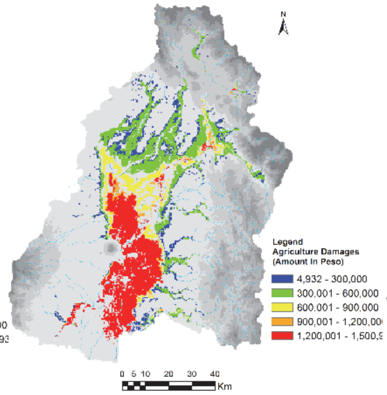
Pattern B



Pattern C



Pattern D



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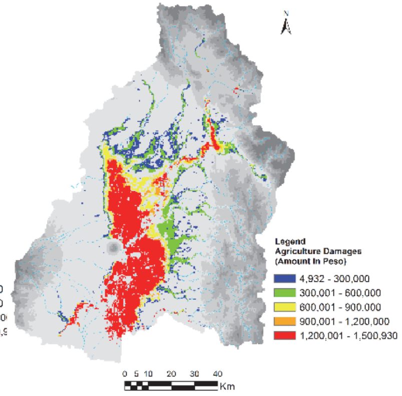

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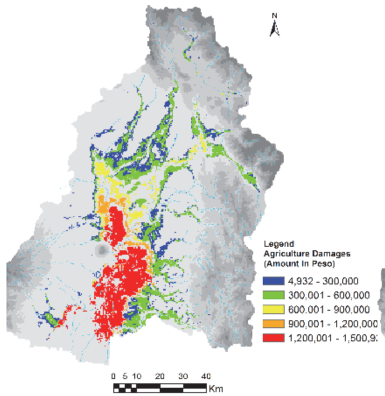
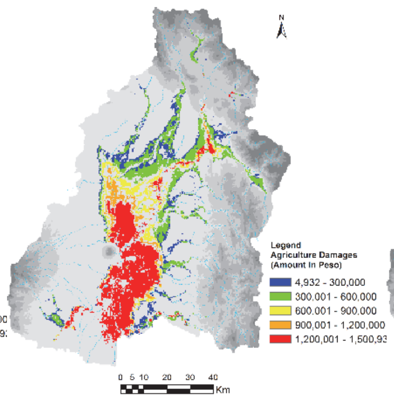
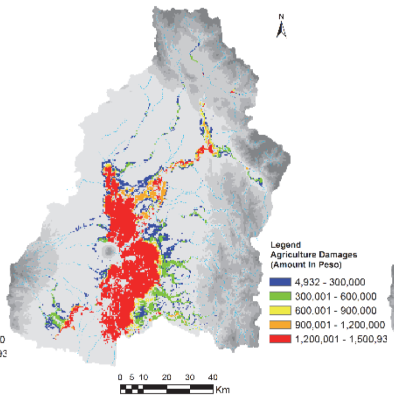


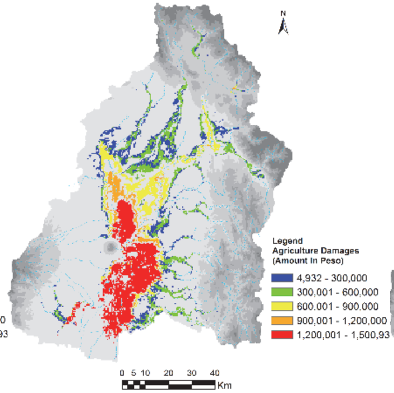
Pattern G



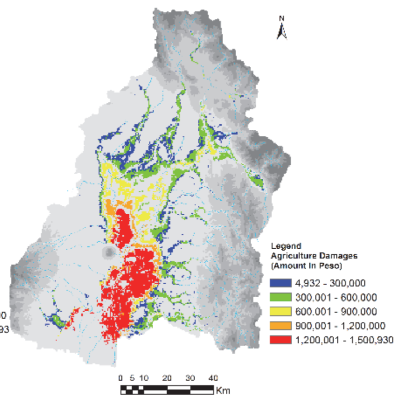
Pattern H



Pattern I



Pattern J



4. Research Result

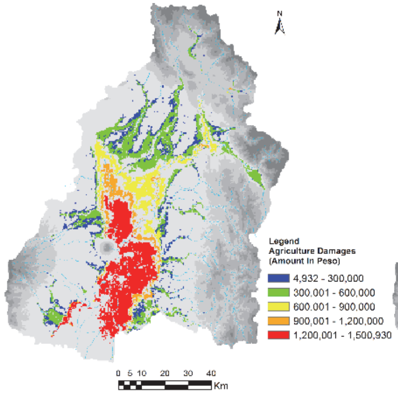
4.2 Flood risk assessment

Agricultural damage assessment by conducting hazard analysis using 10 different precipitation patterns with rainfall amount of 100 year return period

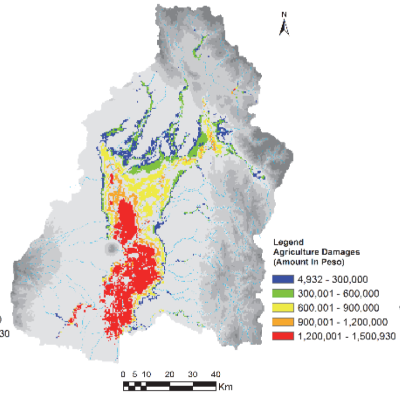
100-Year Flood **(2/2)**

Under Future Climate (2075-2099): SFA rcp8.5

Pattern A



Pattern B



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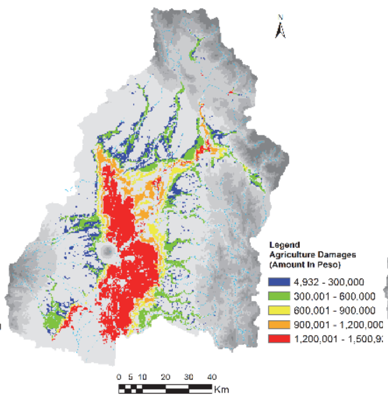

