“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 and Drought Risk Assessment under Climate Change in Asia

-Overview of Output in Indonesia by SOUSEI Program-

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

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

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CMIP5 (Coupled Model Intercomparison Project Phase 5)

CMIP5 Coupled Model Intercomparison Project
WCRP World Climate Research Programme

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)**

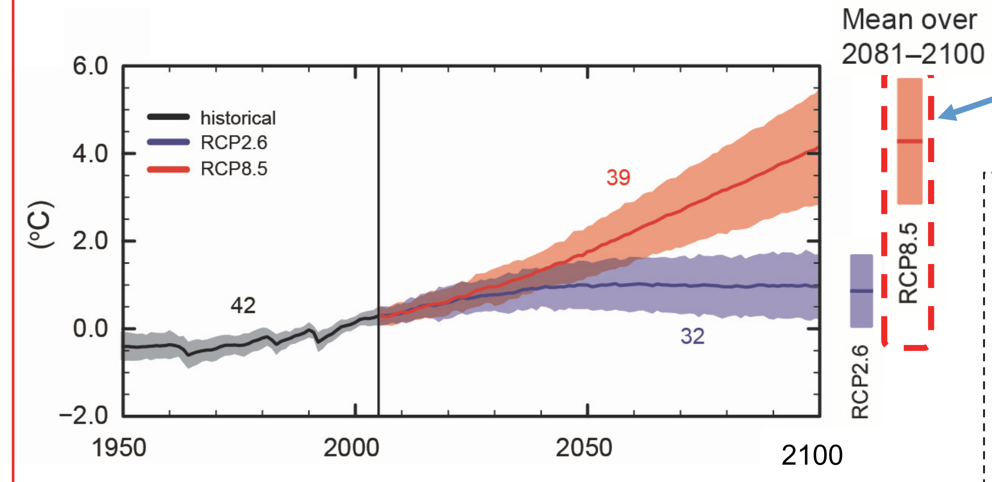


Fig. Global average surface temperature change (in AR5)

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)

Objectives

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

Outline

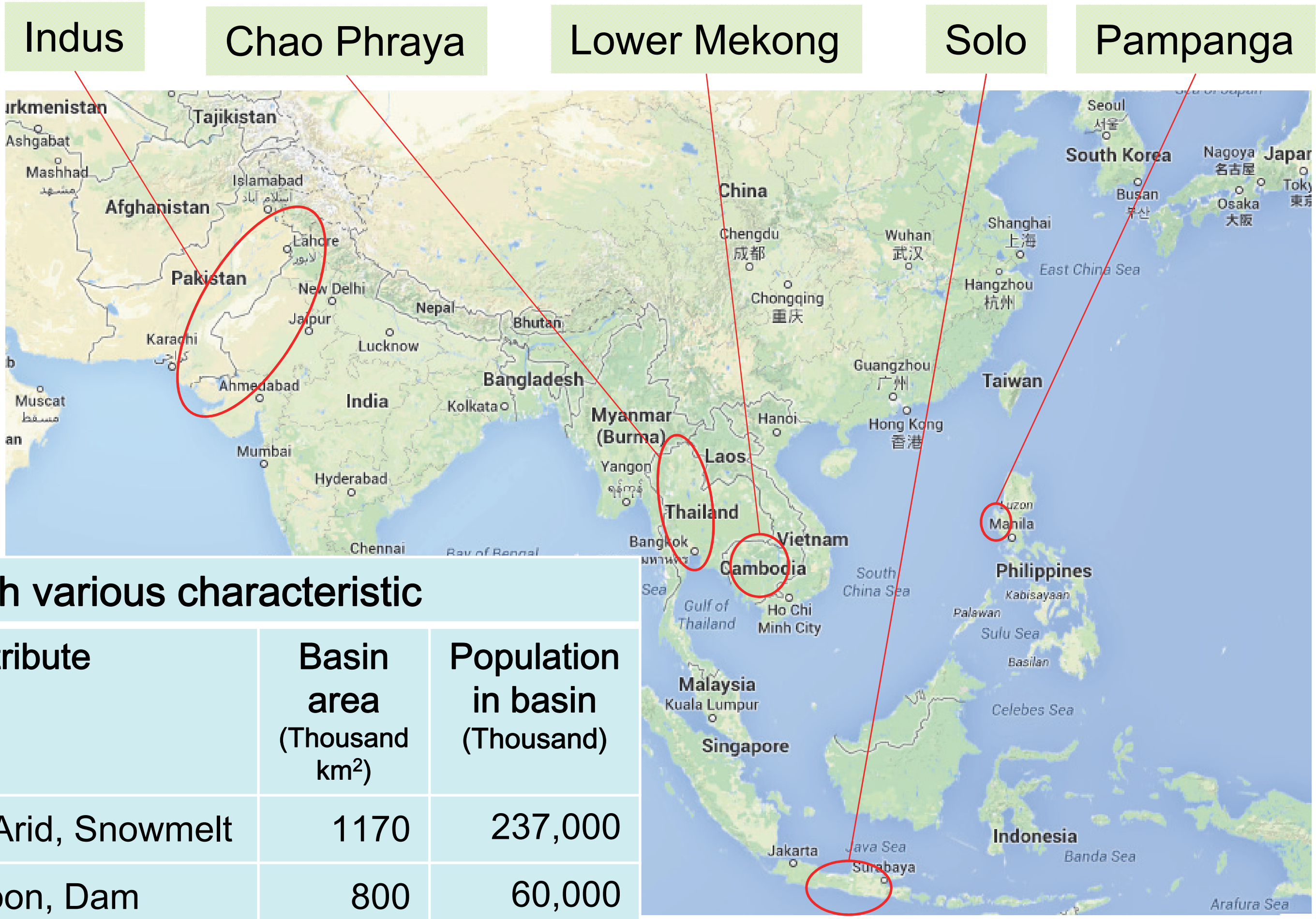
- The program is a five-year (2012-2016) research program funded by MEXT (Ministry of Education, Culture, Sports, Science and Technology, Japan).
- Co-workers are Kyoto Univ., Yamanashi Univ., etc., and the research collaborators in relative governments.

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

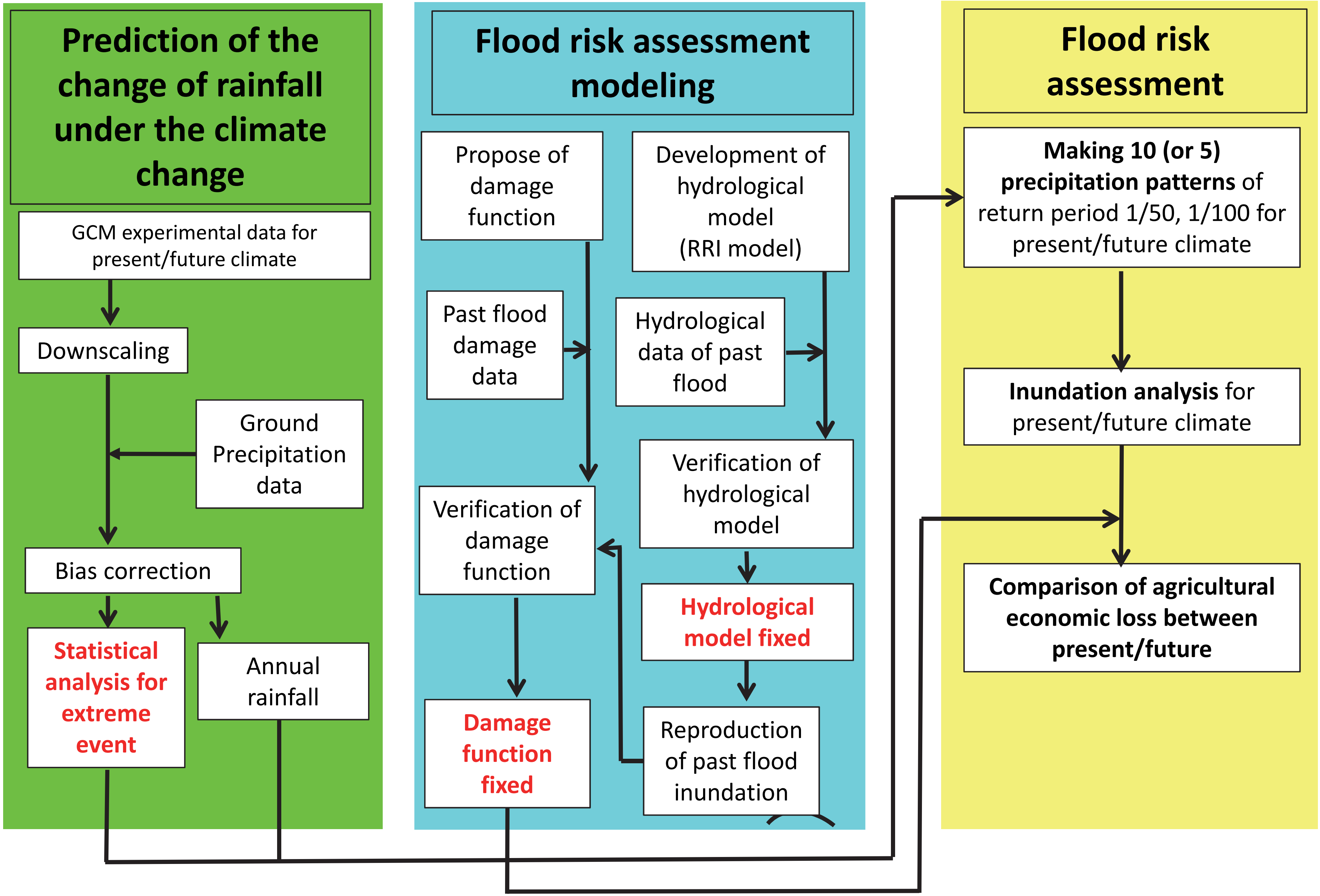
2. Outline of SOUSEI Program (2/2)

Target River Basins (5 basins)



River basins with various characteristic			
River	**Attribute**	**Basin area (Thousand km^2)**	**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)



Prediction of the change of rainfall under the climate change

GCM experimental data for present/future climate

Downscaling

Ground Precipitation data

Bias correction

Statistical analysis for extreme event

Annual rainfall

Flood risk assessment modeling

Propose of damage function

Development of hydrological model (RRI model)

Past flood damage data

Hydrological data of past flood

Verification of hydrological model

Verification of damage function

Hydrological model fixed

Damage function fixed

Reproduction of past flood inundation

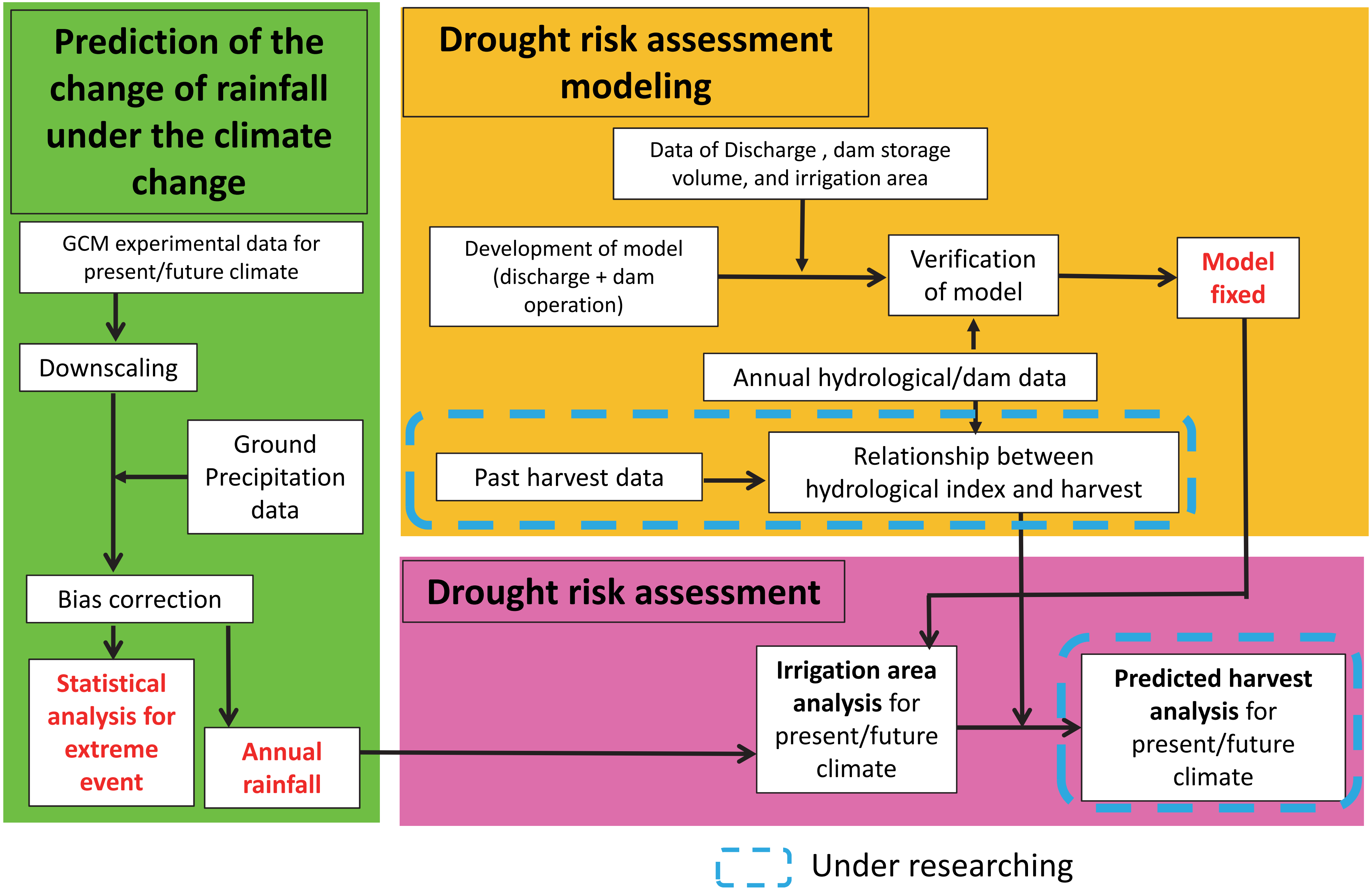
Flood risk assessment

Making 10 (or 5) precipitation patterns of return period 1/50, 1/100 for present/future climate

Inundation analysis for present/future climate

Comparison of agricultural economic loss between present/future

3. Research Methodology (2/2)



Prediction of the change of rainfall under the climate change

GCM experimental data for present/future climate

Downscaling

Ground Precipitation data

Bias correction

Statistical analysis for extreme event

Annual rainfall

Drought risk assessment modeling

Data of Discharge , dam storage volume, and irrigation area

Development of model (discharge + dam operation)

Verification of model

Model fixed

Annual hydrological/dam data

Past harvest data

Relationship between hydrological index and harvest

Drought risk assessment

Irrigation area analysis for present/future climate

Predicted harvest analysis for present/future climate

Under researching

3. Research Methodology 3.1 Rainfall change assessment

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GCM experimental data for present/future climate

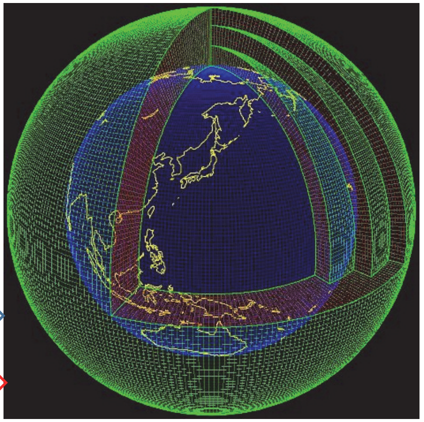
Input data:
CMIP5 dataset, etc.

Atmospheric General Circulation Model:
MRI-AGCM 3.2S

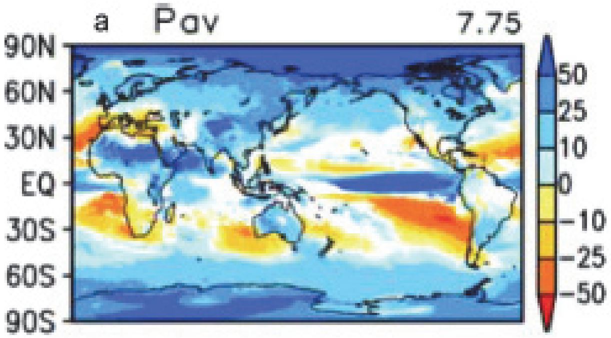
Output:
Precipitation change

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

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



Hydrological Effect of Global Warming



(Kitoh & Endo, 2016 WCE)

Merits of MRI-AGCM:

✓Horizontal resolution is higher (20km) than those of coupled GCMs (CGCMs) in CMIP5 (100+km)
→ **Better precipitation (topography, TCs, etc.)**

✓Uncertainty in CGCMs can be separated:
- ➢Uncertainty of model physics
- ➢**Uncertainty of SST distribution**

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.*

3. Research Methodology 3.1 Rainfall change assessment

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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

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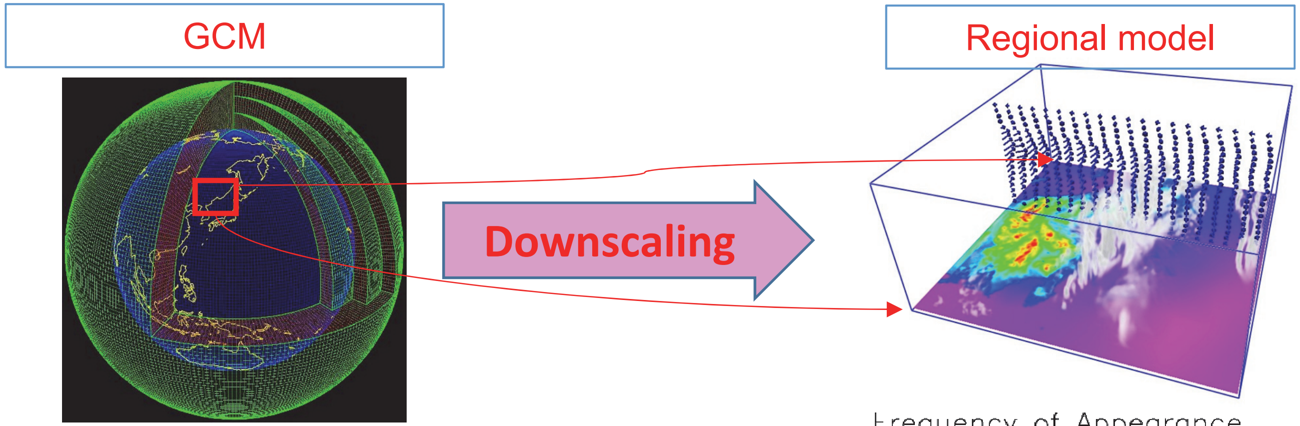
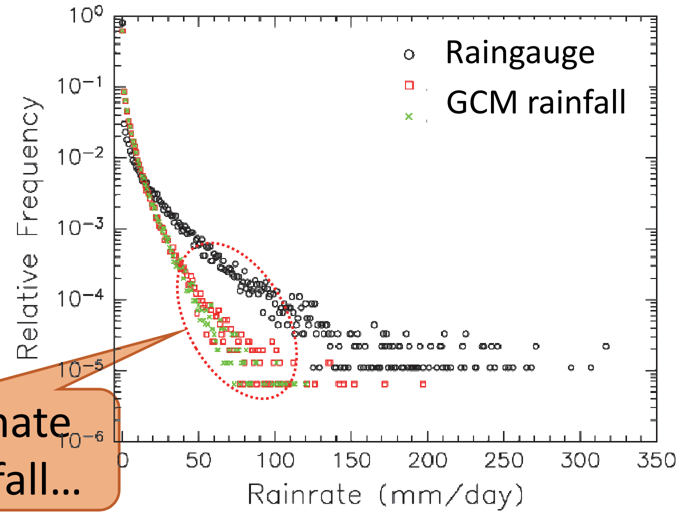
気候変動リスク情報創生プログラム

Dynamic downscaling

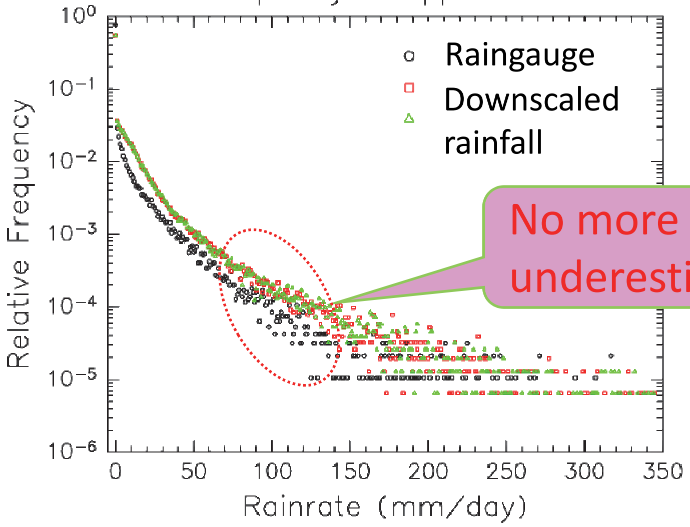
- General Circulation Model (GCM) is **too coarse** to compute precipitation processes in typically 20-30 km size clouds with the effect of complex terrains.
- Dynamic downscaling by a regional model reproduces **more accurate** rainfall via realistic representation with high resolution model in a limited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





Underestimate strong rainfall…

Frequency of Appearance



No more underestimation!