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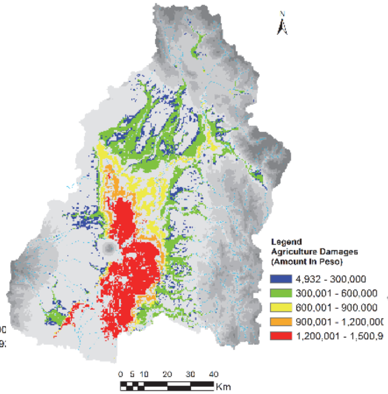

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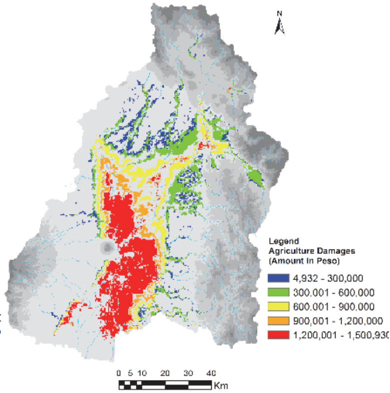
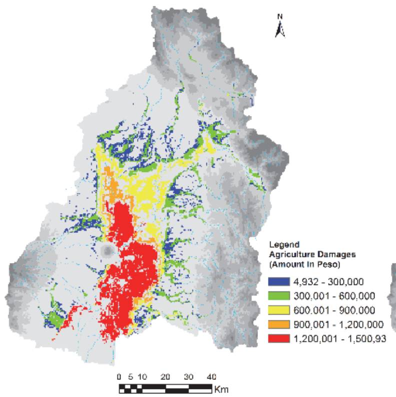
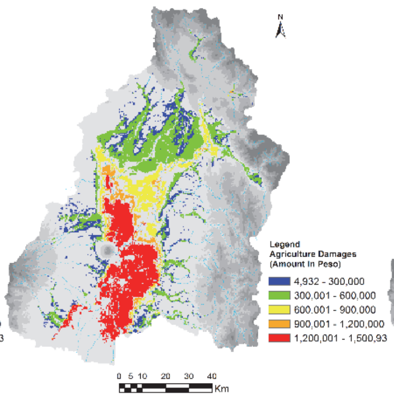