3. Research Methodology

3.1 Rainfall change assessment

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*

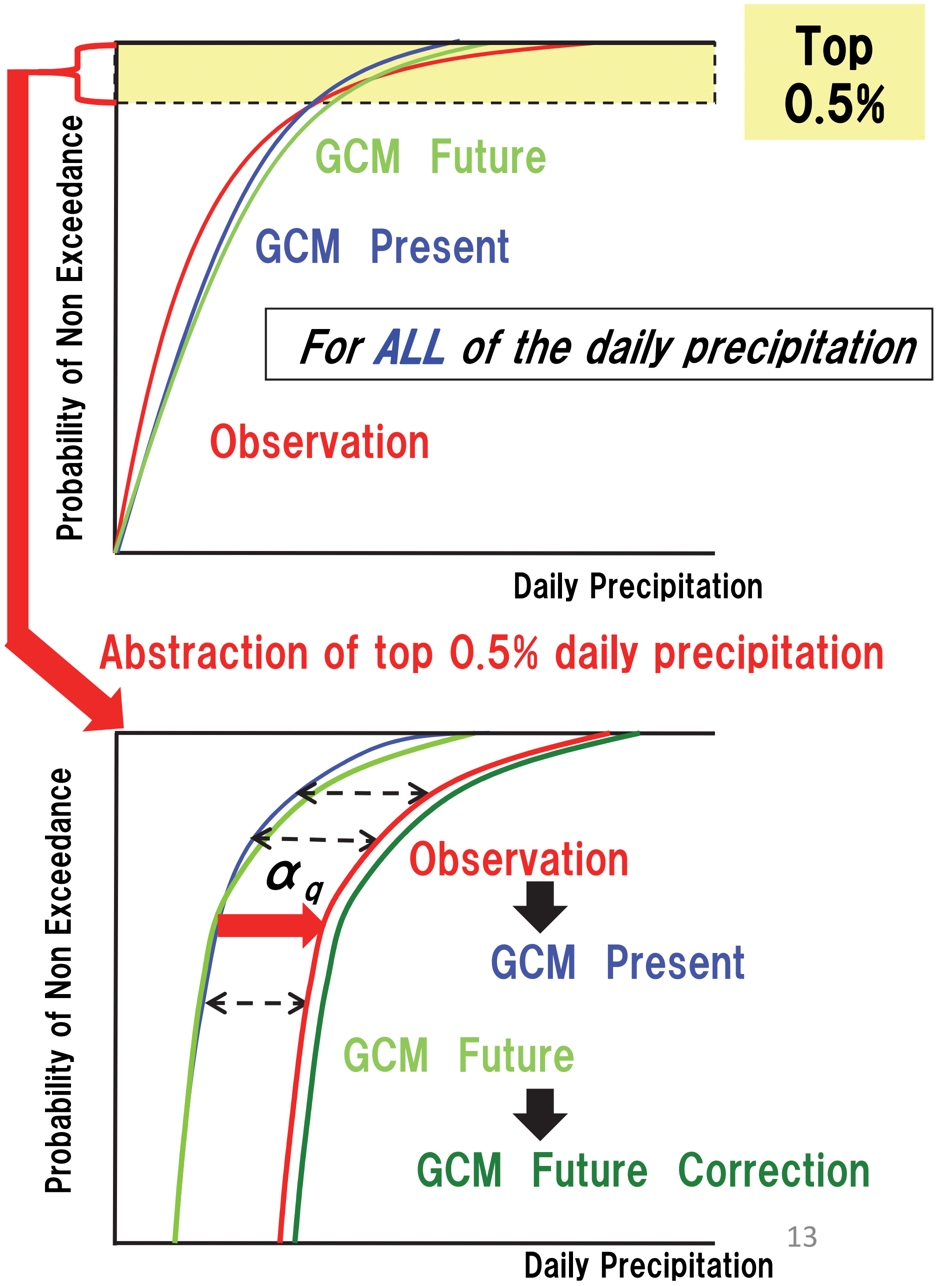
3. Research Methodology

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.

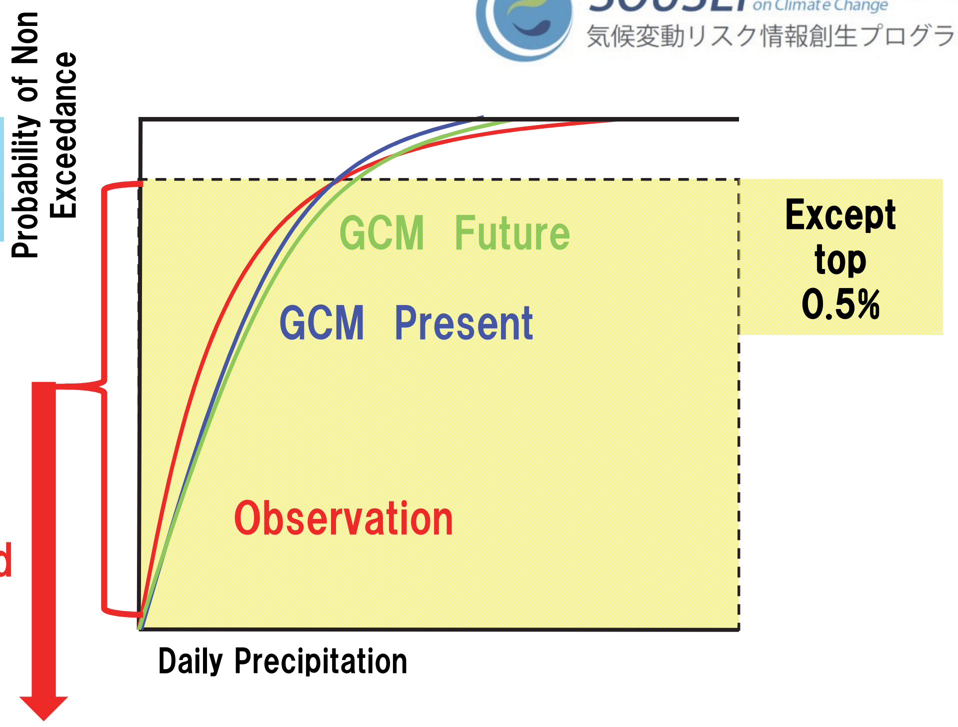


Reference:
Inomata, H., K. Takeuchi and K. Fukami (2011) Development of a statistical bias correction method for daily precipitation data of GCM20, J. of Japan Soc. of Civil Engineers, Ser. B1 (Hydraulic Engineering), 67, I_247-I_252, DOI:10.2208/jscejhe.67.I_247.

3. Research Methodology

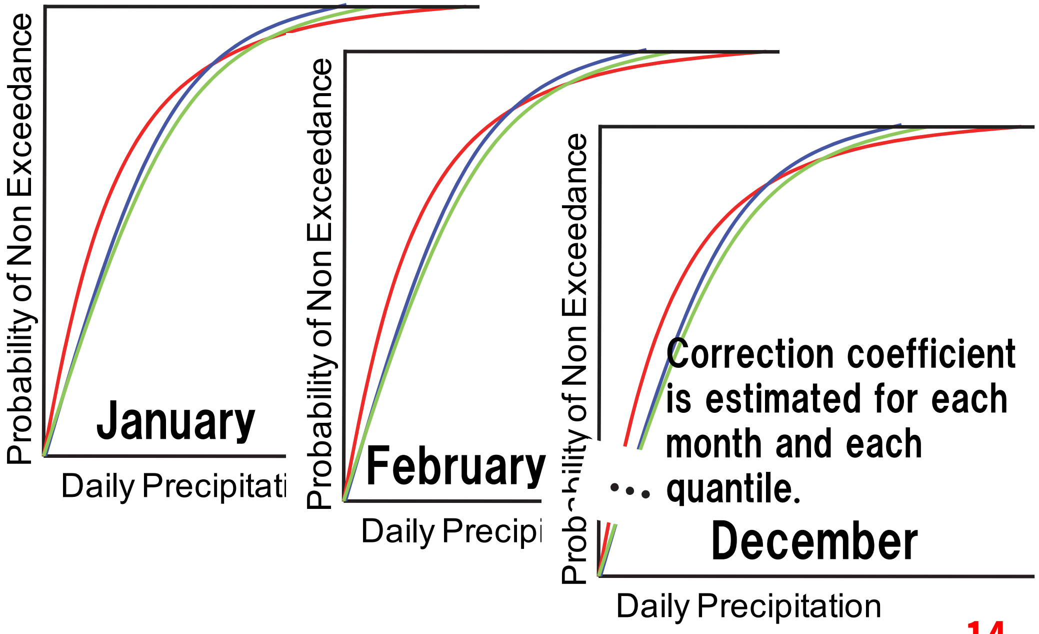
Concept of bias correction method for GCM -Hybrid Method- (2/2)

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



Samples except top 0.5% is 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.



Correction coefficient is estimated for each month and each quantile.

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.

4. Research Result

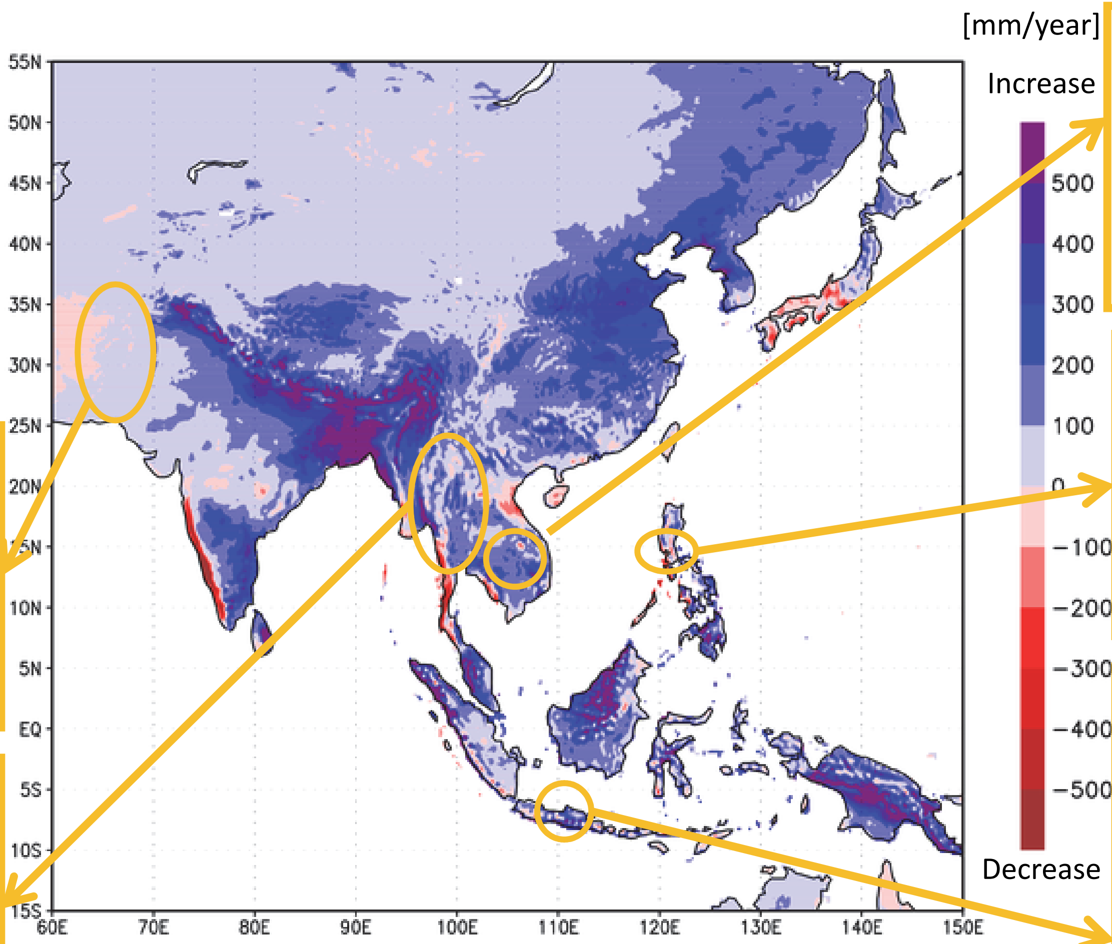
4.1 Rainfall change assessment for 5 river basins

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

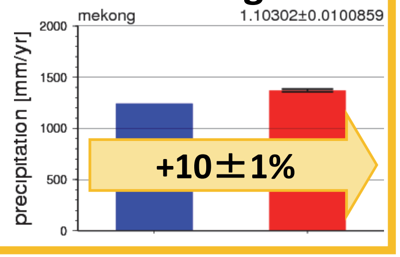
Difference in average yearly precipitation between present and future climate for 4 Sea Surface Temperature (SST) patterns (MME, C1, C2, and C3)

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

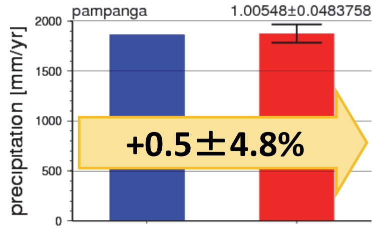
Average and standard deviation in 4 SSTs



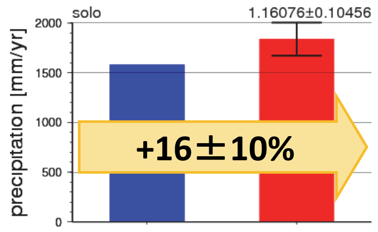
Mekong



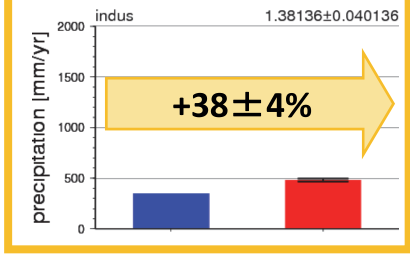
Pampanga



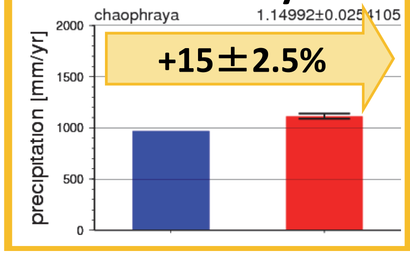
Solo



Indus



Chao Phraya



4. Research Result

4.1 Rainfall change assessment for 5 river basins

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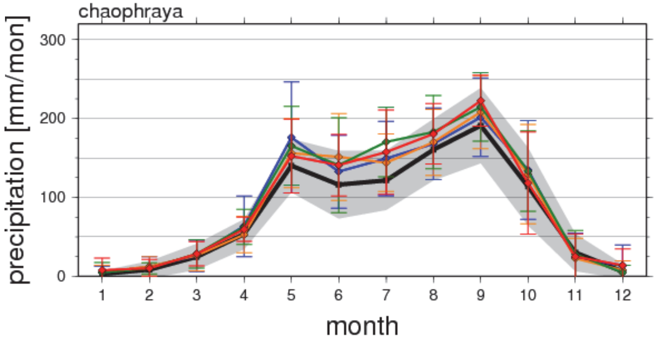
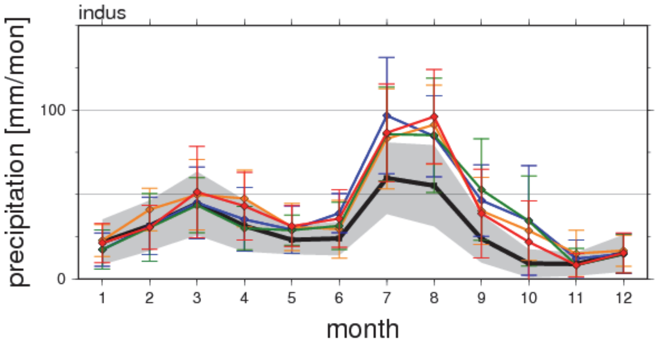
Analysis result –Comparison of 5 river basin- (2/2)

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

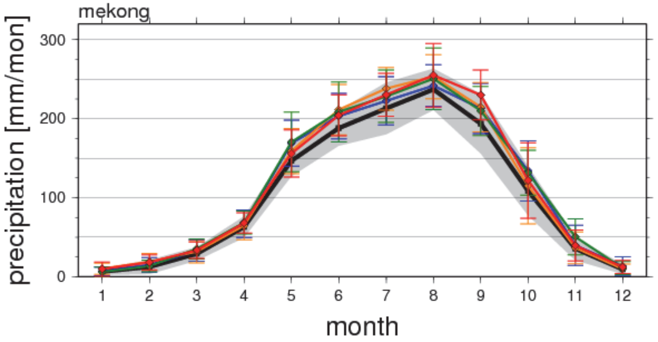
Chao Phraya



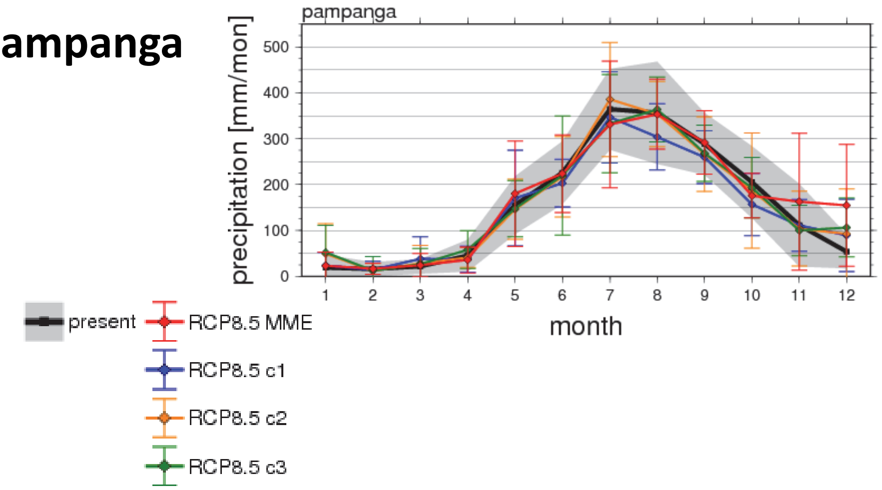
Indus



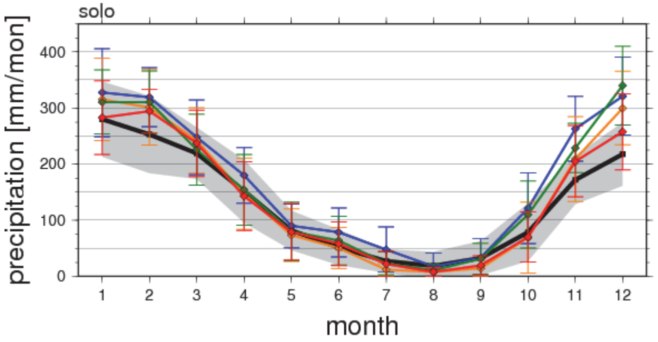
Mekong



Pampanga



Solo



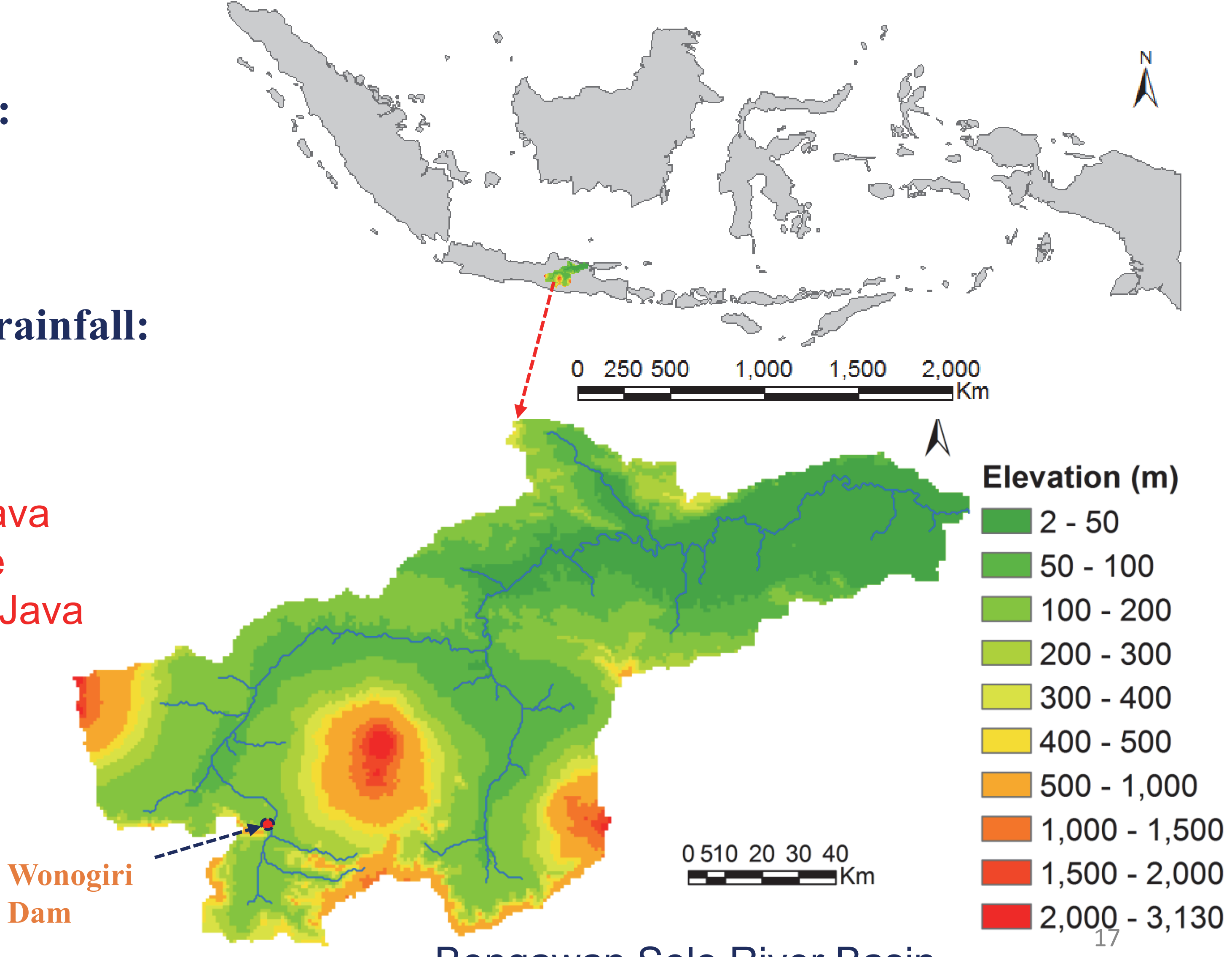
Reference: *Iwami et al, Comparative study on climate change impact on precipitation and flood in the Asian river basins (2016), HRL*

4. Research Result

Outline of the basin

Catchment Area:
16,100 km²
River Length:
600 km
Average annual rainfall:
2,100mm/year