Maximum damaged agricultural area

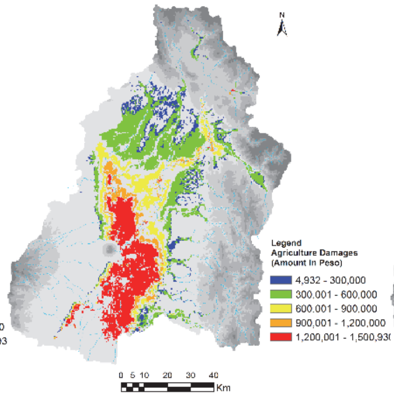
Pattern F



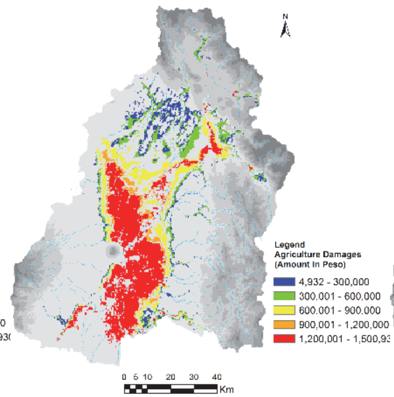
Pattern G



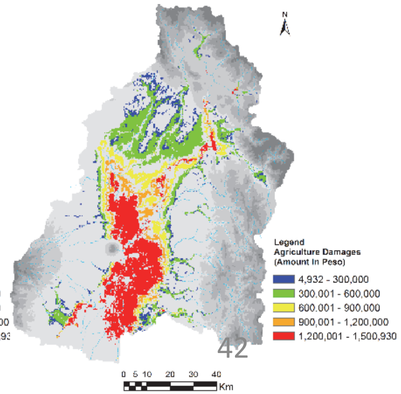
Pattern H



Pattern I



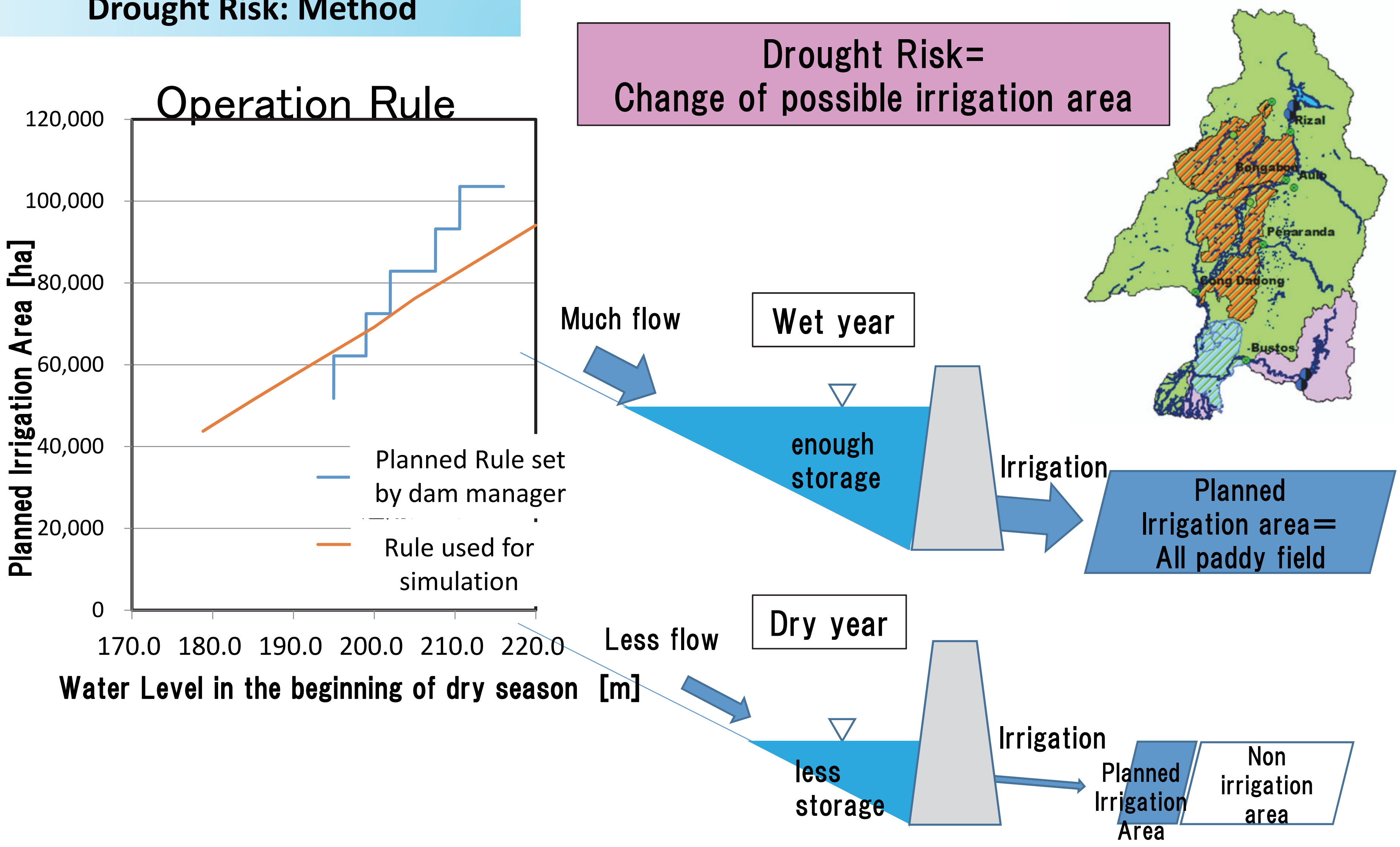
Pattern J

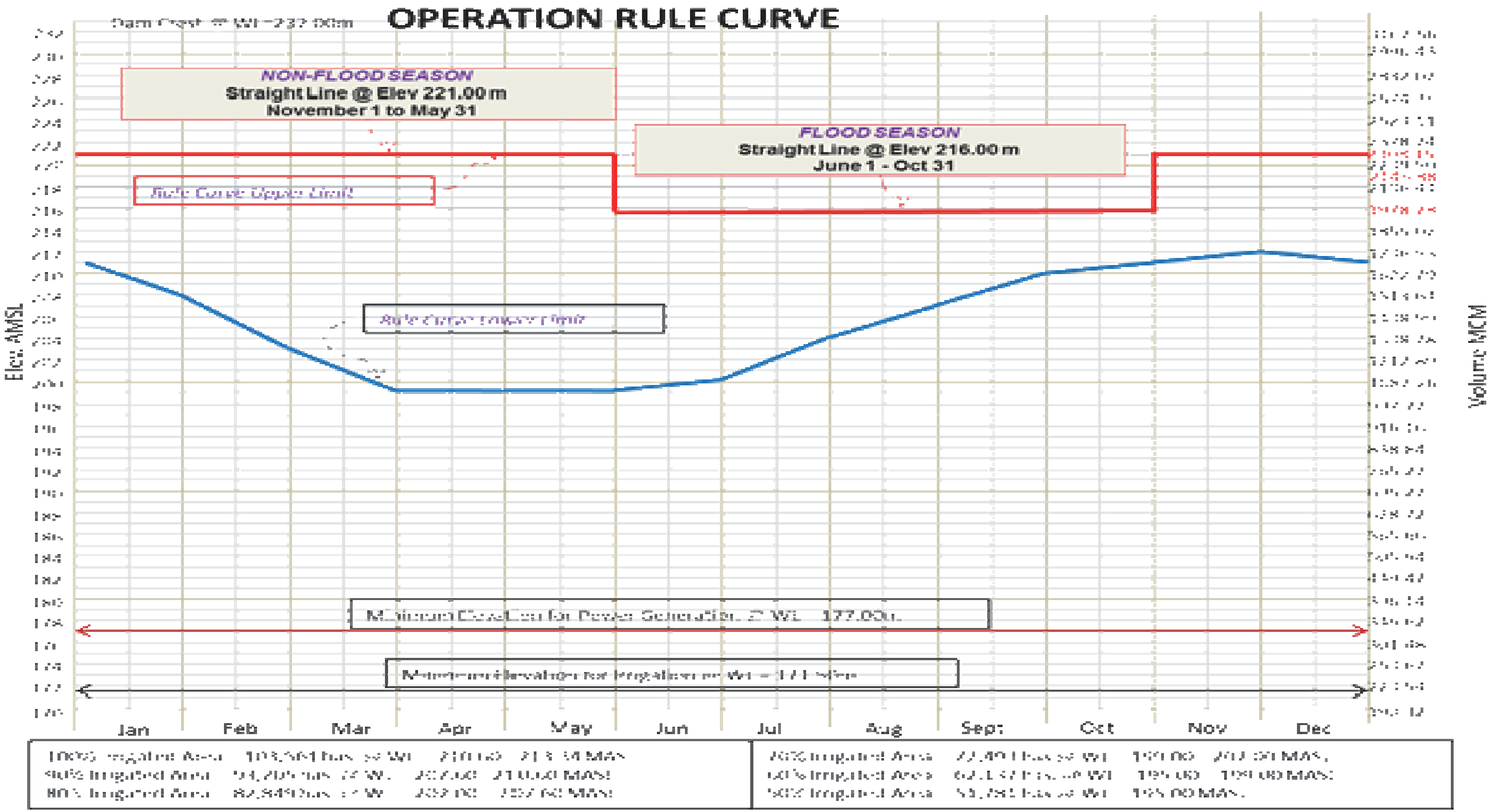


4. Research Result

4.3 Drought risk assessment under climate change

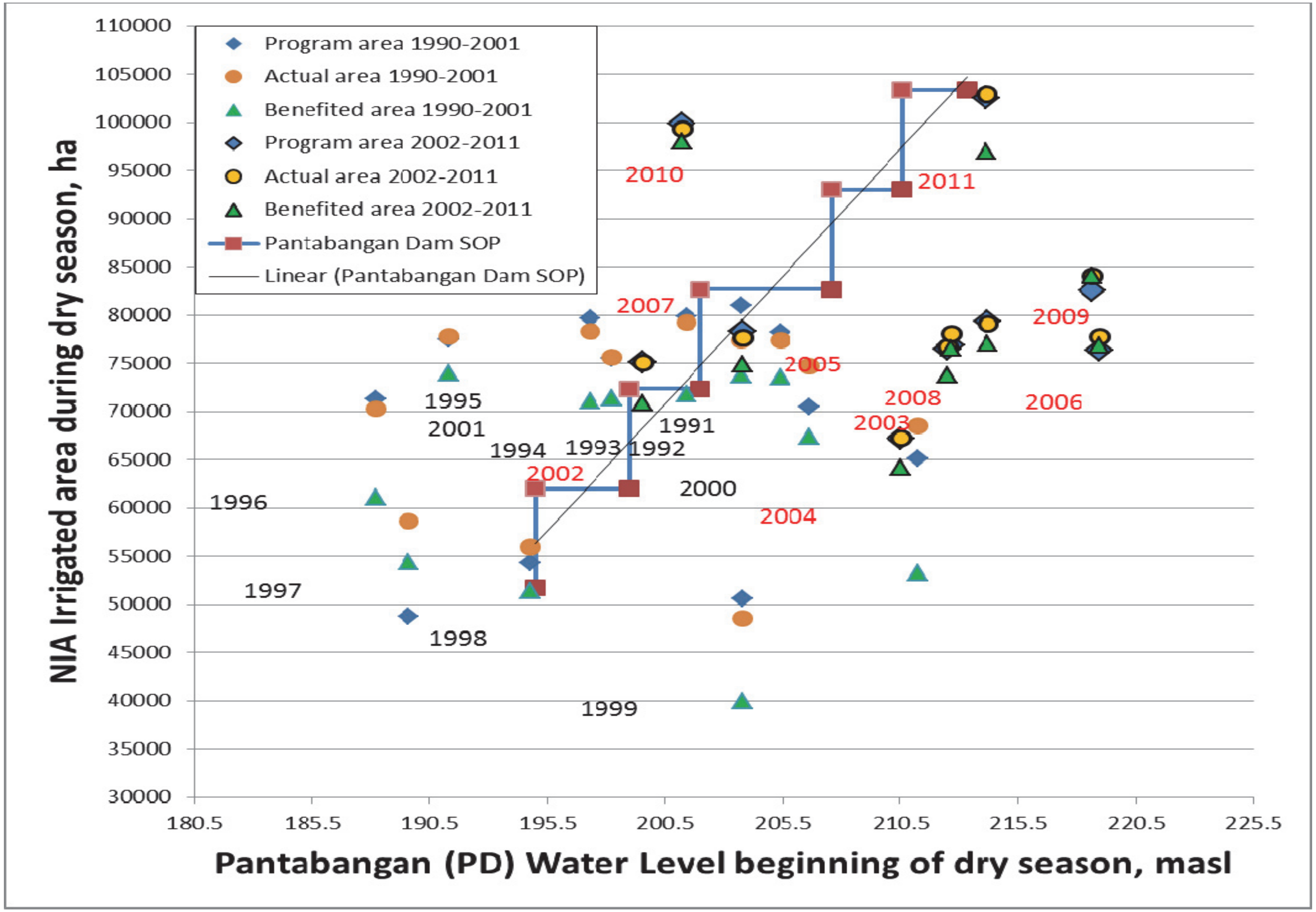
Drought Risk: Method





by National Irrigation Administration Philippines

Pantabagan Irrigated area from 1990-2011 (CASECNAN operation started in 2002)