Largest river in Java and located in the Central and East Java provinces


Indonesia

Bengawan Solo River Basin

PWRI

ICHARM

UNESCO
United Nations
Educational, Scientific and
Cultural Organization

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4.2 Flood hazard assessment in the Solo River basin under climate change

Target Basin

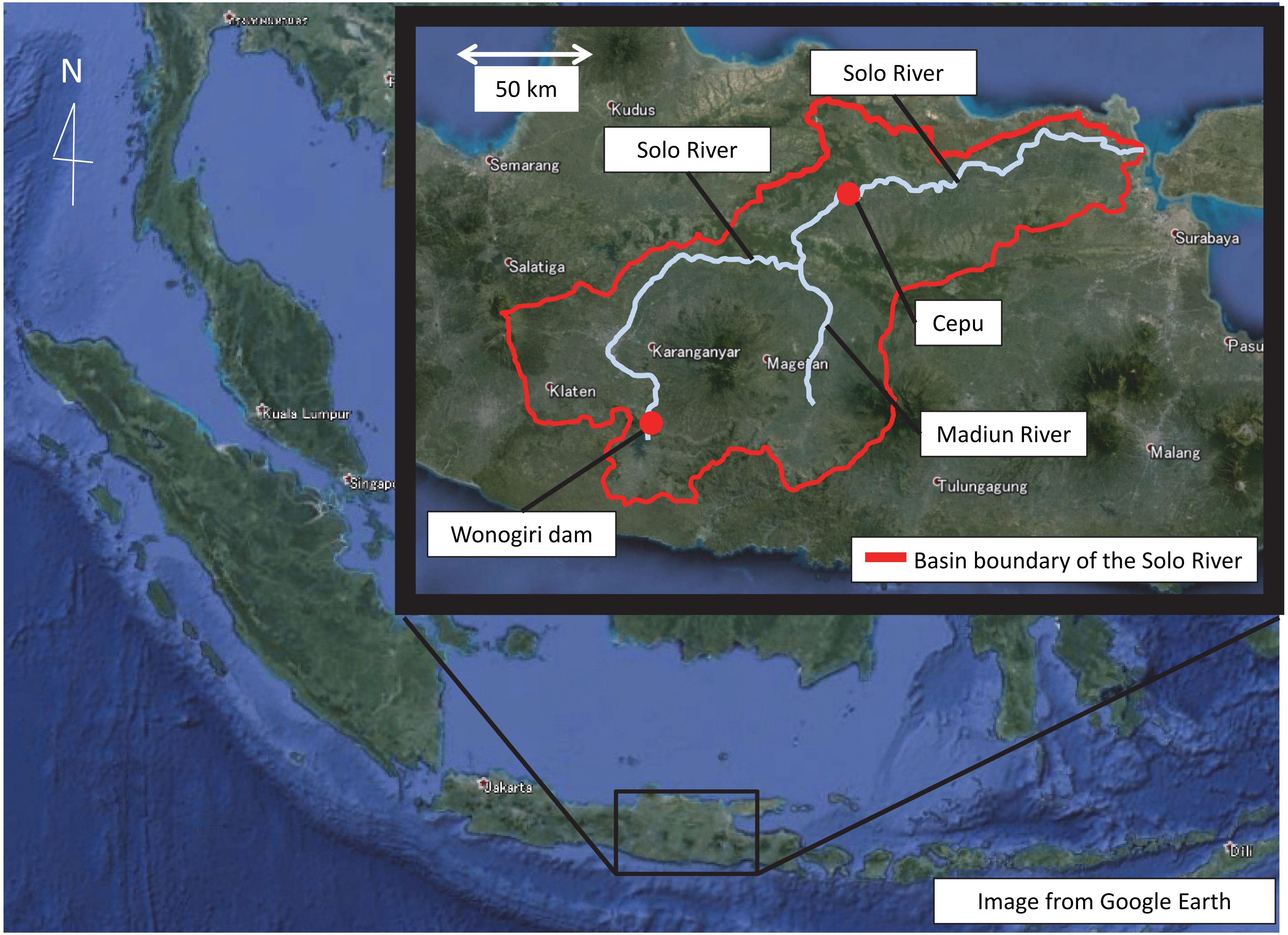


Image from Google Earth

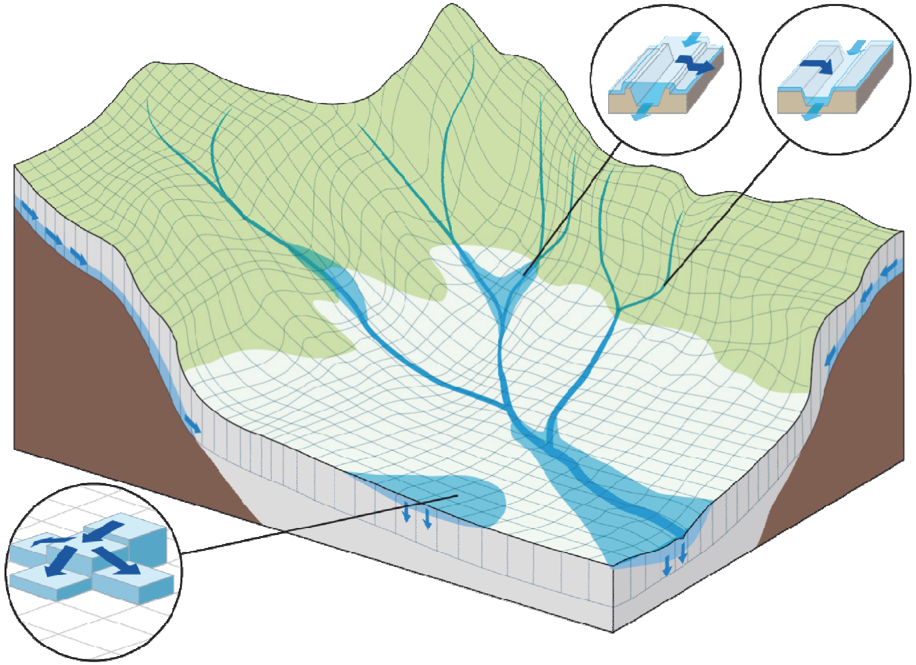
Objective of this research

To analyze effects of climate change in flood discharge and inundation in the basin.

Contents

1. Calibration of a model then simulate runoff inundation process.
2. Analysis of the flood risk change in terms of discharge and inundation in the future climate

Rainfall-Runoff-Inundation (RRI) model



Governing equation

$$\frac{\partial h}{\partial t}+\frac{\partial q_x}{\partial x}+\frac{\partial q_y}{\partial y}=r-f$$

$$\frac{\partial q_x}{\partial t}+\frac{\partial uq_x}{\partial x}+\frac{\partial vq_x}{\partial y}=-gh\frac{\partial H}{\partial x}-\frac{\tau_x}{\rho_w}$$

$$\frac{\partial q_y}{\partial t}+\frac{\partial uq_y}{\partial x}+\frac{\partial vq_y}{\partial y}=-gh\frac{\partial H}{\partial y}-\frac{\tau_y}{\rho_w}$$

Infiltration (Green-Ampt model)）

$$f=k_v\left[1+\frac{(\phi-\theta_i)S_f}{F}\right]$$

h : water deoth H: Water level

q_x, q_y : unit width discharge

τ_x, τ_y : Shear stress

F : Accumulated infiltration amount

Parameter used in the calculation

n(m$^{-1/3}$s)	0.4
n_{river}(m$^{-1/3}$s)	0.035
d(m)	0.5
k_v(m/s)	1.89E-6
Φ	0.501
S_f(m)	0.1668

n(m$^{-1/3}$s) : equivalent roughness coefficient on slope
n_{river}(m$^{-1/3}$s) : roughness coefficient within river channel
d(m) : Soil depth
k_v(m/s) : vertical satulated hydraulic conductivity
ϕ : soil porosity
S_f(m):suction at the vertical wetting front

Width of river channel

$$W = C_W A^{S_W}$$

Depth of river channel

$$D = C_D A^{S_D}$$

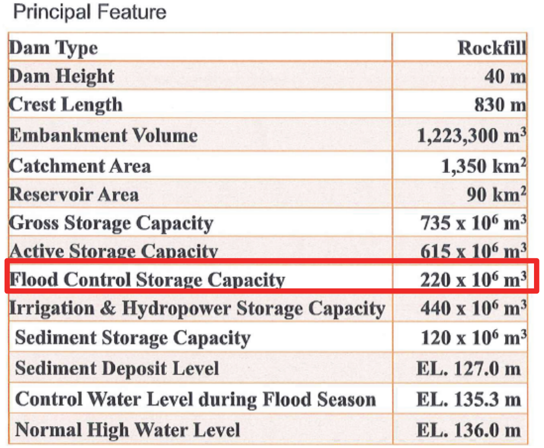
A : upstream contributing area (km2)
CW=5.0, SW=0.4, CD=0.95, SD=0.2

Wonogiri dam operation in the calculation

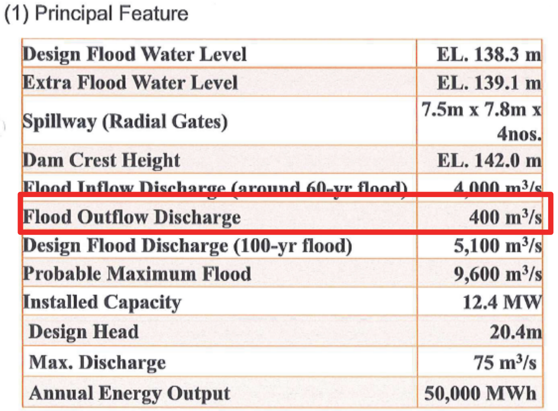

KEMENTERIAN PEKERJAAN UMUM
DIREKTORAT JENDERAL SUMBER DAYA AIR
BALAI BESAR WILAYAH SUNGAI BENGAWAN SOLO

Countermeasure for Sediment in Wonogiri Multipurpose Dam Reservoir

September 8, 2013


Principal Feature

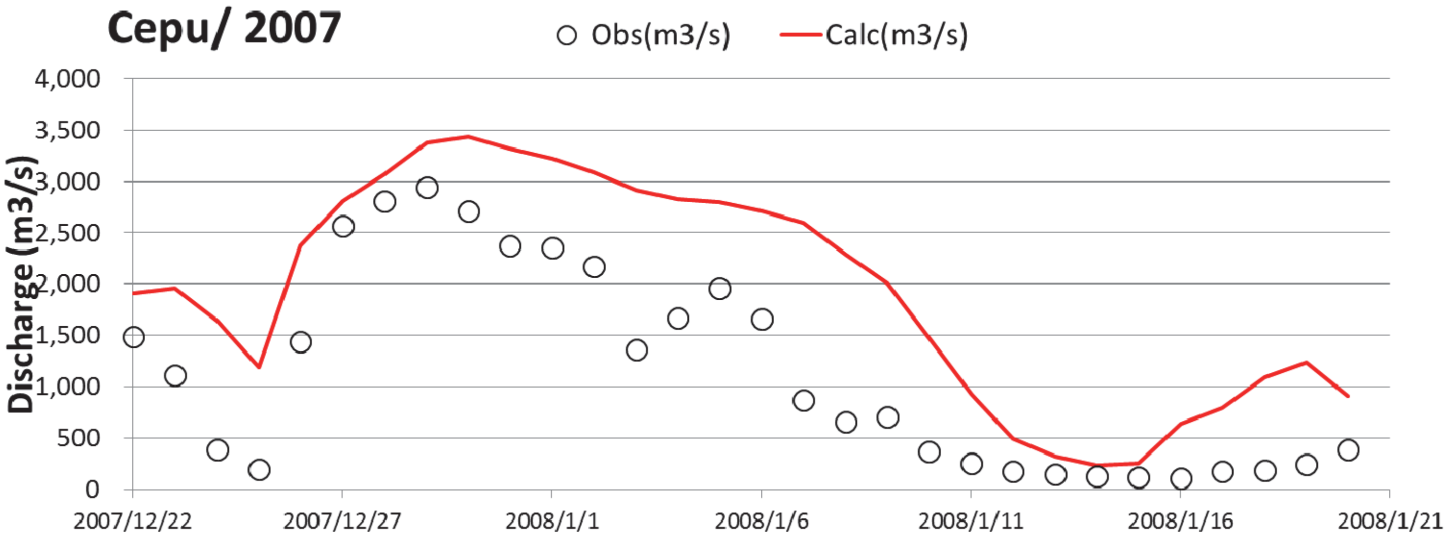
Dam Type	Rockfill
Dam Height	40 m
Crest Length	830 m
Embankment Volume	1,223,300 m^3
Catchment Area	1,350 km^2
Reservoir Area	90 km^2
Gross Storage Capacity	735 x 10^6 m^3
Active Storage Capacity	615 x 10^6 m^3
Flood Control Storage Capacity	220 x 10^6 m^3
Irrigation & Hydropower Storage Capacity	440 x 10^6 m^3
Sediment Storage Capacity	120 x 10^6 m^3
Sediment Deposit Level	EL. 127.0 m
Control Water Level during Flood Season	EL. 135.3 m
Normal High Water Level	EL. 136.0 m


(1) Principal Feature

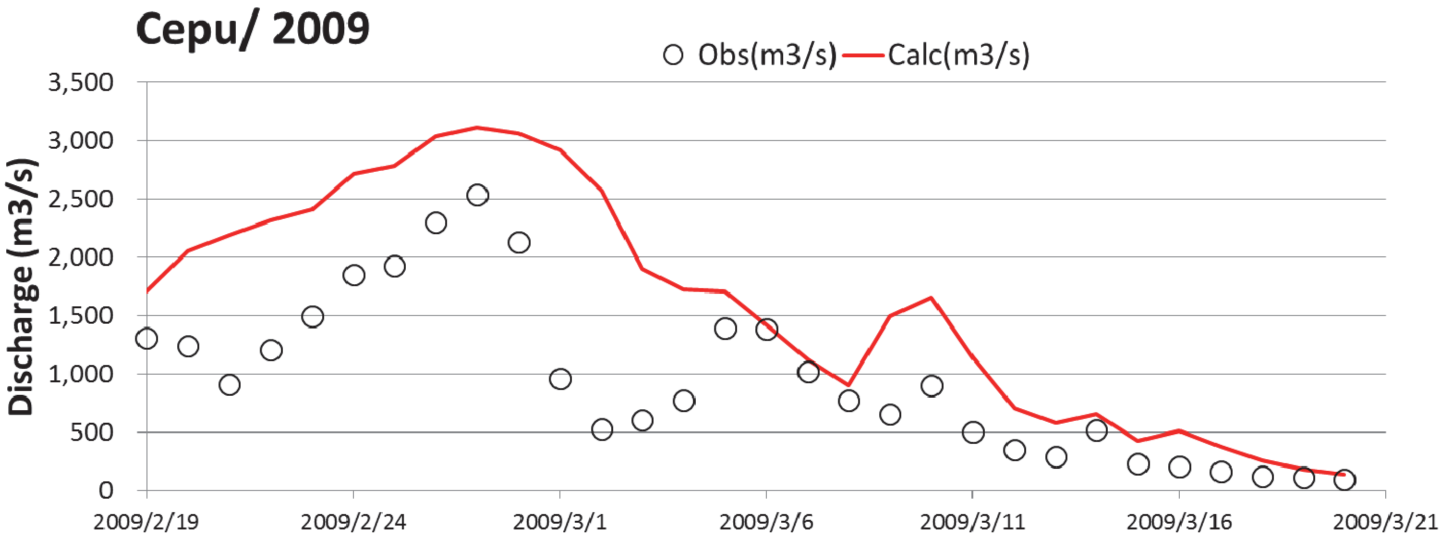
Design Flood Water Level	EL. 138.3 m
Extra Flood Water Level	EL. 139.1 m
Spillway (Radial Gates)	7.5m x 7.8m x 4nos.
Dam Crest Height	EL. 142.0 m
Flood Inflow Discharge (around 60-yr flood)	4,000 m^3/s
Flood Outflow Discharge	400 m^3/s
Design Flood Discharge (100-yr flood)	5,100 m^3/s
Probable Maximum Flood	9,600 m^3/s
Installed Capacity	12.4 MW
Design Head	20.4m
Max. Discharge	75 m^3/s
Annual Energy Output	50,000 MWh

Outflow discharge is controlled to be 400 m3/s when the inflow into the dam exceeds 400 m3/s.
In addition, the flood control storage capacity is set as 220 million m3. When the storage volume of the dam exceeds the capacity, outflow of the dam is to be same as inflow.

Validation of the model with the floods in 2007 and 2009



Cepu/ 2007



Cepu/ 2009

Relationship between peak discharge and precipitation

year	Annual peak discharge (m3/s)	Accumulated precipitation amount (mm)							
		1 day	2 day	3 day	**4 day**	5 day	6 day	7 day	8 day
2003	1649.30	23	39	49	57	73	86	95	105
2004	1522.29	20	47	75	90	99	105	125	131
2005	2297.45	9	36	48	61	75	85	90	101
2006	2322.11	16	27	51	53	55	56	56	58
2007	2947.44	19	47	57	167	173	177	180	197
2008	2633.32	14	42	56	60	65	88	109	112
2009	2537.69	7	48	83	111	132	154	163	174
	Correlation	-0.463	0.093	-0.050	**0.503**	0.449	0.478	0.418	0.416

4 days precipitation has the strongest correlation with peak discharge.

Analysis of flood risk change in the future climate

- Daily precipitation from MRI-AGCM3.2S whose bias was corrected with APHRODITE (daily precipitation grid data with observation data) was used as present (1979-2003) and future (2075-2099) climate forcing data.
- RCP 8.5 scenario which corresponds to the pathway with the highest greenhouse gas emissions among the scenarios was selected for the future climate.

Analysis of flood risk change in the future climate

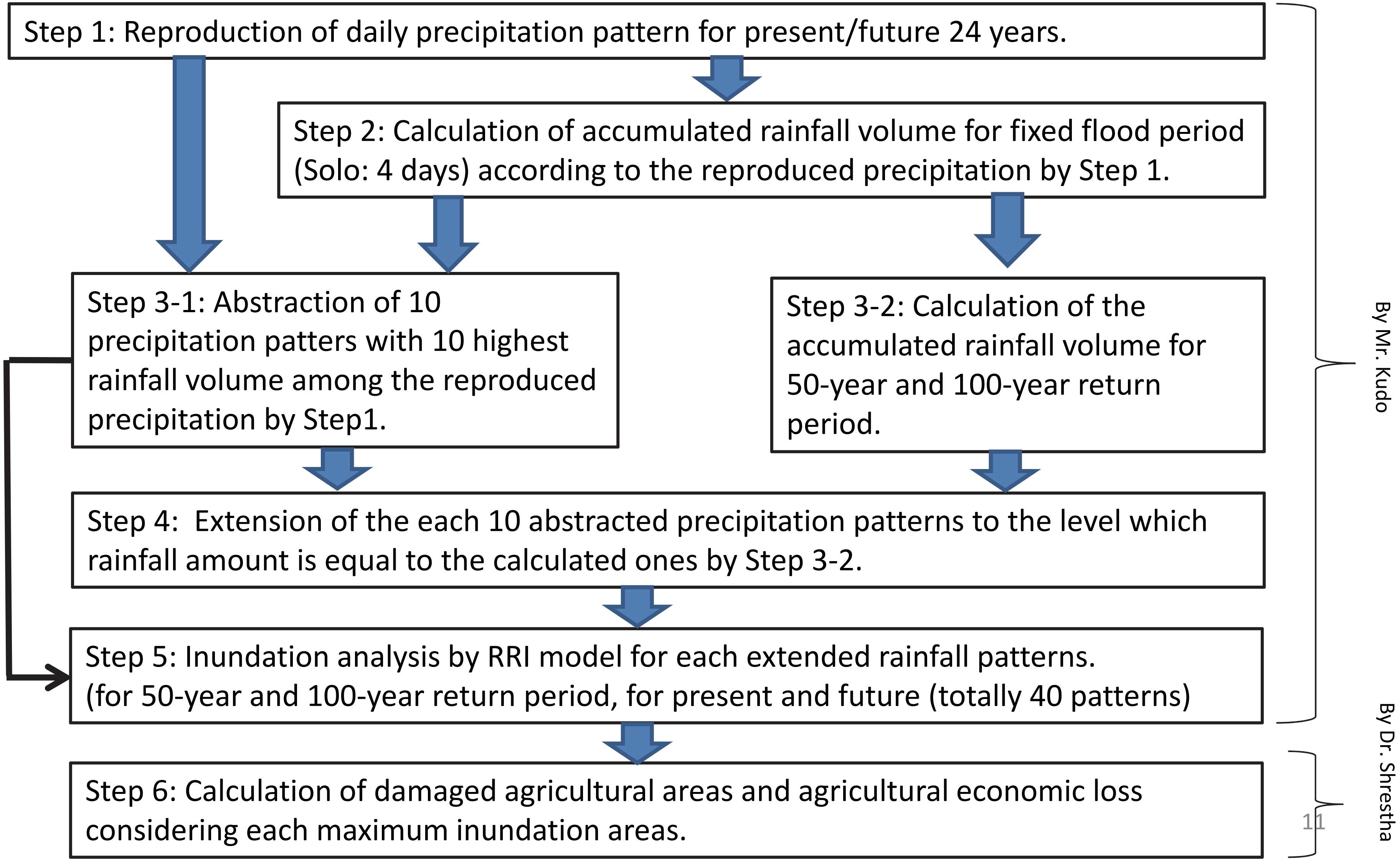
From July 1 to June 30 is selected as a hydrological year of the basin. This is to avoid the flood season is separated into two years. (The flood season of the Solo River Basin includes December and January.)

e.g. “1979” means the 365 days from July 1, 1979 to June 30, 1980.

Hence there are 24 years for each climate.

Analysis of flood risk change in the future climate

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



Step 1: Reproduction of daily precipitation pattern for present/future 24 years.

Step 2: Calculation of accumulated rainfall volume for fixed flood period (Solo: 4 days) according to the reproduced precipitation by Step 1.

Step 3-1: Abstraction of 10 precipitation patters with 10 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 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.