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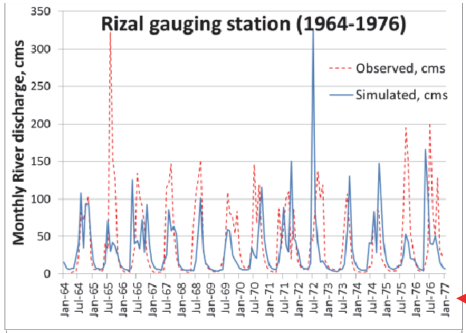
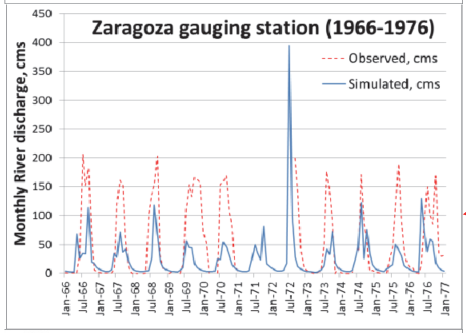
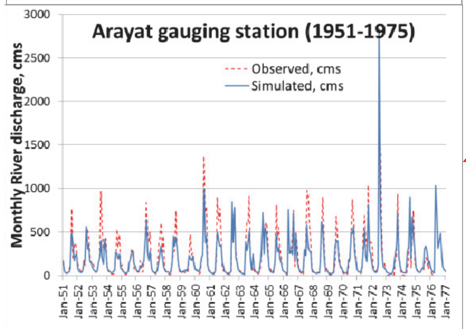
4. Research Result

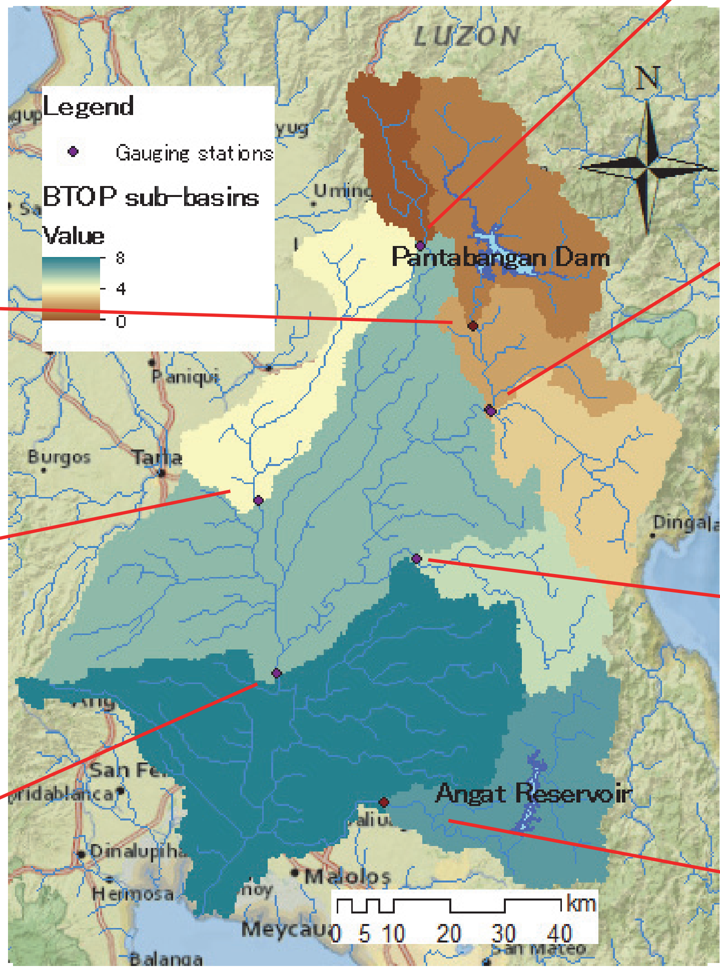
4.3 Drought risk assessment under climate change

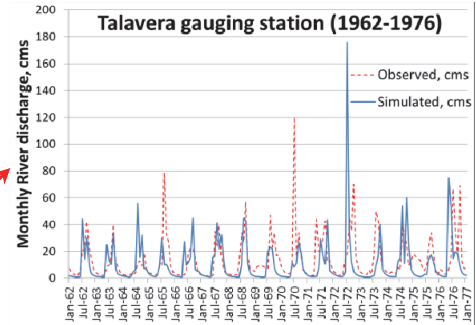
- Simulation period: 57yrs with daily step on 0.5km grid size
- Precipitation: 1951-2007 APHROMA V1003R1 dataset
- Output: daily simulated soil moisture and river discharge
- Calibration: monthly river discharge at 7 gauging stations

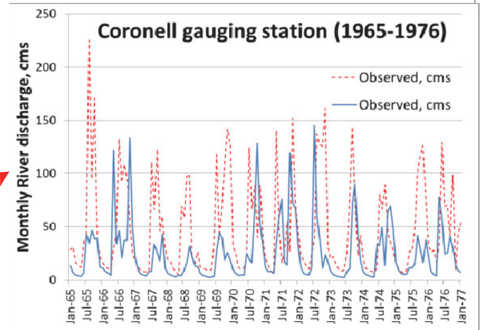


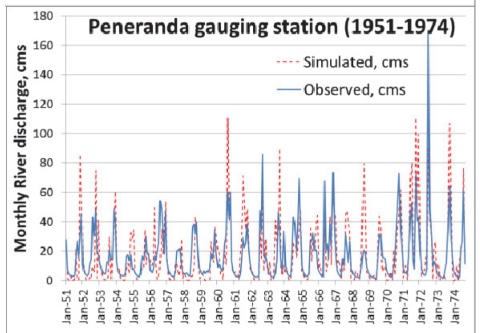


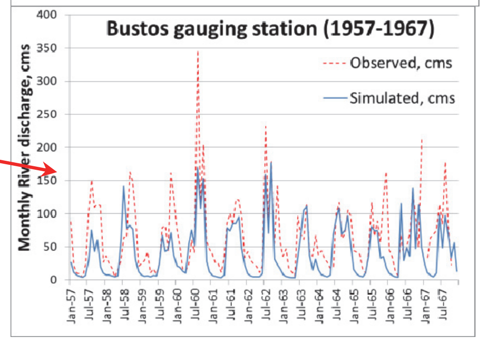










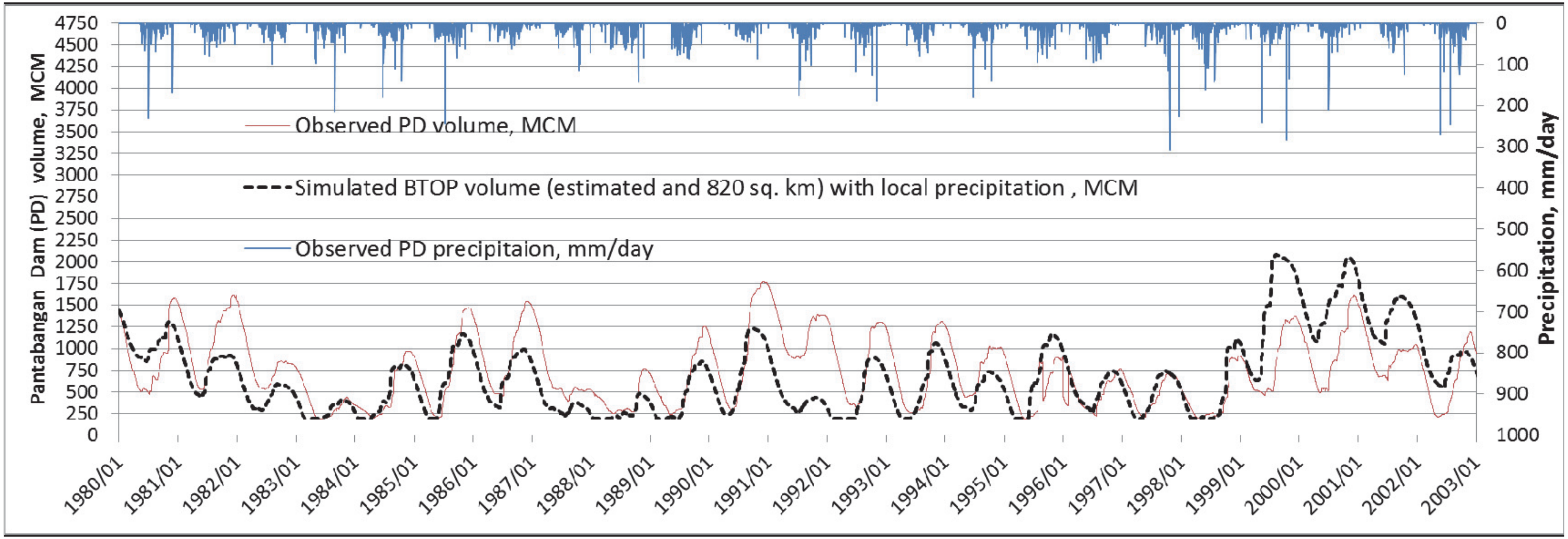


4. Research Result

4.3 Drought risk assessment under climate change

SOUSEI Program for Risk Information on Climate Change
気候変動リスク情報創生プログラム

Verification of BTOP model

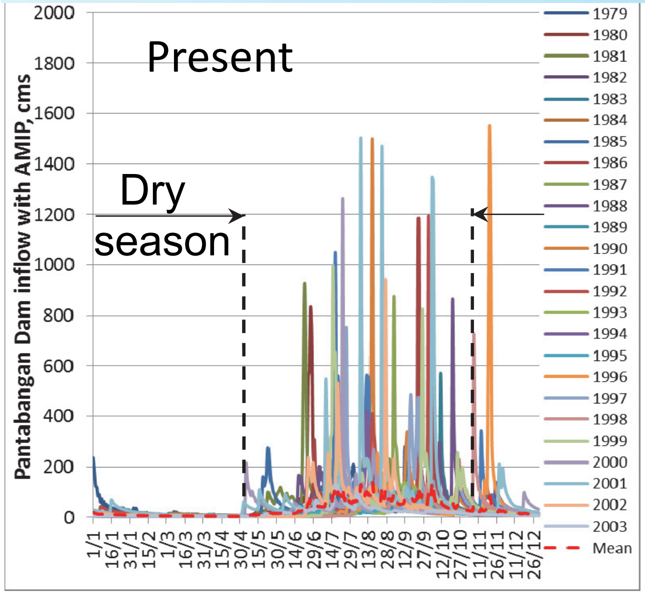


Simulated successive change in storage of Pampanga dam reservoir in the past

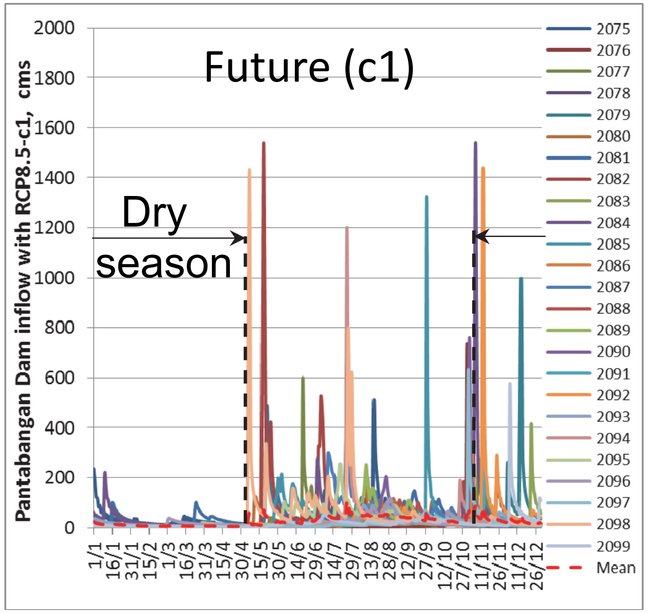
4. Research Result

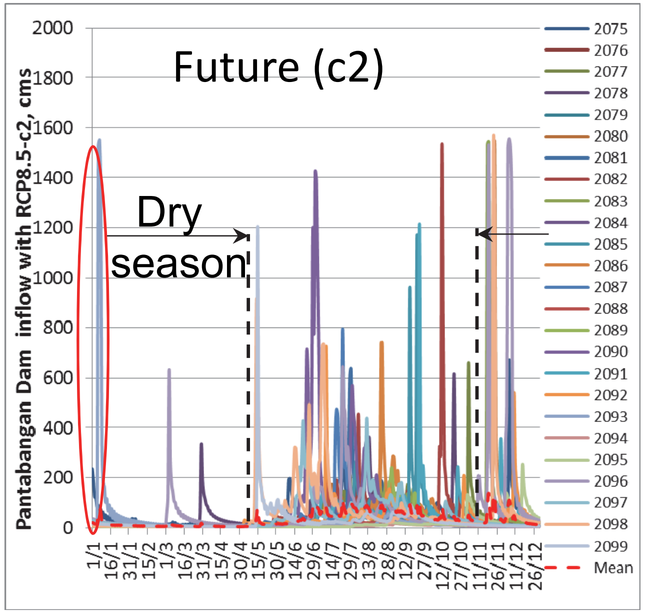
4.3 Drought risk assessment under climate change

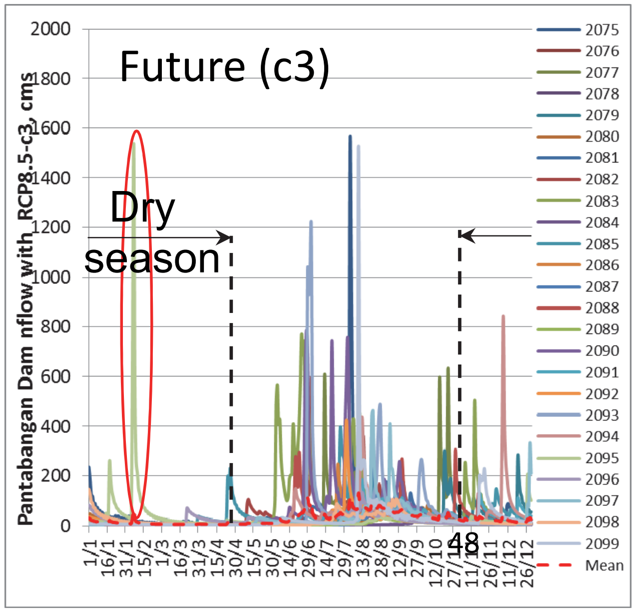
Projected changes in the inflow into Pantabamgan Dam (1/2)



【Characteristics of projected inflow in the future climate】
- The period of rainy season may be longer.
- Heavy inflow can occur in the middle of (current) dry season.