By Mr. Kudo

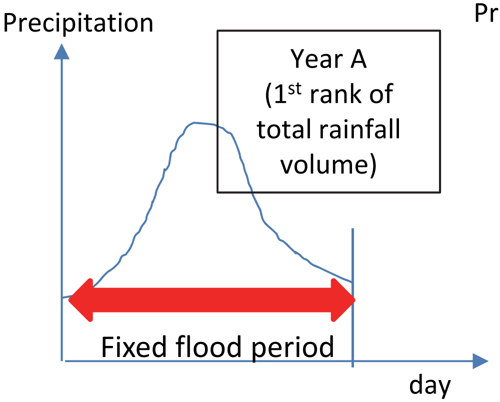
By Dr. Shrestha

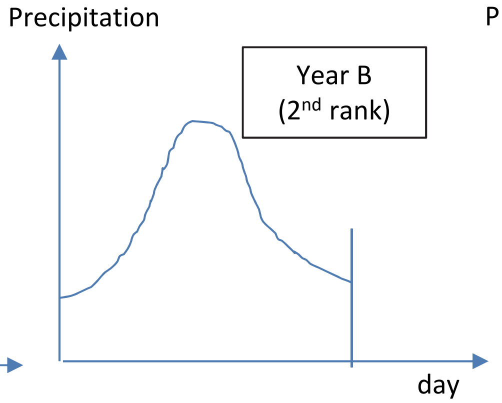
Analysis of flood risk change in the future climate

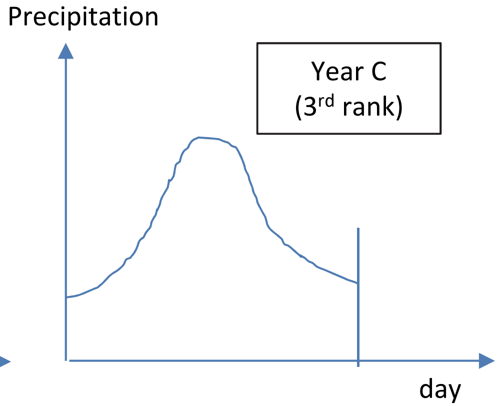
SOUSEI Program for Risk Information on Climate Change
気候変動リスク情報創生プログラム

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

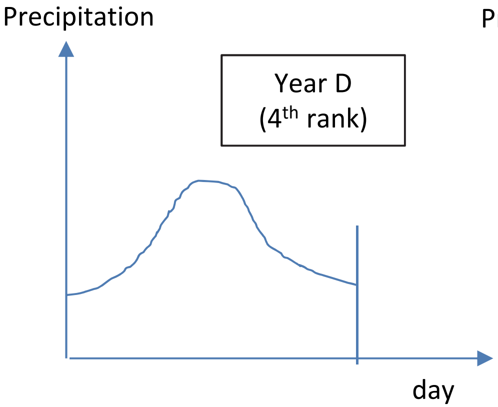
Step 3-1:
Abstraction of 10 precipitation patterns with 10 highest rainfall volume

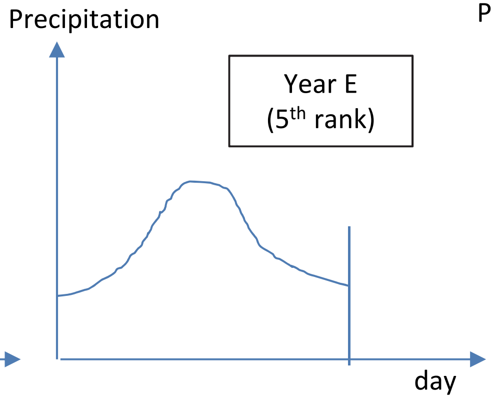


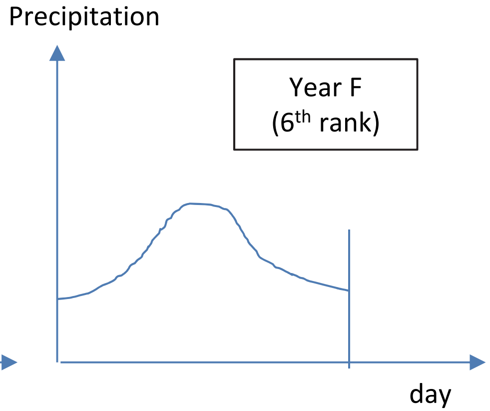


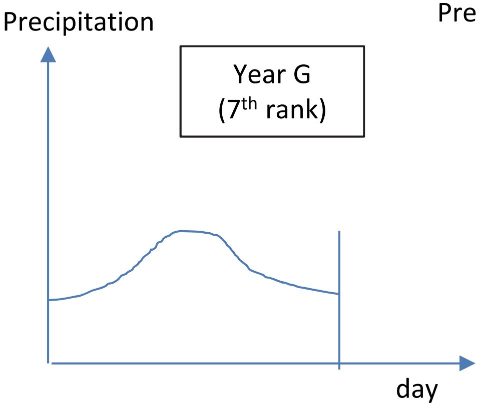


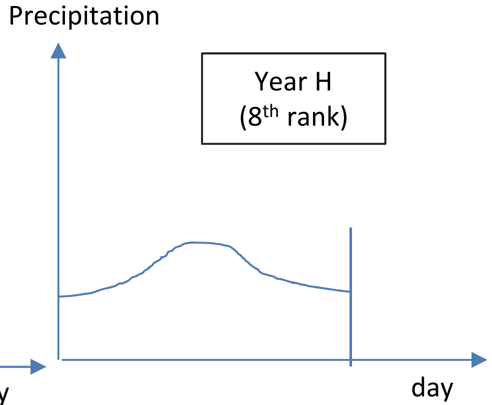
10 original precipitation patterns

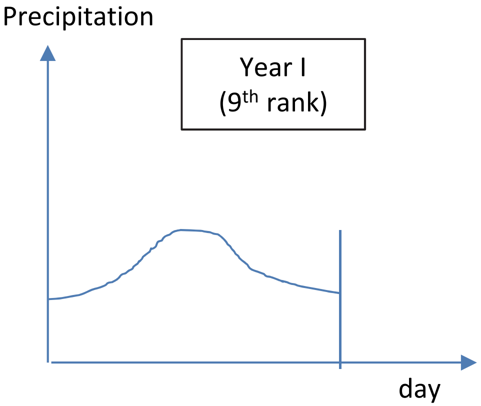


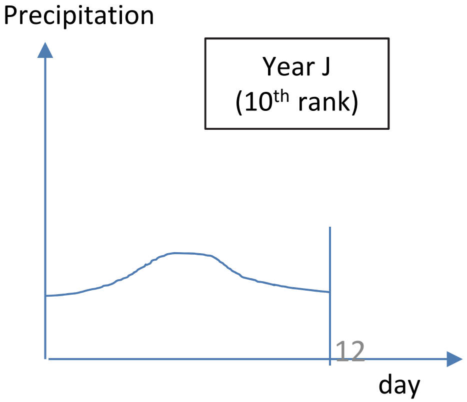










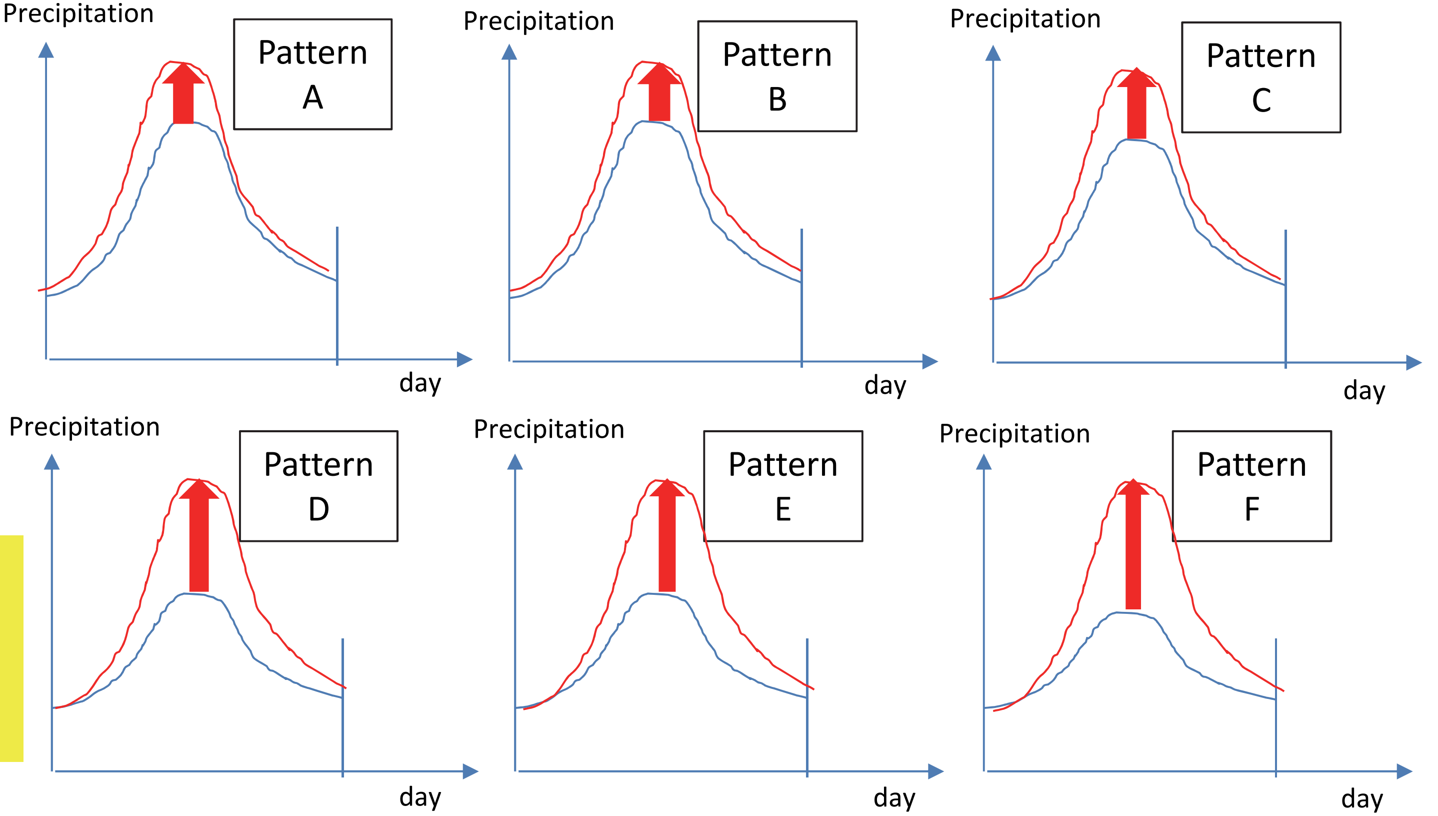


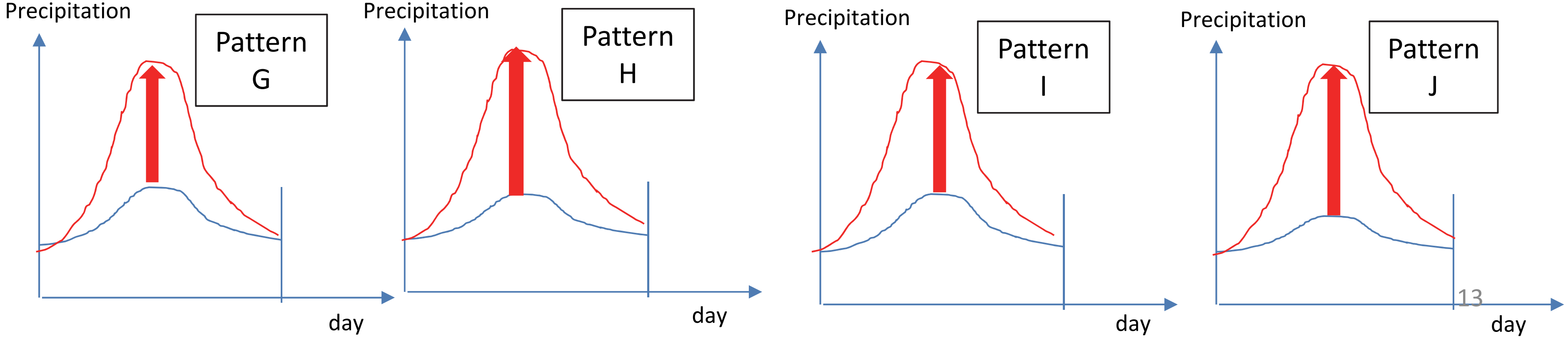
Analysis of flood risk change in the future climate

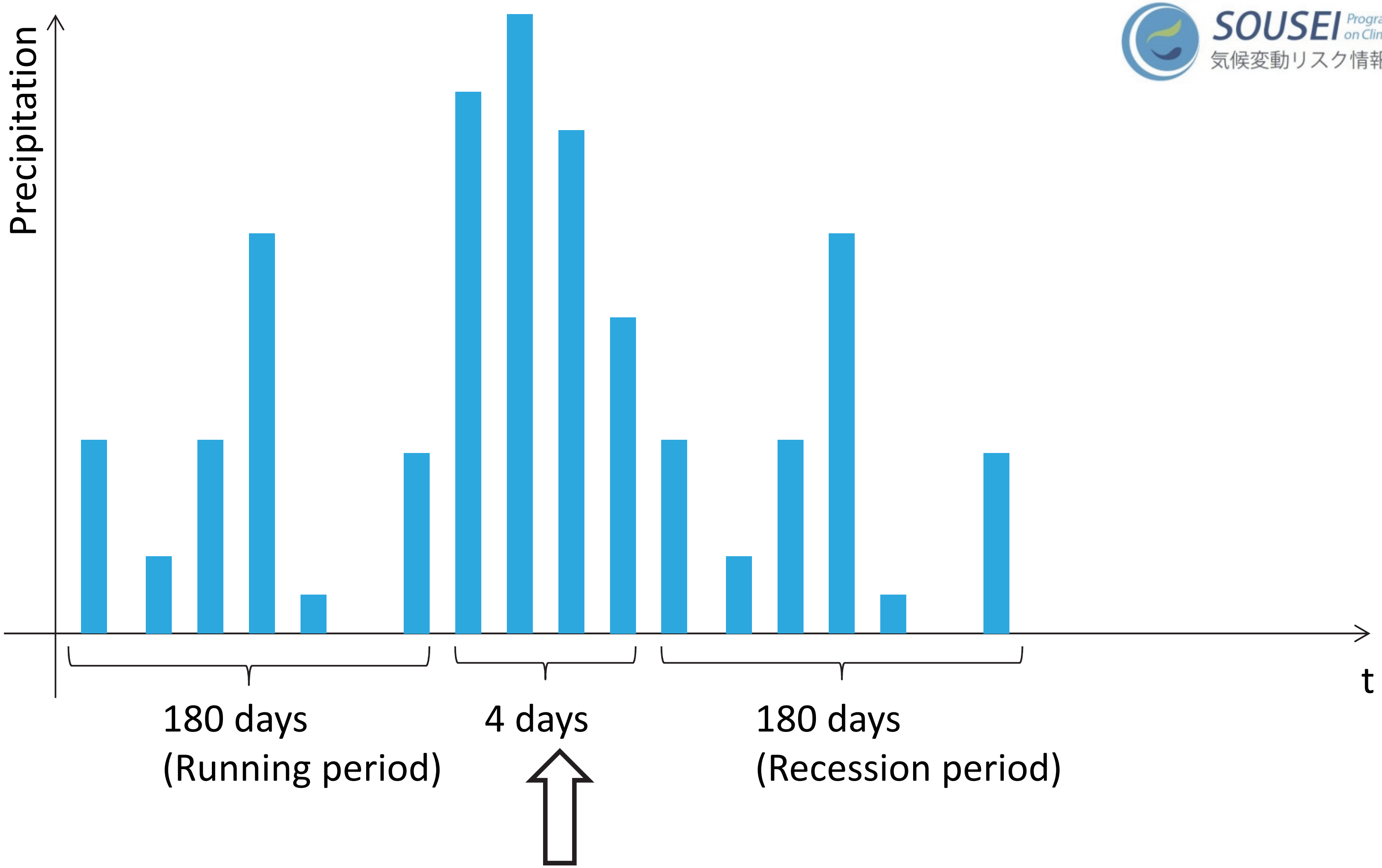
Methodology of flood risk assessment considering various precipitation patterns for present/ future climate

Step 4:
Extension of the each 10 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







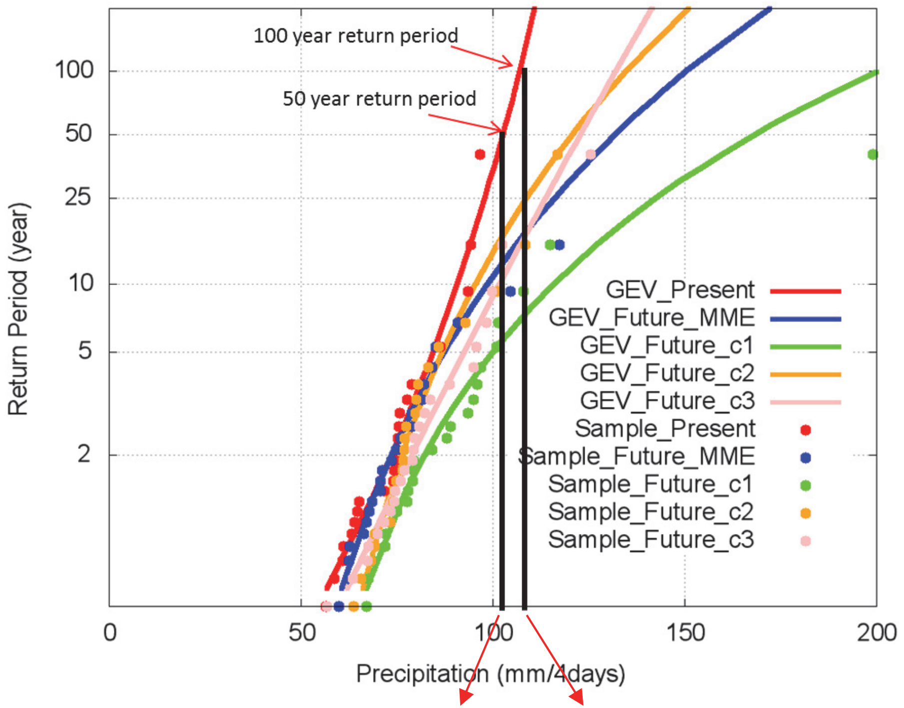
4 days precipitation of the return periods

364 days rainfall includes running period (180 days) and recession period(180 days) is created for each calculation.

Frequency analysis of annual maximum 4 days precipitation

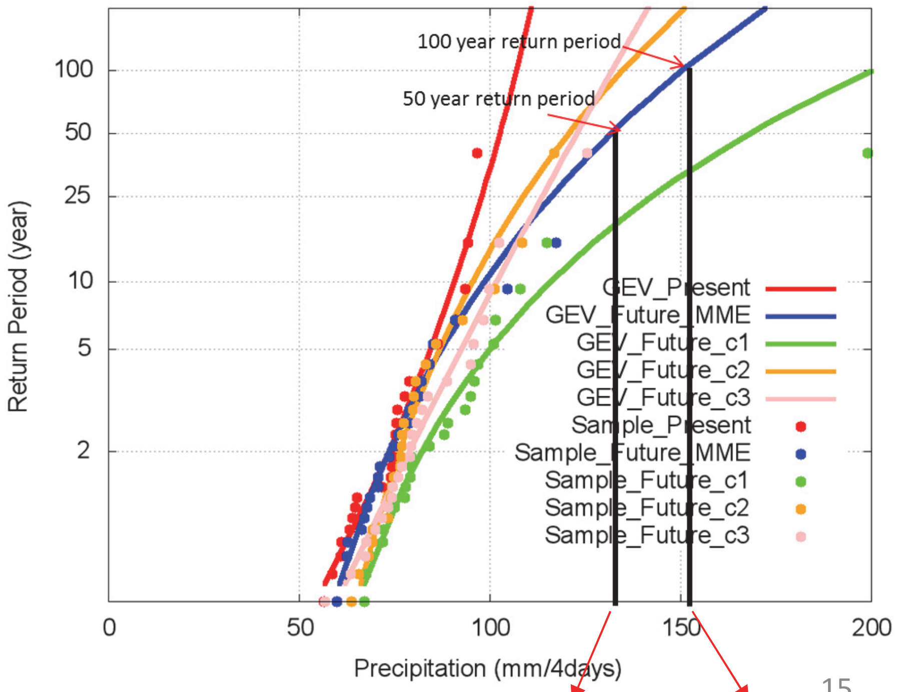
	Present	**Future (MME)**
1/50	103 mm	132 mm
1/100	107 mm	150 mm

Present Climate



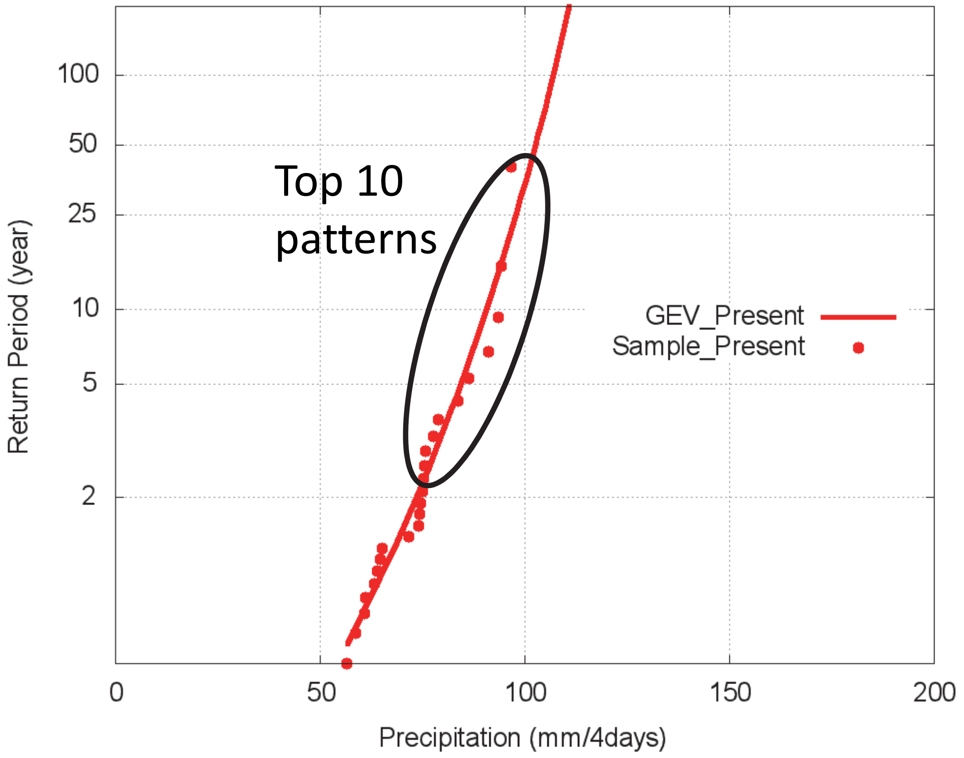
103 mm 107 mm

Future Climate (RCP8.5)



132 mm 150 mm

Extension of precipitation amount to create 100 year return period data.