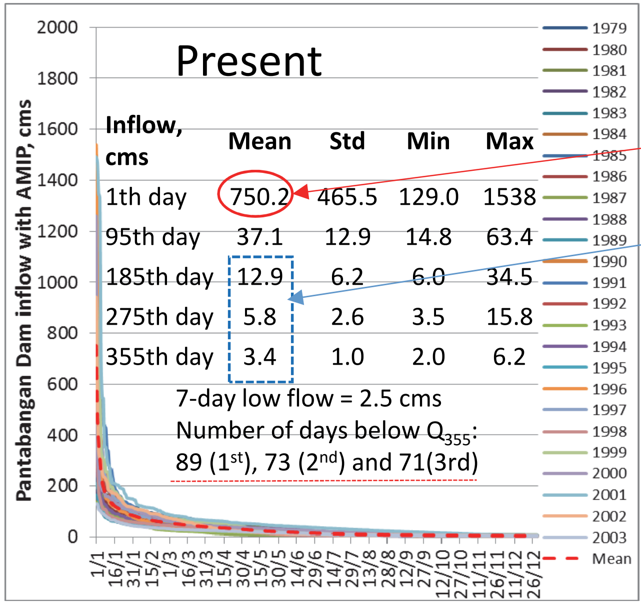




4. Research Result

4.3 Drought risk assessment under climate change

Projected changes in the inflow into Pantabamgan Dam (2/2)

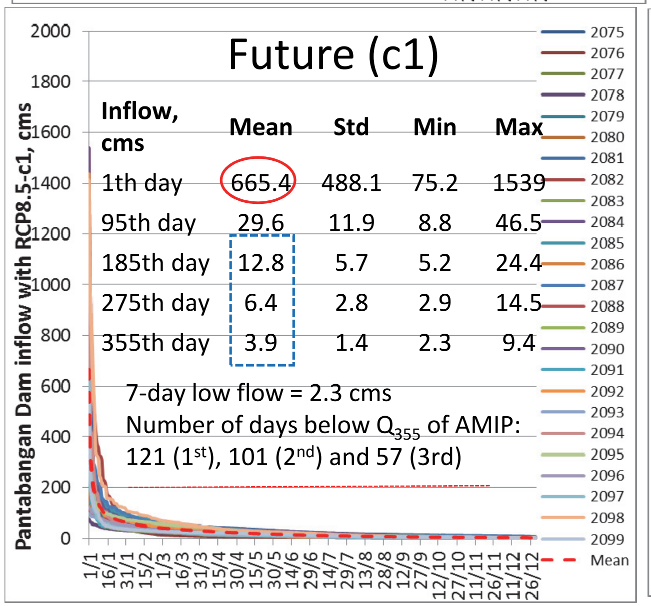


Inflow, cms	Mean	Std	Min	Max
1th day	750.2	465.5	129.0	1538
95th day	37.1	12.9	14.8	63.4
185th day	12.9	6.2	6.0	34.5
275th day	5.8	2.6	3.5	15.8
355th day	3.4	1.0	2.0	6.2

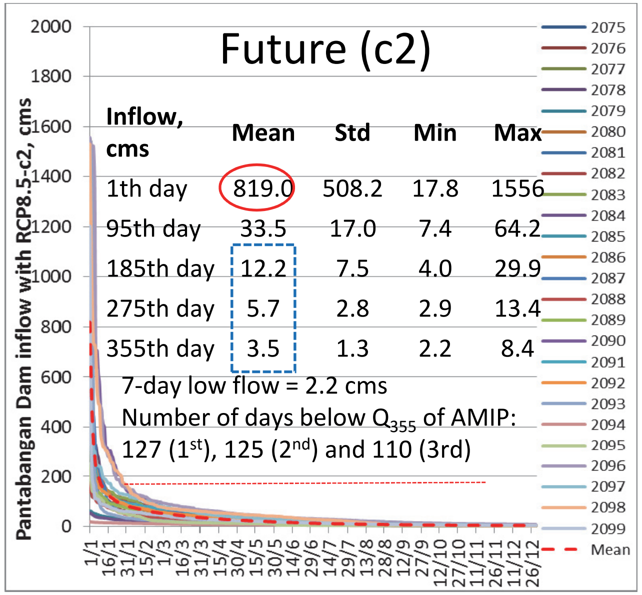
【Characteristics of projected inflow in the future climate】

- Mean of maximum yearly inflow may be decreased for c1 and c3 case, but may be increased for c2 case.
- Mean of normal flow (185th-day inflow), low flow (275th-day inflow) and drought flow (355th-day inflow) is not be changed so much.

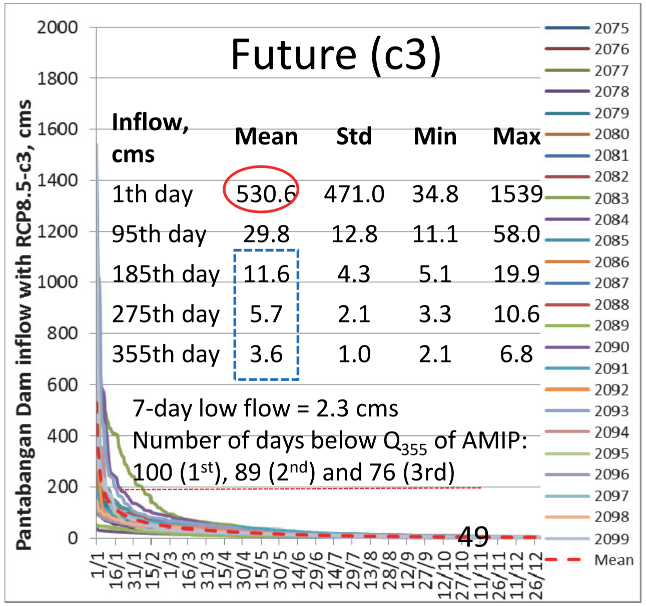
Std: Standard deviation



Inflow, cms	Mean	Std	Min	Max
1th day	665.4	488.1	75.2	1539
95th day	29.6	11.9	8.8	46.5
185th day	12.8	5.7	5.2	24.4
275th day	6.4	2.8	2.9	14.5
355th day	3.9	1.4	2.3	9.4



Inflow, cms	Mean	Std	Min	Max
1th day	819.0	508.2	17.8	1556
95th day	33.5	17.0	7.4	64.2
185th day	12.2	7.5	4.0	29.9
275th day	5.7	2.8	2.9	13.4
355th day	3.5	1.3	2.2	8.4