100 year return period precipitation : 107 mm

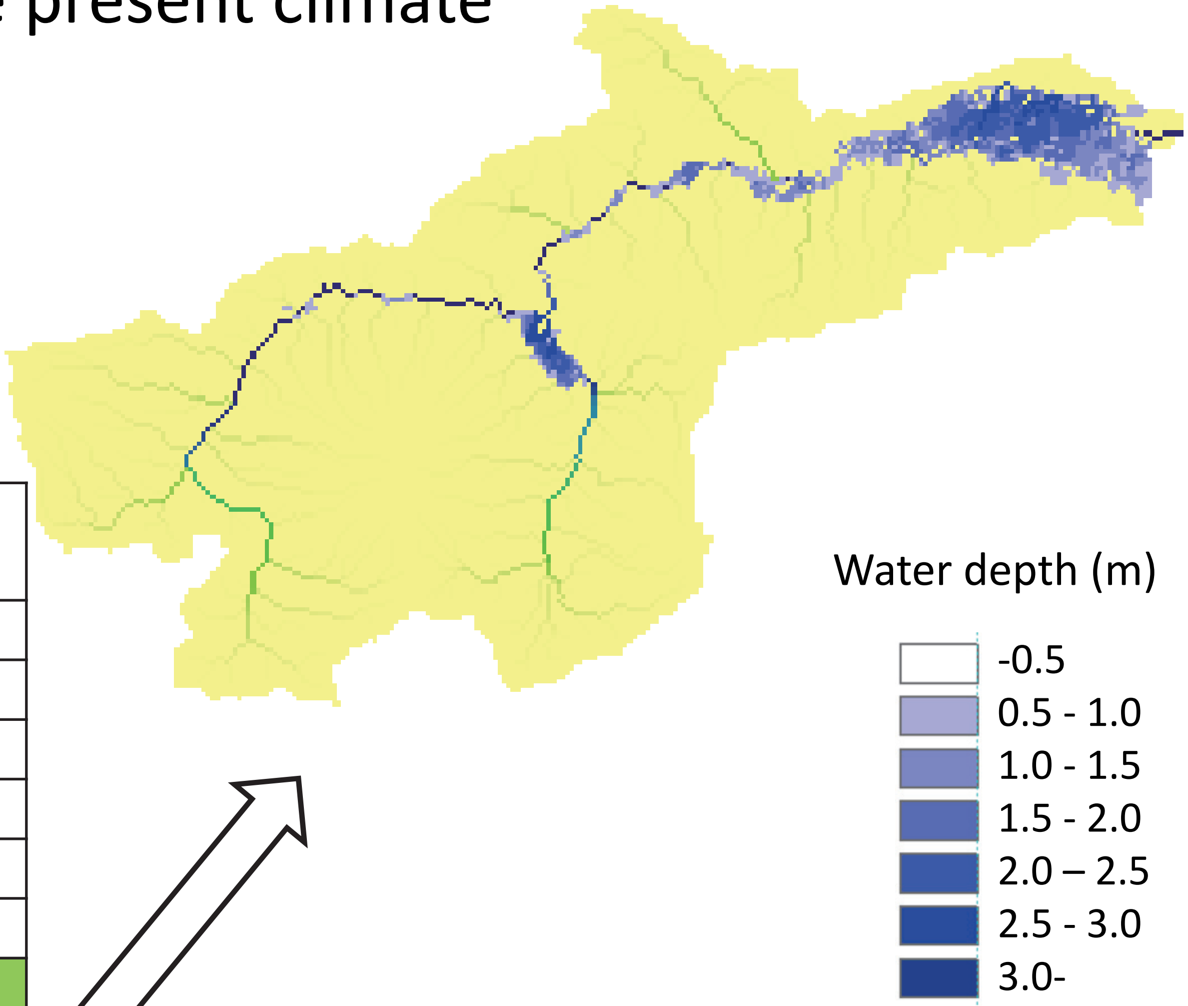
Top 10 patterns	Precipitation (mm / 4days)	Extension ratio
1	97	1.11
2	94	1.13
3	94	1.14
4	91	1.17
5	86	1.24
6	84	1.28
7	79	1.36
8	78	1.38
9	76	1.41
10	75	1.42

Analysis of flood risk change in the future climate

- Maximum inundation area and maximum discharge were compared for each precipitation pattern and each return period.

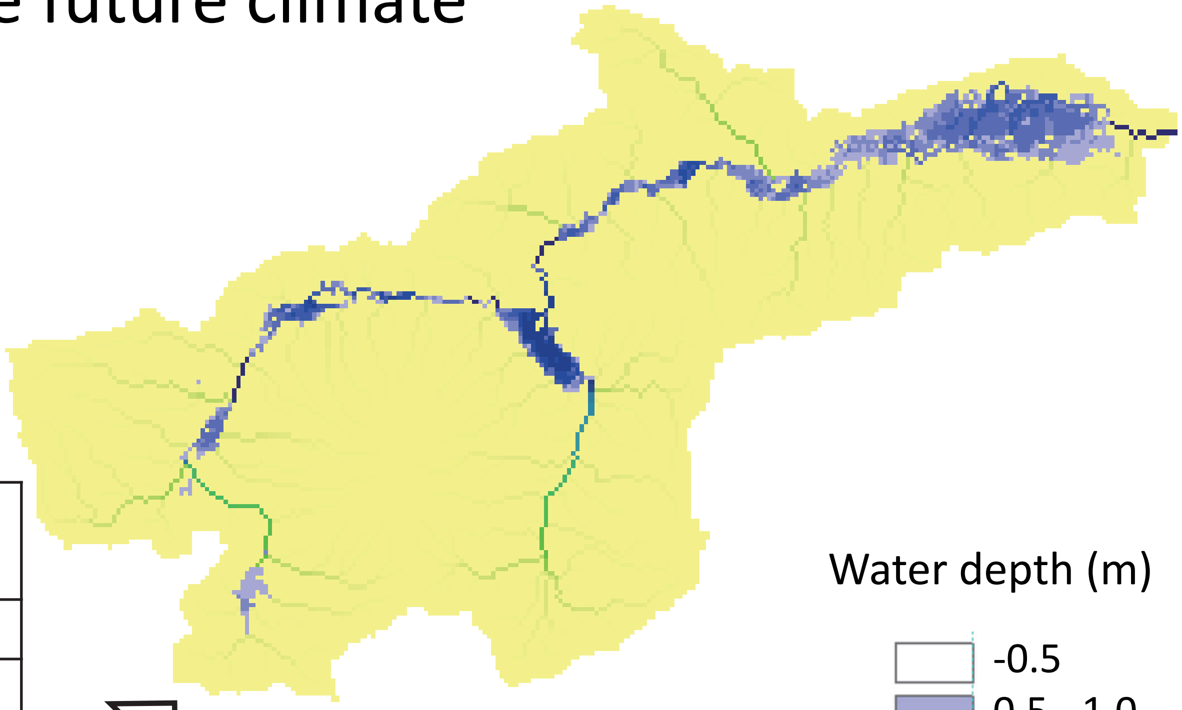
Maximum inundation area for 100 year return period in the present climate

Rainfall pattern	Maximum Inundation area (km2)
1	932
2	808
3	1,019
4	390
5	932
6	683
7	1,055
8	803
9	836
10	357
Average	782



Present / 100 year return period

Maximum inundation area for 100 year return period in the future climate



Rainfall pattern	Maximum Inundation area (km2)
1	1,049
2	855
3	926
4	1,024
5	1,119
6	733
7	1,009
8	1,053
9	959
10	793
Average	952

	Maximum	Average
Present	1,055 (km2)	782 (km2)
Future	1,119 (km2)	952 (km2)
Increased by	6 %	22 %

Future / 100 year return period

Target points for discharge

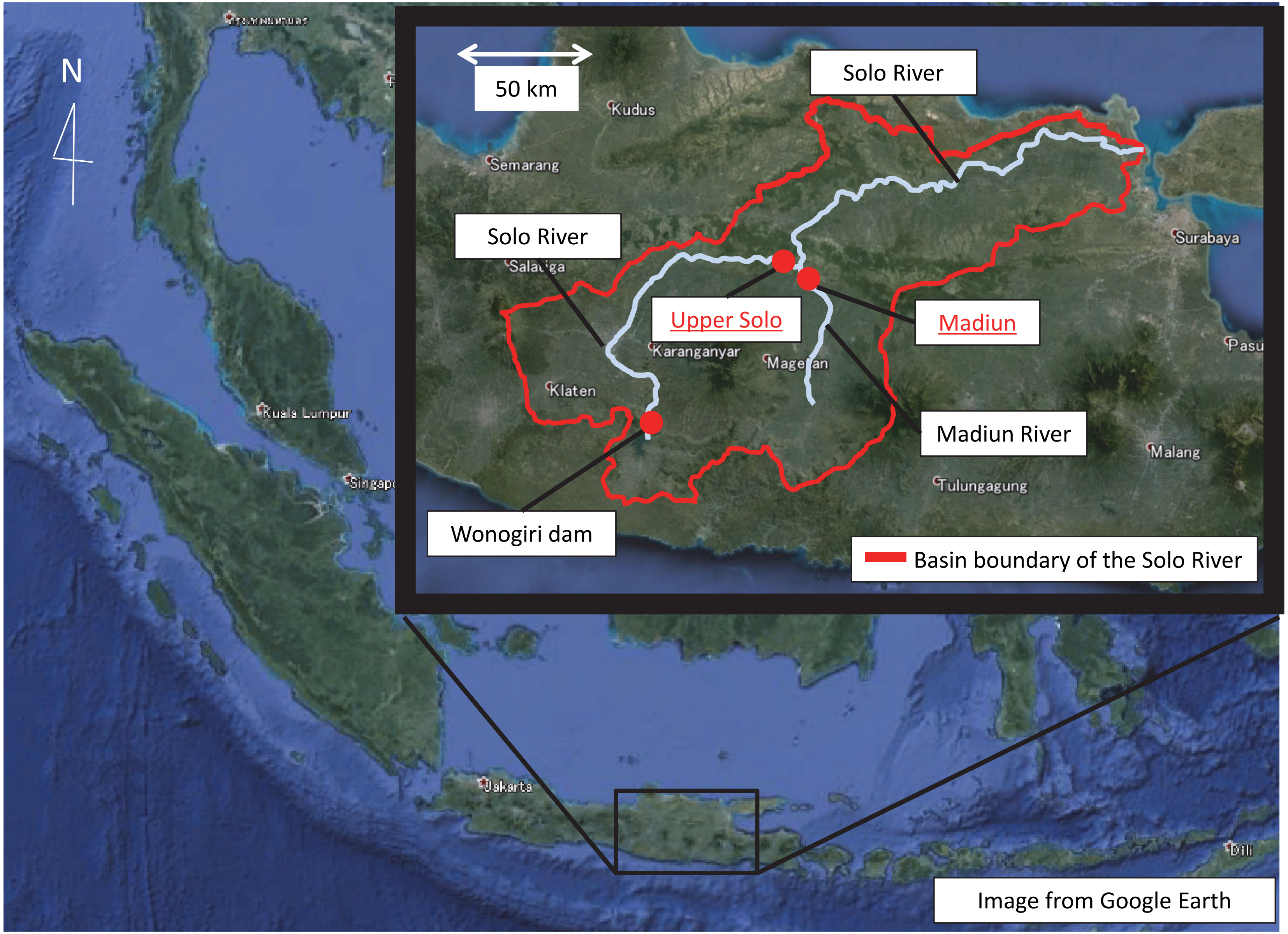


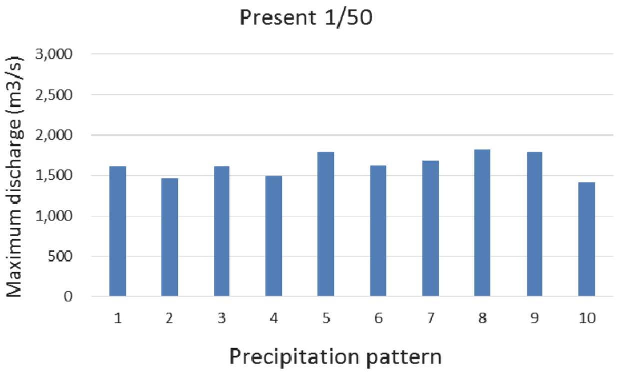
Image from Google Earth

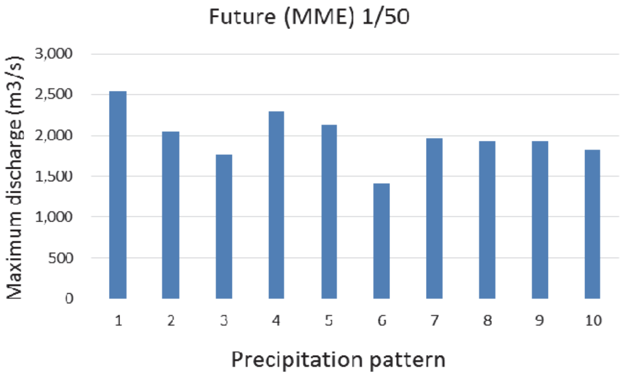
<u>Area of Upper Solo: 5,717 km2</u> <u>Area of Madiun: 3,138 km2</u>

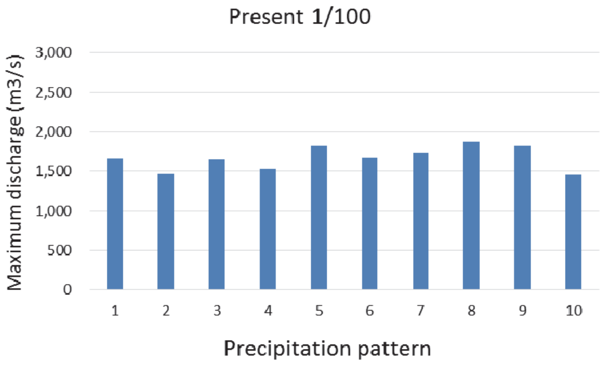
Maximum discharge (Upper Solo)

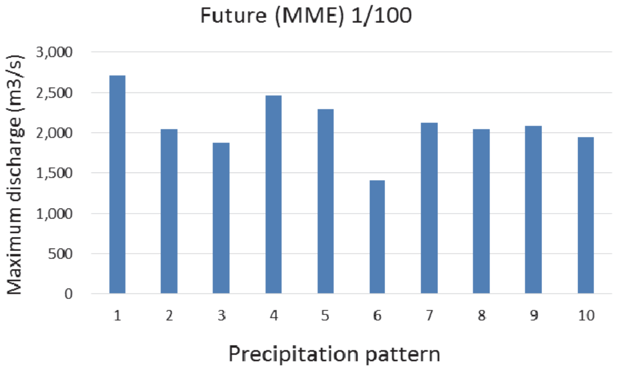
Present climate

Future climate


Present 1/50


Future (MME) 1/50


Present 1/100

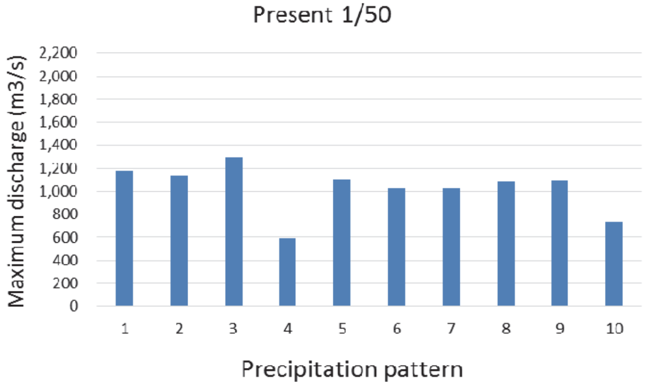

Future (MME) 1/100

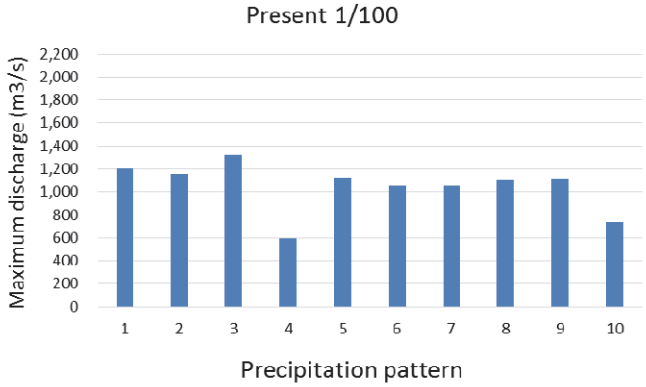
Maximum discharge among the top 10 patterns

	Present	Future	Increased by
1/50	1,823 (m3/s)	2,539 (m3/s)	39 %
1/100	1,872 (m3/s)	2,721 (m3/s)	45 %

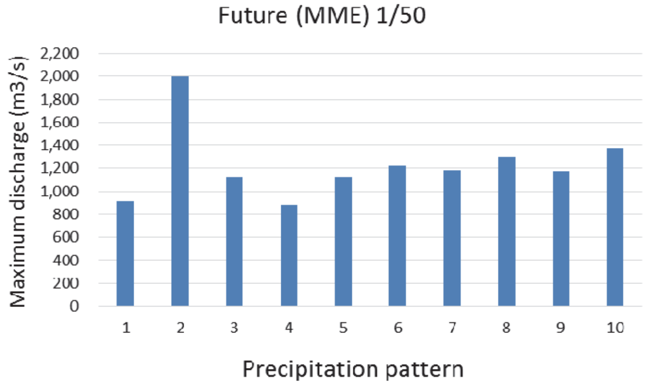
Maximum discharge (Madiun)

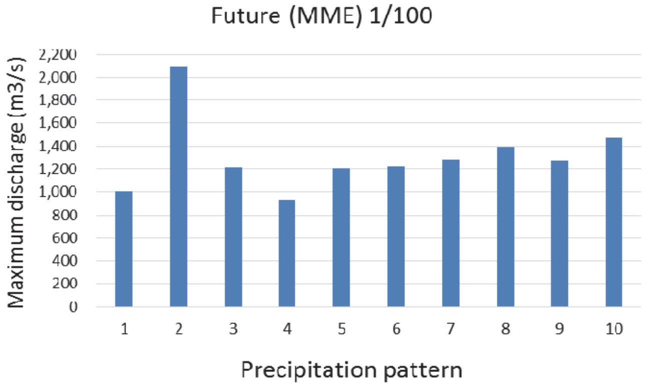
Present climate


Present 1/50


Present 1/100

Future climate


Future (MME) 1/50


Future (MME) 1/100

Maximum discharge among the top 10 patterns

	Present	Future	Increased by
1/50	1,295 (m3/s)	1,999 (m3/s)	54 %
1/100	1,321 (m3/s)	2,091 (m3/s)	58 %

United Nations
Educational, Scientific and
Cultural Organization

4.3 Flood risk assessment in the Solo River basin under climate change

Outline of this Study

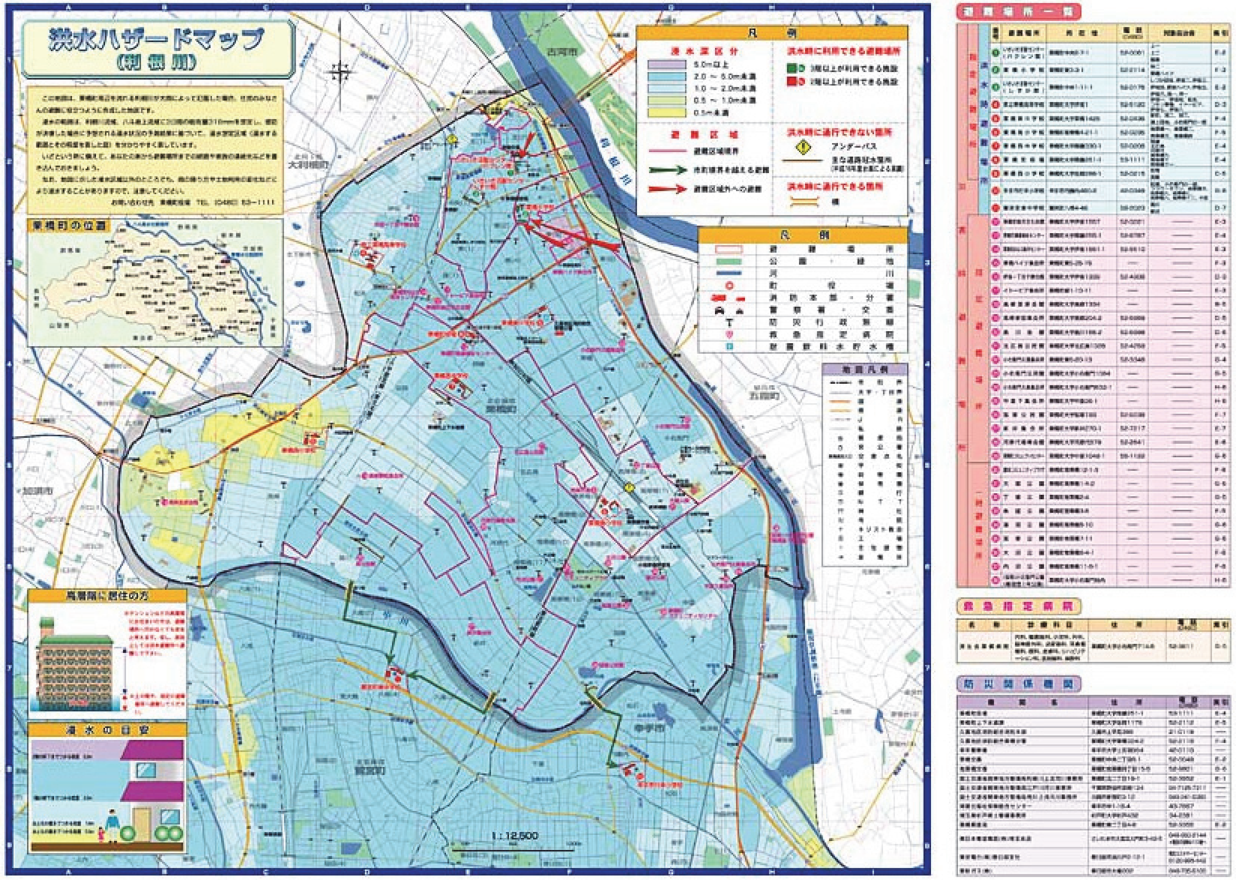
This study focuses on

- ☐ Flood Risk Assessment: Assessment of agricultural economic loss (flood damage to rice-crops) under climate change.
  - ➢ Verification of Flood Hazard and Damage Assessment (December 2007 Flood)
  - ➢ Flood Damage Assessment under Climate Change
    [Present Climate (1979-2003) and Future Climate (2075-2099): RCP 8.5 MME]