Inflow, cms	Mean	Std	Min	Max
1th day	530.6	471.0	34.8	1539
95th day	29.8	12.8	11.1	58.0
185th day	11.6	4.3	5.1	19.9
275th day	5.7	2.1	3.3	10.6
355th day	3.6	1.0	2.1	6.8

Period below 250 MCM based on simulated Pantabangan Dam volumes with AMIP(01/1979-12/2003) and RCP8.5 ensemble average (01/2075-12/2099) , cluster 1 (c1), cluster 2 (c2), and cluster 3 (c3) precipitation

Total number of days below 250 MCM						
		1 st	2 nd	3 rd	4 th	5 th
Present	AMIP	188 Days from Feb 3rd	170	139	134	123
Future	RCP8.5	247 Jan 10th	189	178	175	166
	RCP8.5-c1	244 Jan 28th	239	187	180	168
	RCP8.5-c2	310 Jan 1st	202	191	163	155
	RCP8.5-c3	228 Jan 9th	217	196	189	155

Based on the BTOP analysis, the longest period of zero water supply in present 25 years is for 188 days. Above figure shows period of the drought in the future will be longer.

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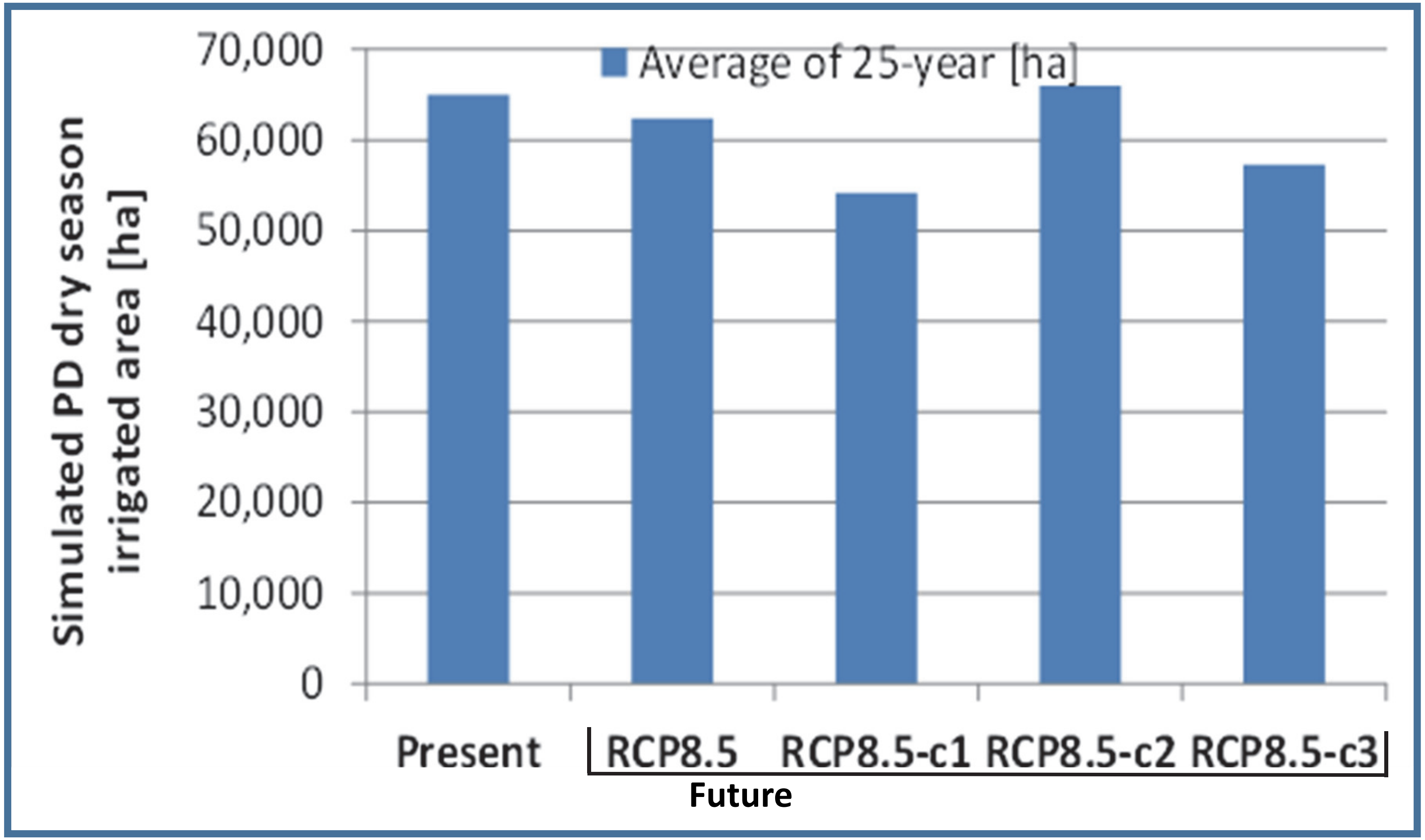
4. Research Result

4.3 Drought risk assessment under climate change

SOUSEI Program for Risk Information on Climate Change 気候変動リスク情報創生プログラム

Expected yearly-average rice crop yield in dry season



5. Summary

[Flood Risk]

- The results show that flood damage to rice-crops area can be increased in the future by 12 % in the case of 50-year flood and 16 % in the case of 100-year flood.
- The results of flood damage assessment can be used to implement flood mitigation actions as well as to formulate the policies for flood disaster risk reduction.
- The presented method of flood damage assessment can be applied in other river basins of developing countries.

[Drought Risk]

- The period of rainy season may be longer.
- Heavy inflow can occur in the middle of (current) dry season.
- Average of maximum yearly inflow may be decreased for c1 and c3 case, but may be increased for c2 case.
- Mean of normal flow (185^{th}-day inflow), low flow (275^{th}-day inflow) and drought flow (355^{th}-day inflow) is not be changed so much.

6. Issues to be solved

- Data/information on past flood damage/hazard and socio-economical information are essential for risk assessment. It is thus essential to establish mechanism to collect and accumulate damage/hazard data.
- In further study, assessment of flood damage to other crops is also necessary.