Method of Flood Risk Assessment

Flood Hazard Assessment:

- Generally flood risk assessment is conducted for probable future flood event. Hydrological/hydraulic simulation models are thus employed for estimation of flood hazard areas.
- Identify hazard condition by flood hazard simulation model e.g. RRI Model



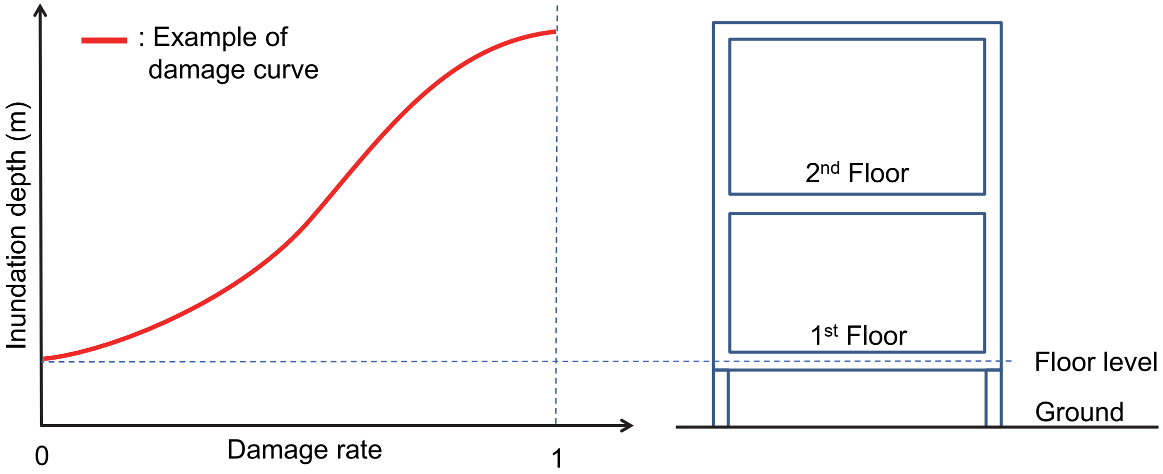
Estimated inundation maps in Tone River, Japan

(This map shows inundation area and depth)

Method of Flood Risk Assessment

Identification Exposed Elements and Vulnerability Assessment:

- After hazard areas are identified, population, infrastructure, property, etc. exposed to hazard areas have to be identified.
- Then, probable damage to each items should be identified by risk indicators with noting vulnerability factors. Risk indicator shows correlation of hazards with damage.
- Generally, damage curve which shows a relation of hazard and damage (Risk Indicator) has to be prepared for an estimation of flood damages.

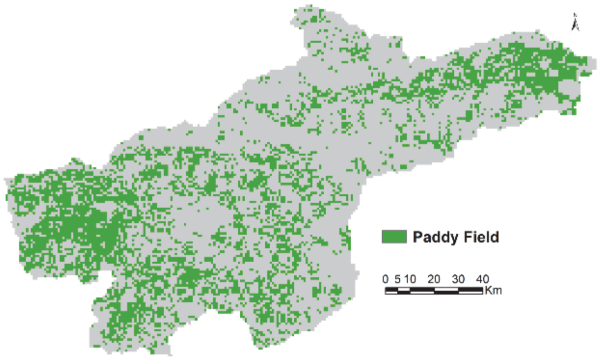


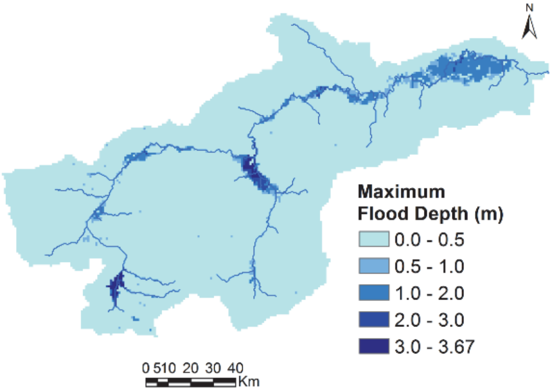
Damages = Exposure (people, housing etc.) × damage rate

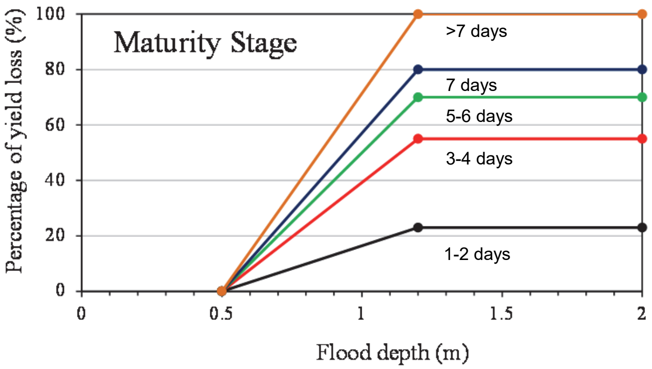
- Normally, flood damage curves are prepared based on actual flood damages and hazard condition. Therefore, surveys on past flood damages and inundation record have to be conducted.

Method of Agricultural Economic Loss Estimation

Schematic of Agricultural Economic Loss Calculation (Rice Production)







Paddy field area (Global data)

Inundation area, depth, duration by RRI model

Damage curve for rice production

Value of farm gate price (4650 Rupiah/kg)*

Rice yield (5230 kg/ha)**

Agricultural economic loss

Sources:

** Thom W. 2014. Indonesia Grain and Feed Annual: Indonesia grain and feed annual report 2014. GAIN Report Number ID1407*

***Panuji D R, Mizuno K, Trisasongko B H. 2013. The Dynamics of rice production in Indonesia 1961-2009. Journal of the Saudi Society of Agricultural Sciences **12**: 27-37.*

Flood Damage Assessment: Damage to Agriculture

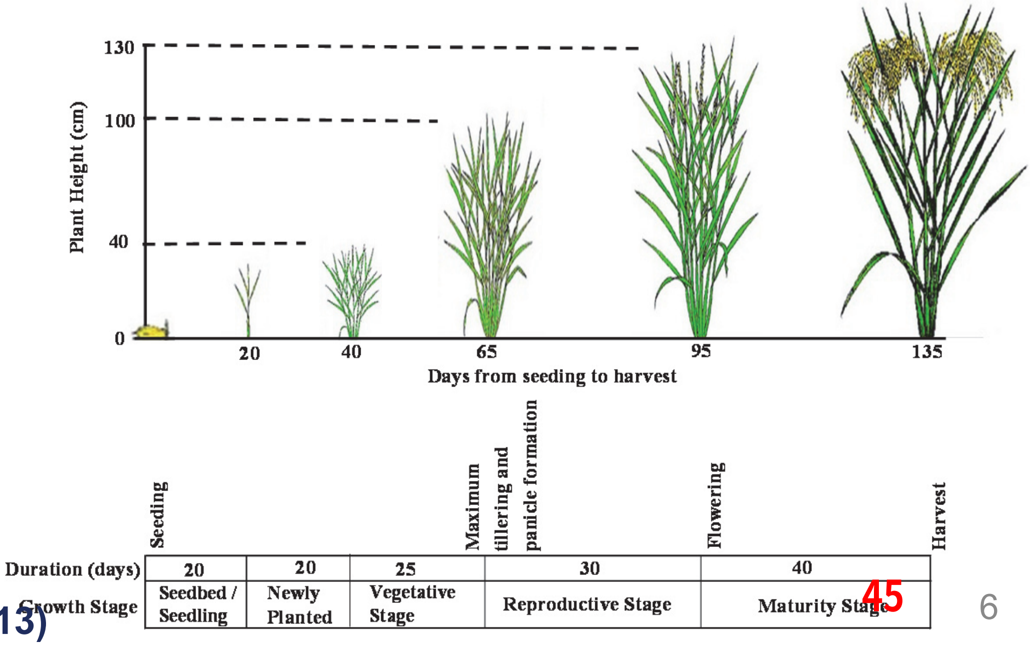
Process of Damage Assessment (Damage to Rice-Crops):

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



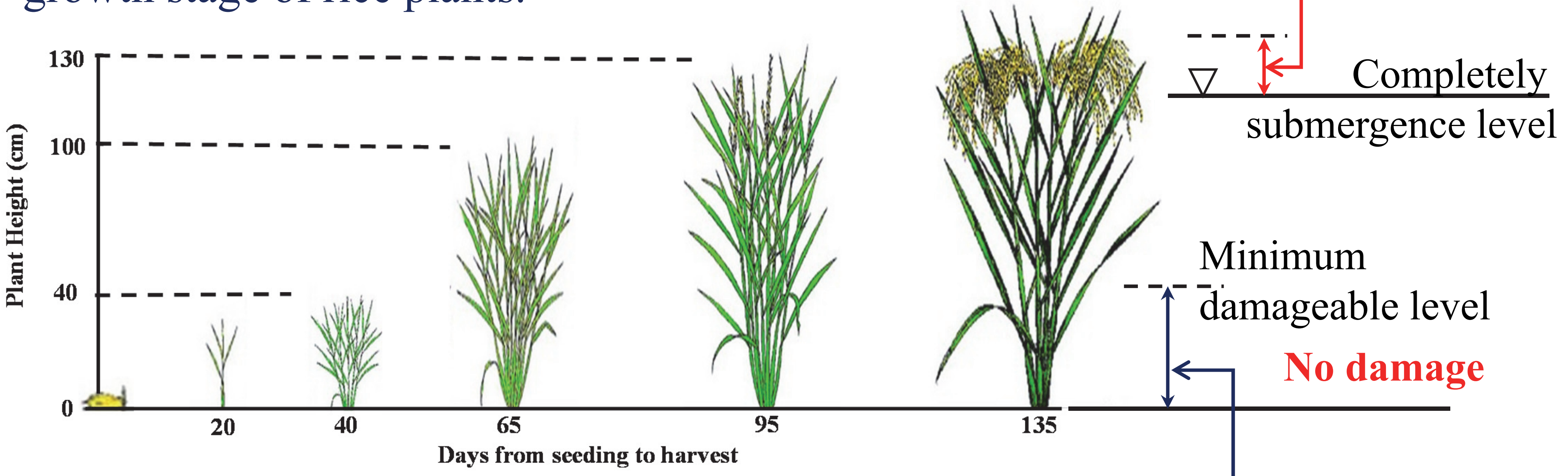
Duration (days)	20	20	25	30	40
Growth Stage	Seedbed / Seedling	Newly Planted	Vegetative Stage	Reproductive Stage	Maturity Stage

Source: Bureau of Agricultural Statistics, Philippines (2013)

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.

Assumed: 10 cm (9 to 15 cm, BAS, Philippine, 2013)



For vegetative stage: 20 cm

For reproductive, maturity and ripening stages: 50 cm

Seeding

Maximum tillering and panicle formation

Flowering

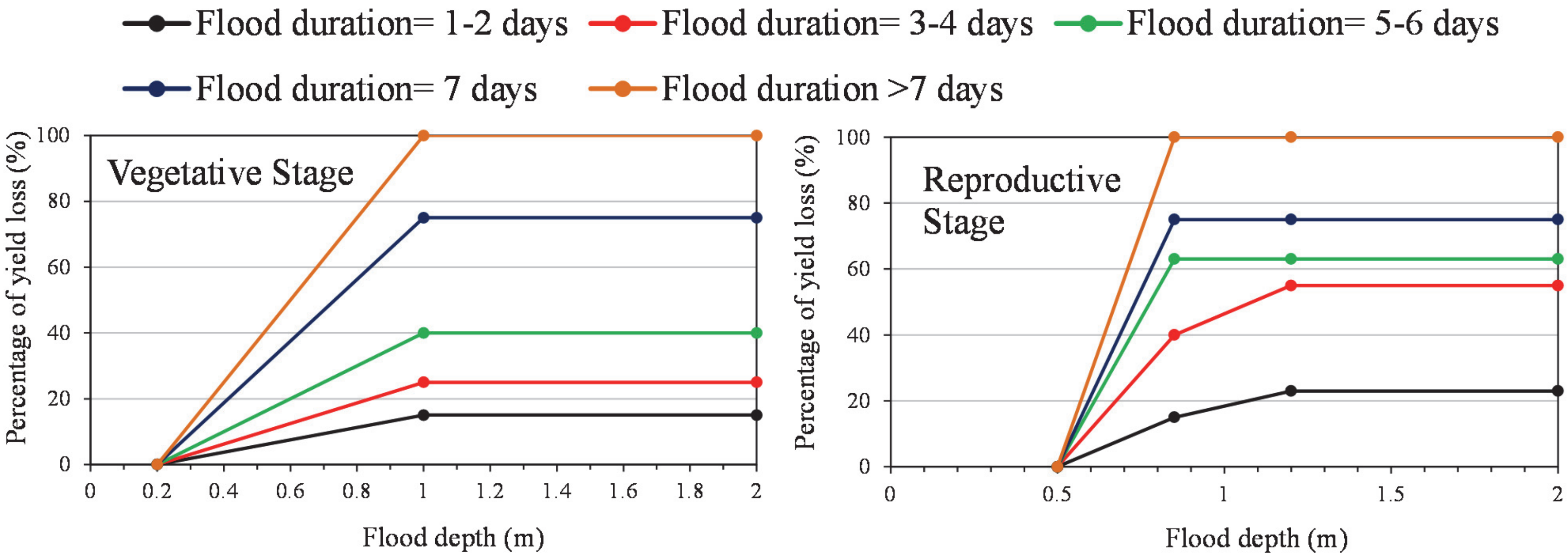
Harvest

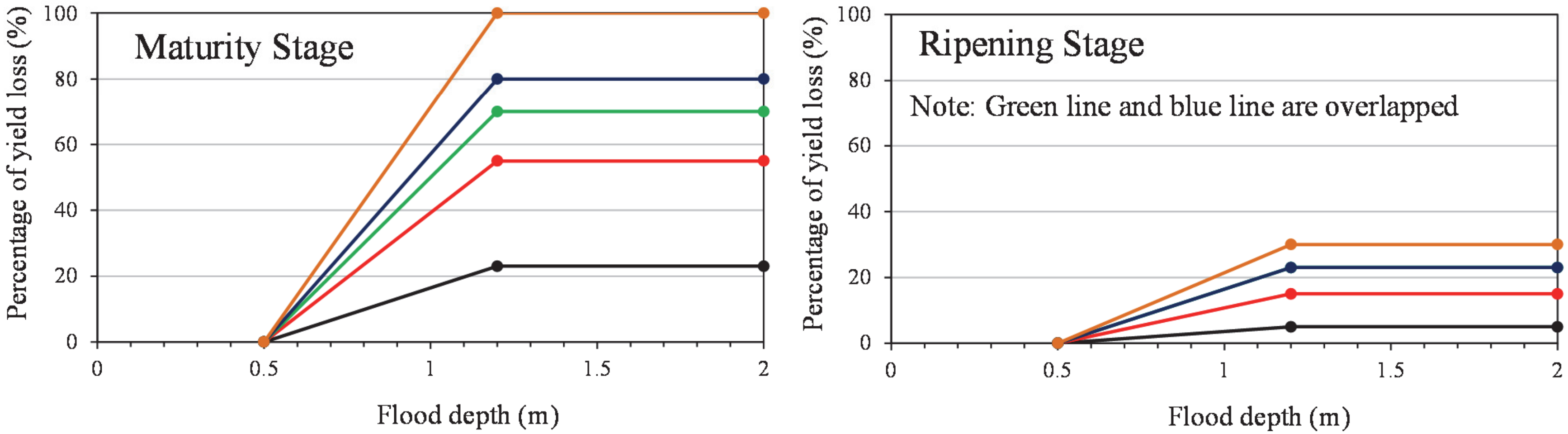
Duration (days)	20	20	25	30	40
Growth Stage	Seedbed / Seedling	Newly Planted	Vegetative Stage	Reproductive Stage	Maturity Stage

Flood Damage Assessment: Damage to Agriculture

Process of Damage Assessment (Damage to Rice-Crops):

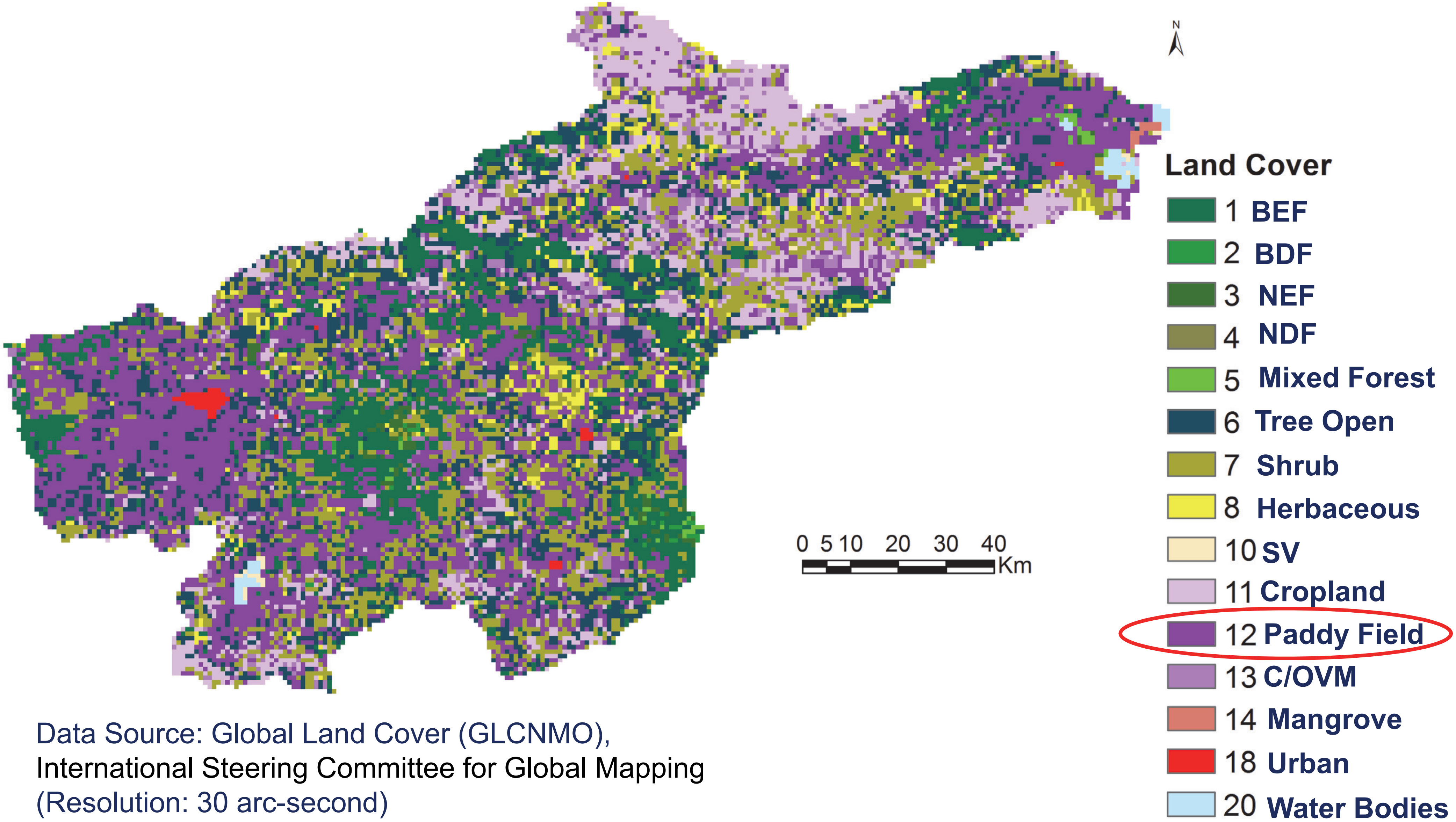
Proposed damage curves: Rice Crops





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*

Solo River Basin: Land Cover Condition



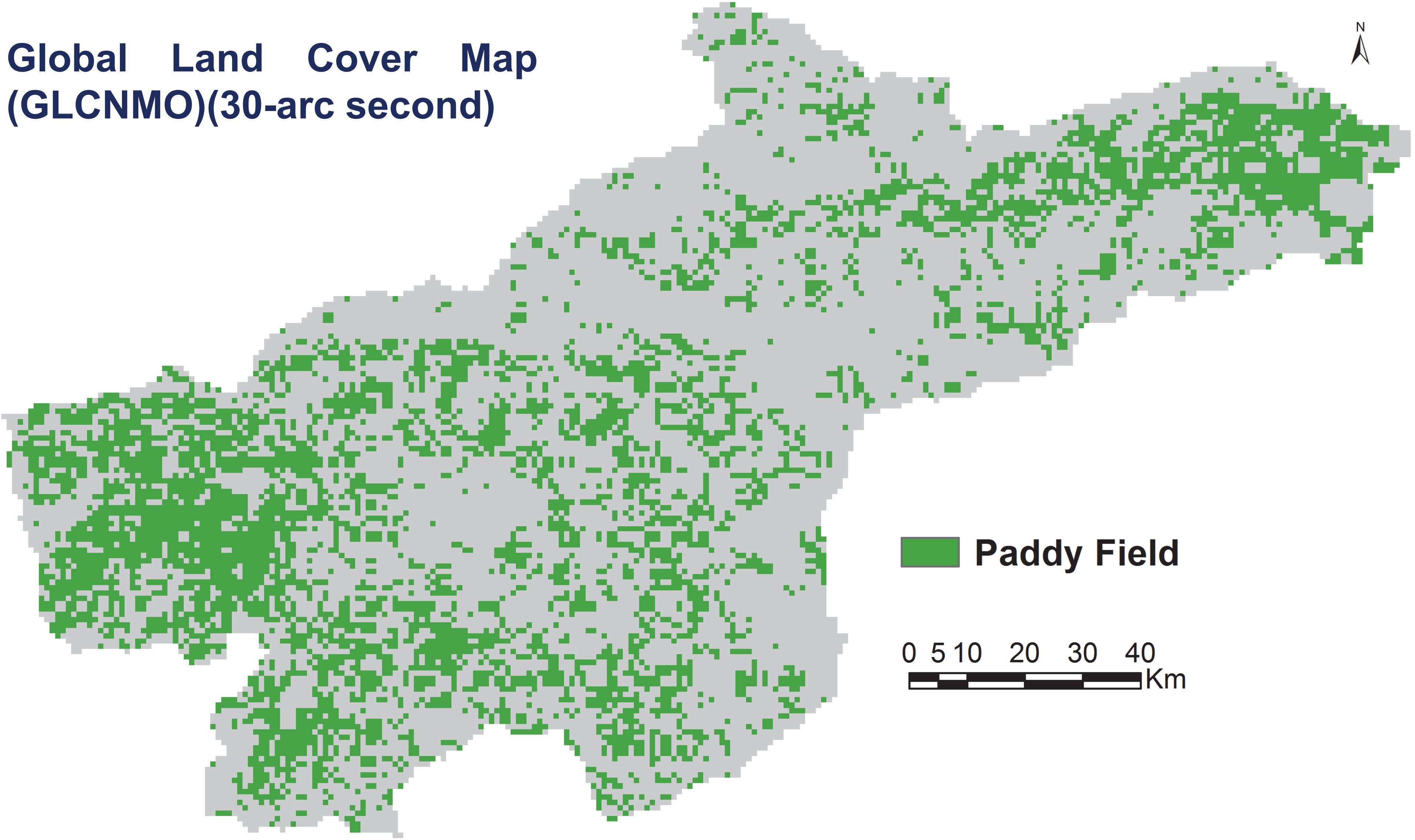
Data Source: Global Land Cover (GLCNMO),
International Steering Committee for Global Mapping
(Resolution: 30 arc-second)

BEF: Broadleaf Evergreen Forest, BDF: Broadleaf Deciduous Forest, NEF: Needleleaf Evergreen Forest, NDF: Needleleaf Deciduous Forest, SV= Sparse Vegetation, C/OVM: Cropland/Other Vegetation Mosaic

The Global Land Cover by National Mapping Organizations (**GLCNMO**) *https://globalmaps.github.io/*

Paddy Field in Solo River Basin

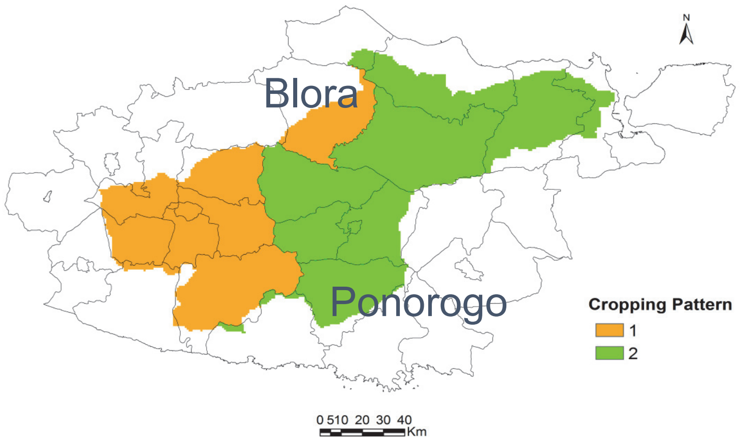
Global Land Cover Map (GLCNMO)(30-arc second)



Total paddy area based on GLCNMO in the basin =492,885.8 ha

Reported paddy area in the basin = 555,000 ha (Source: Comprehensive Development Master Plan Study Master Plan Report (2001)

Cropping Pattern in Solo River Basin

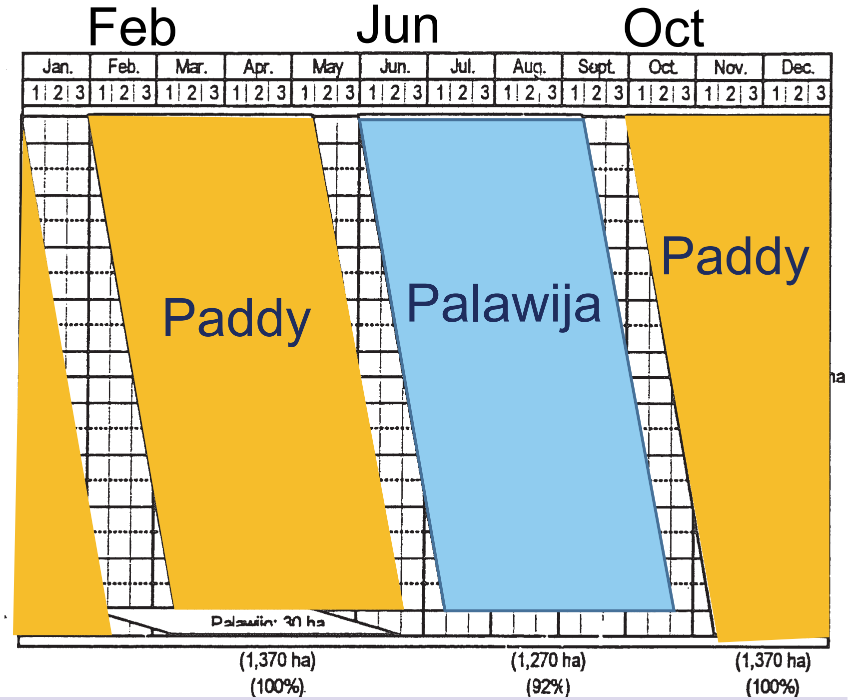


Based growth stage of rice plant and rice cropping pattern, the stage of rice plant during flood event of 25 December 2007 to 2 January 2008 (Biggest Recorded Flood Event) is as:

Pattern -1: Maturity Stage Paddy Field = 237,828.4 ha

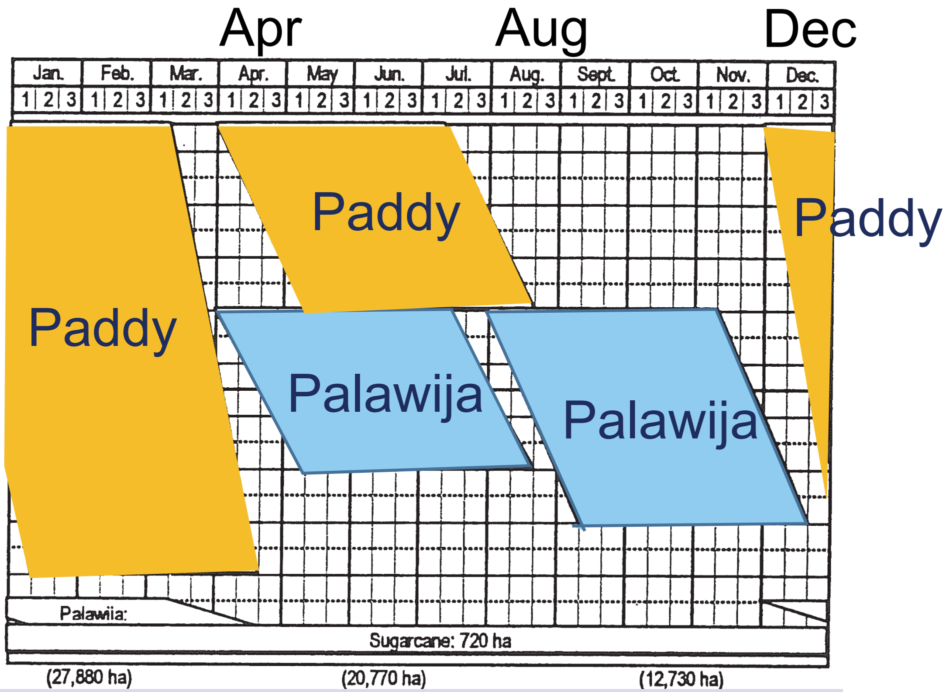
Pattern -2: Vegetative Stage Paddy Field = 255,057.4 ha

Pattern -1



Blora District

Pattern -2



Ponorogo District

Source: *Comprehensive development and management plan study for Bengawan Solo River Basin under Lower Solo River Improvement Project, 2001 (Dep. of Settlement and Regional Infrastructure, Directorate General of Water Resources Bengawan Solo River Basin Development Project)*

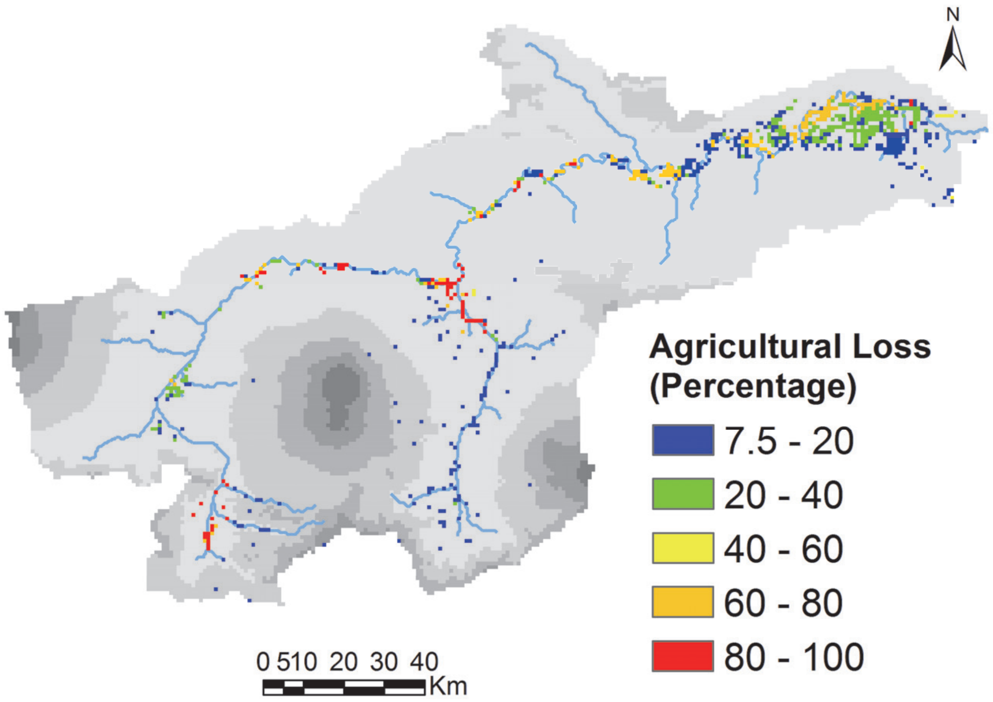
Flood Risk Assessment

- Verification of Damage Assessment Method -

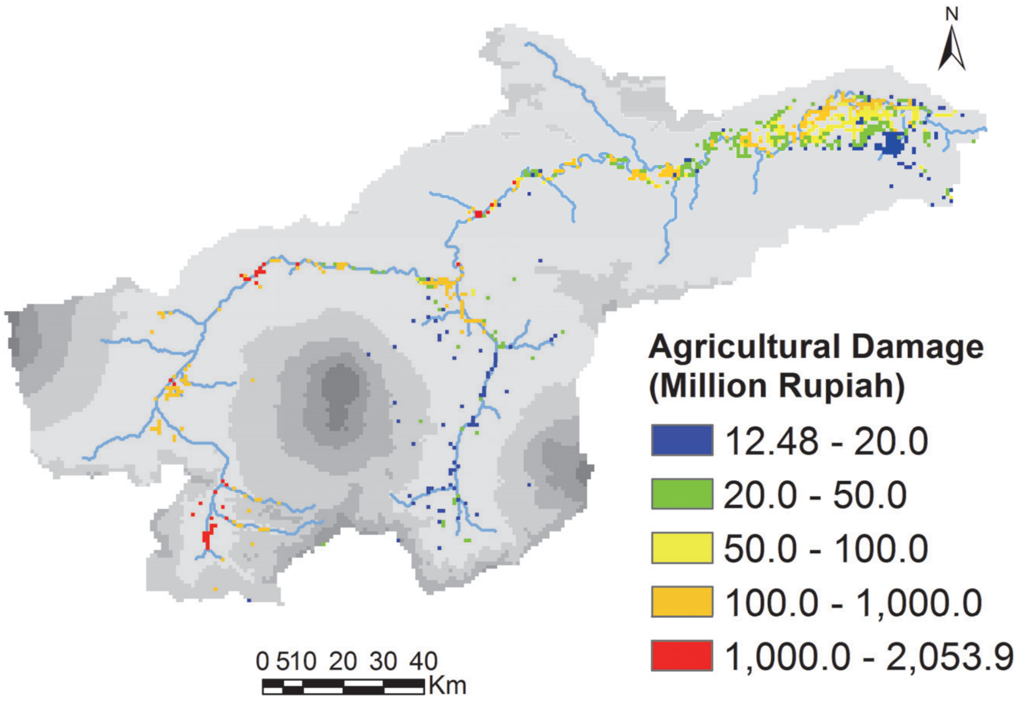
Flood Risk Assessment in Solo River Basin

Flood event: 25 December 2007 to 2 January 2008

Yield Loss of Rice Crop



Agricultural Economical Loss



Total estimated damage: 143.8 billion Rp

Yield = 5230 kg/ha *
Farm get price = 4650 Rupiah / kg **
Cost of Input = 1,970,414 Rupiah / ha ***

** Panuji D R, Mizuno K, Trisasongko B H. 2013. The Dynamics of rice production in Indonesia 1961-2009. Journal of the Saudi Society of Agricultural Sciences* ***12****: 27-37.*

*** Thom W. 2014. Indonesia Grain and Feed Annual: Indonesia grain and feed annual report 2014. GAIN Report Number ID1407.*

**** Zakaria A, Aring H L D, Indriani Y. 2004. The impact of irrigation development on rice production in Lampung Province. Research Report, University of Lampung.*

Flood Risk Assessment in Solo River Basin

Flood event: 25 December 2007 to 2 January 2008

Comparison of calculated damage with reported data (Whole Basin)

Damaged Rice Crop Area (ha)		Agricultural Economic Loss (Rice-crops) (billion Rp)	
Calculated	Reported[*1]	Calculated	Reported[*2]
66,298	60,630	143.8	93.3

Calculated damage area with reported data in districts

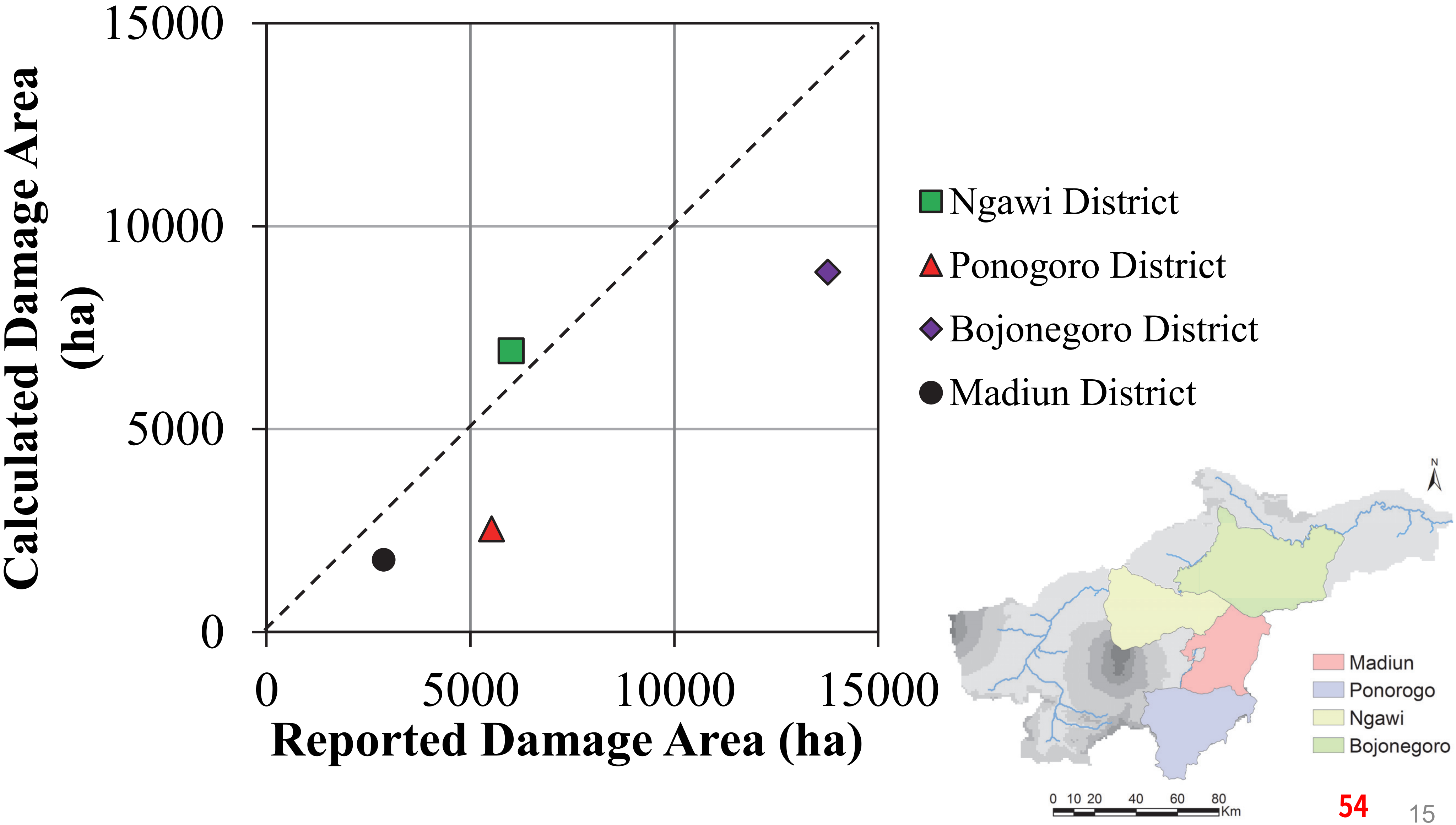
District	Damaged Rice Crop Area (ha)		Agricultural Economic Loss (Rice-crops) (billion Rp)
	Calculated	Reported[*1]	
Ngawi	6,925	5,997	8.319
Ponogoro	2,534	5,528	0.473
Bojonegoro	8,868	13,771	7.39
Madiun	1,774	2,873	0.287

[*1] *Directorate of Food Crop Protection (DFCP), Indonesia. 2010. Indonesia broad flood damage in rice plant: Solo River Basin. Flood Damage Data Published by the Directorate of Food Crop Protection.*

[*2] *Hidayat F, Sungguh H M, Harianto. 2008. Impact of climate change on floods in Bengawan Solo and Brantas River Basins, Indonesia. Proceeding of the 11th International Riversymposium September 1-4, 2008 Brisbane, Australia.*

Flood Risk Assessment in Solo River Basin

Comparison of calculated agricultural damage area with reported data



Flood Risk Assessment

- under Climate Change -

Flood Risk Assessment Under Climate Change

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

Present Climate: (1979-2003)

Rainfall pattern	4-days rainfall value (mm)	Damaged agricultural area (ha)	Agricultural economic loss (billion Rp)
A	97	60977.3	1127.4
B	94	46281.9	780.1
C	94	57936.9	1018.0
D	91	26941.5	390.8
E	86	52362.8	920.3
F	84	42734.8	721.0
G	79	56839.0	1068.9
H	78	41045.7	635.2
I	76	39018.7	626.9
J	75	24745.6	365.7
Average	85.4	44888.4	765.4

Future Climate: (2075-2099)

Rainfall pattern	4-days rainfall value (mm)	Damaged agricultural area (ha)	Agricultural economic loss (billion Rp)
A	126	77868.5	1437.3
B	117	62750.9	863.6
C	104	54643.1	923.4
D	91	53207.3	891.7
E	85	46281.9	749.3
F	84	22296.4	317.2
G	82	42228.1	675.4
H	81	51180.4	851.1
I	79	45775.2	771.0
J	79	38089.7	640.0
Average	92.8	49432.2	812.0

Flood Risk Assessment Under Climate Change

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

Present Climate: (1979-2003)

Rainfall pattern	Extended 4-days rainfall value (mm)	Damaged agricultural area (ha)	Agricultural economic loss (billion Rp)
A	103	63173.2	1201.1
B		49829.1	864.0
C		63595.4	1120.0
D		28208.3	423.1
E		62075.2	1138.6
F		49322.4	840.6
G		**65369.0**	1285.1
H		53714.1	872.7
I		56416.7	978.9
J		26519.2	393.7
Average		51822.3	911.8

Future Climate: (2075-2099)

Rainfall pattern	Extended 4-days rainfall value (mm)	Damaged agricultural area (ha)	Agricultural economic loss (billion Rp)
A	132	**80402.2**	1498.1
B		68916.2	1004.3
C		64693.4	1160.1
D		66044.7	1233.3
E		67818.3	1265.5
F		23141.0	324.2
G		67311.5	1224.9
H		70943.1	1366.1
I		70605.3	1324.6
J		54812.0	924.7
Average		63468.8	1132.6

Flood Risk Assessment Under Climate Change

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

Present Climate: (1979-2003)

Rainfall pattern	Extended 4-days rainfall value (mm)	Damaged agricultural area (ha)	Agricultural economic loss (billion Rp)
A	107	65369.0	1255.8
B		51602.7	903.4
C		65284.6	1161.2
D		29221.8	437.4
E		64102.2	1194.6
F		51011.5	868.7
G		67311.5	1326.5
H		55318.7	918.9
I		58612.5	1025.8
J		26941.5	405.0
Average		53477.6	949.7

Future Climate: (2075-2099)

Rainfall pattern	Extended 4-days rainfall value (mm)	Damaged agricultural area (ha)	Agricultural economic loss (billion Rp)
A	150	86989.8	1664.5
B		76263.9	1173.5
C		72210.0	1323.1
D		74236.9	1371.3
E		75165.9	1427.8
F		23225.4	325.4
G		75250.4	1385.6
H		75081.5	1510.7
I		77530.7	1505.4
J		63004.3	1096.7
Average		69895.9	1278.4

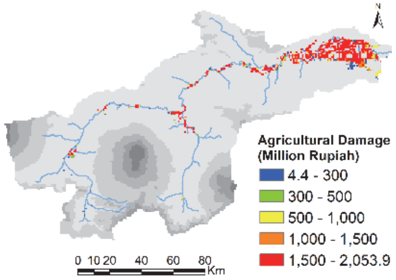
Flood Risk Assessment Under Climate Change

Under Present Climate (1979-2003)

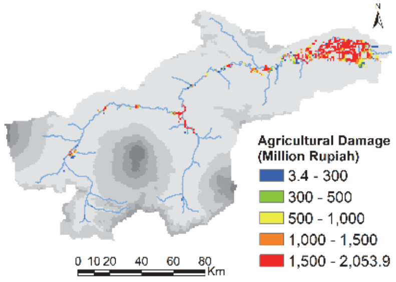
50-Year Flood

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

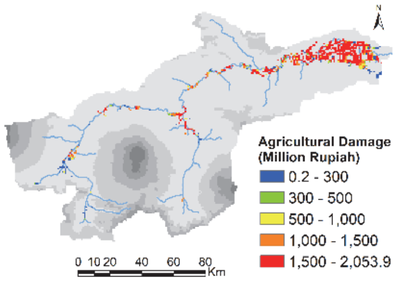
Pattern A



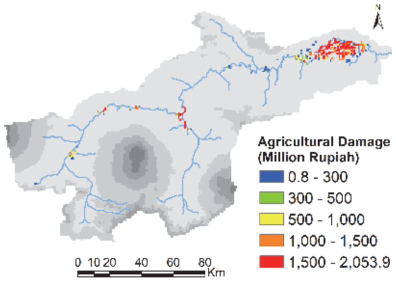
Pattern B



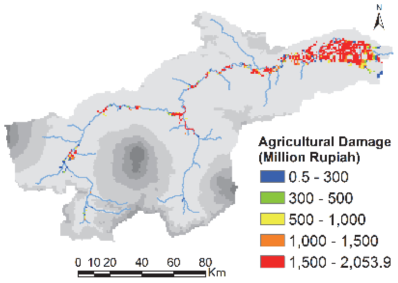
Pattern C



Pattern D

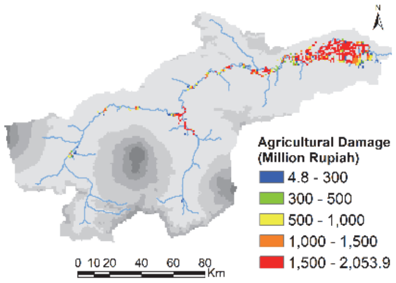


Pattern E

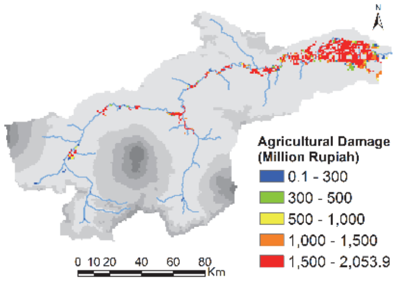


Maximum damaged agricultural area

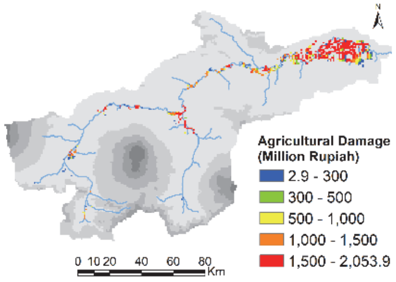
Pattern F



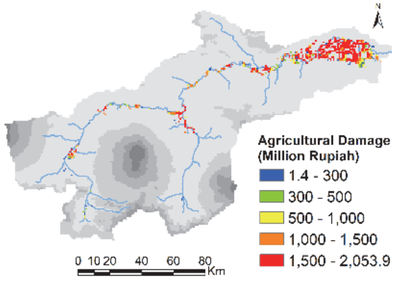
Pattern G



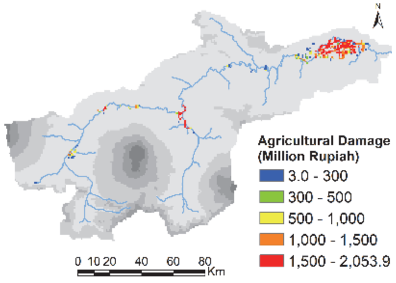
Pattern H



Pattern I



Pattern J



Flood Risk Assessment Under Climate Change

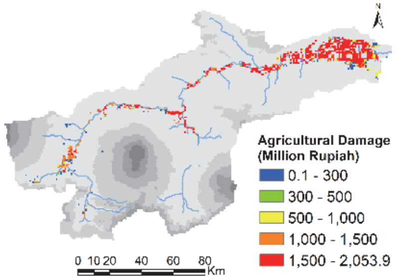
Under Future Climate (2075-2099): RCP 8.5 MME

50-Year Flood

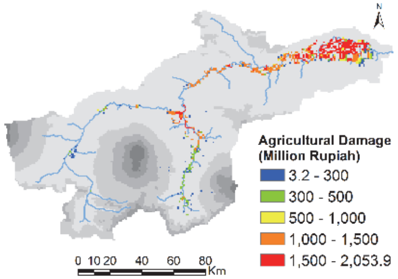
Agricultural damage assessment by conducting hazard analysis using 10 different rainfall patterns with rainfall amount of 50 year return period

Maximum damaged agricultural area

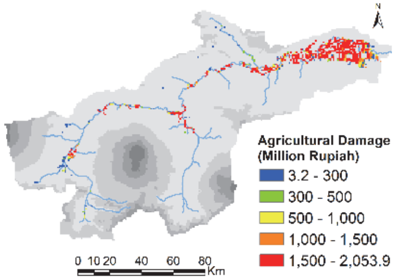
Pattern A



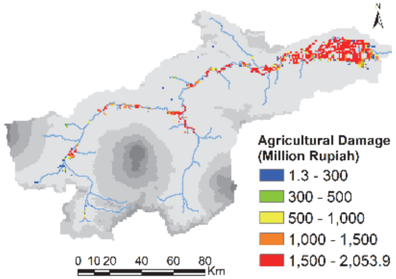
Pattern B



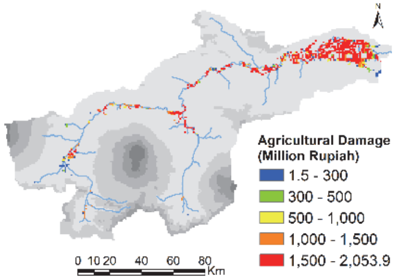
Pattern C



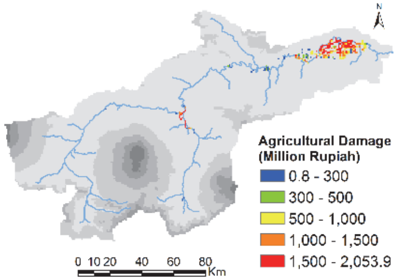
Pattern D



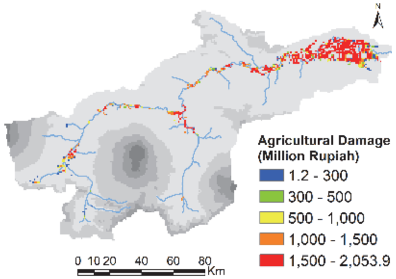
Pattern E



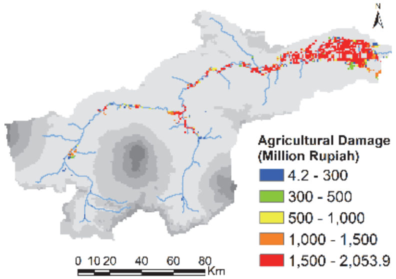
Pattern F



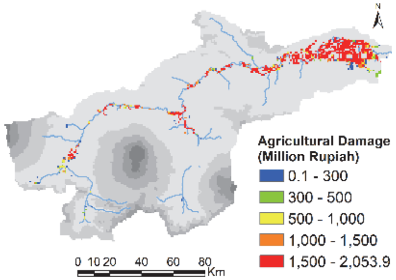
Pattern G



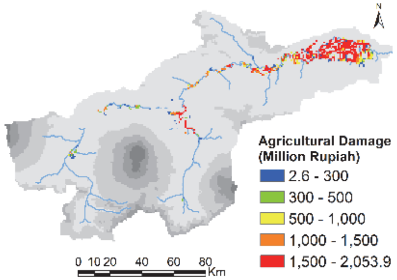
Pattern H



Pattern I



Pattern J



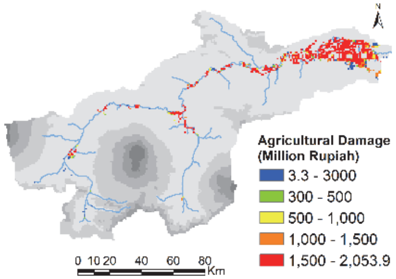
Flood Risk Assessment Under Climate Change

Under Present Climate (1979-2003)

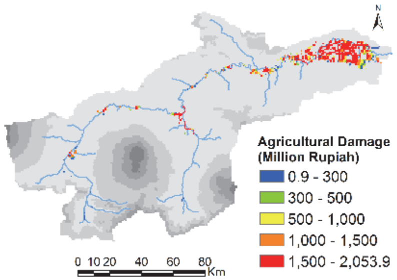
100-Year Flood

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

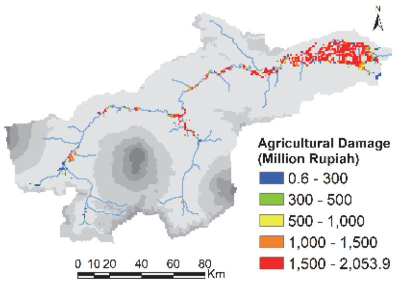
Pattern A



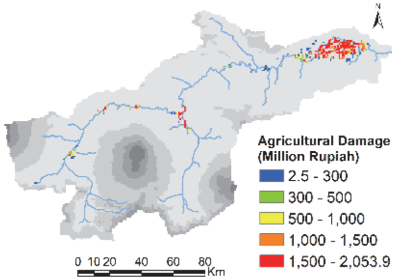
Pattern B



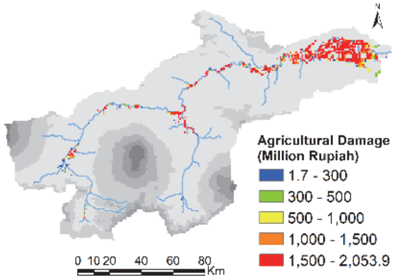
Pattern C



Pattern D

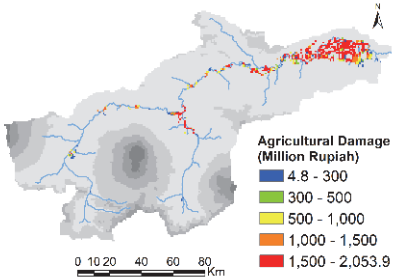


Pattern E

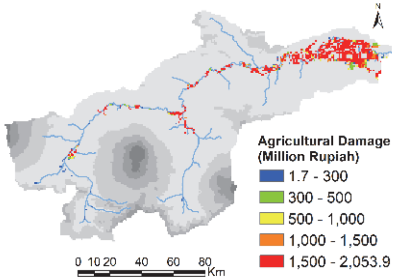


Maximum damaged agricultural area

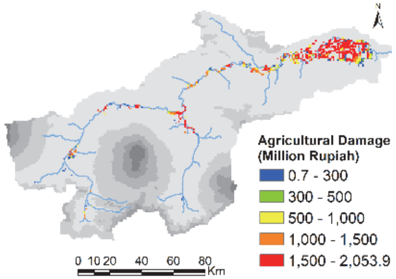
Pattern F



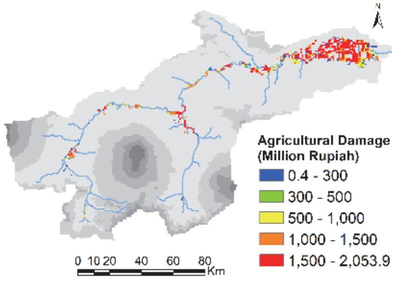
Pattern G



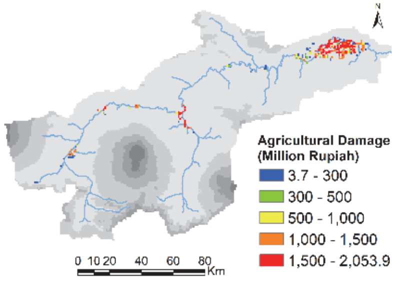
Pattern H



Pattern I



Pattern J



Flood Risk Assessment Under Climate Change

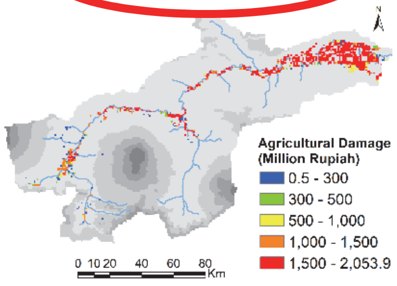
Under Future Climate (2075-2099): RCP 8.5 MME

100-Year Flood

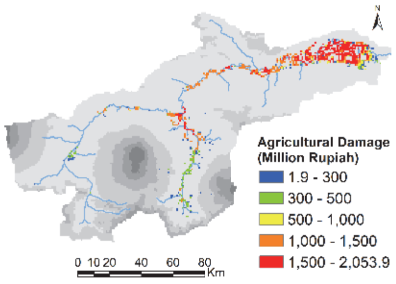
Agricultural damage assessment by conducting hazard analysis using 10 different rainfall patterns with rainfall amount of 100 year return period

Maximum damaged agricultural area

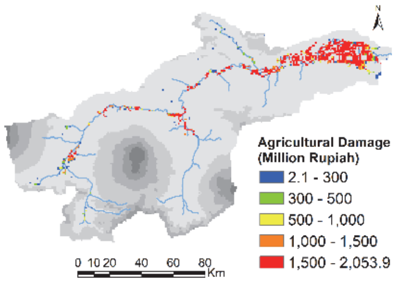
Pattern A



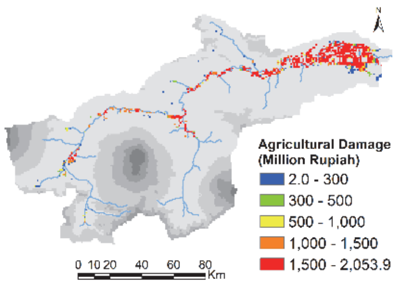
Pattern B



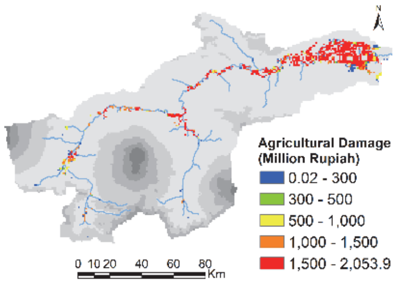
Pattern C



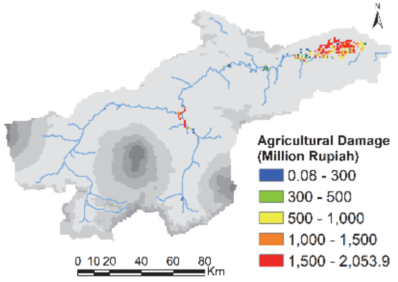
Pattern D



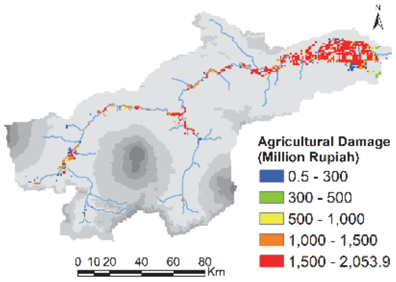
Pattern E



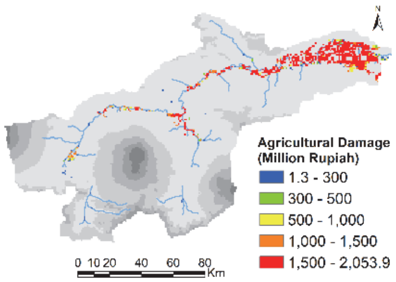
Pattern F



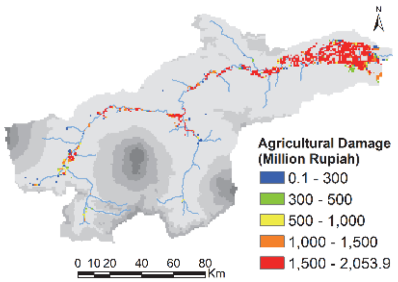
Pattern G



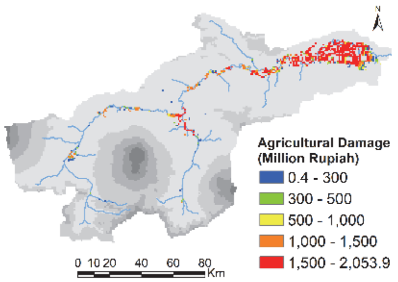
Pattern H



Pattern I



Pattern J



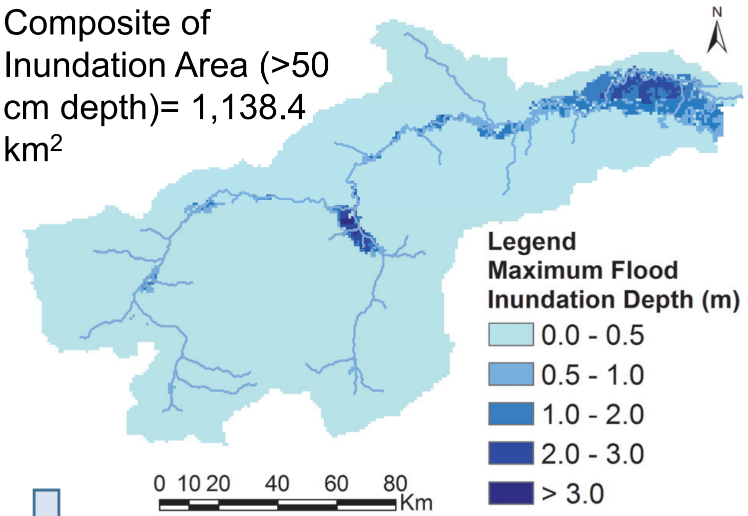
Flood Risk Assessment Under Climate Change

Comparison of agriculture damage under present/future Climate

Worst Cases in terms of Agricultural Damage Area: Original Rainfall

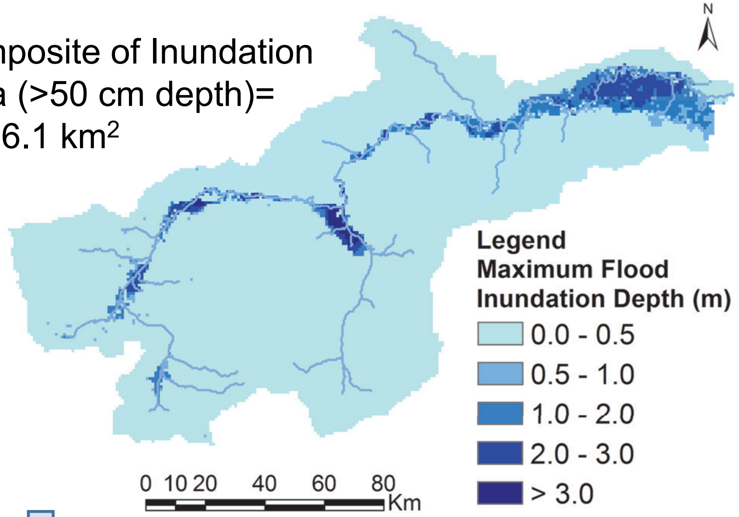
Present Climate: (1979-2003)

Composite of Inundation Area (>50 cm depth)= 1,138.4 km^2

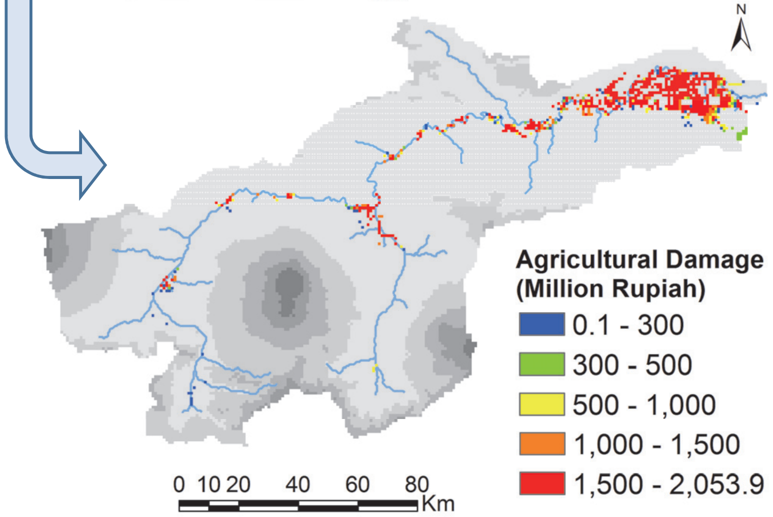


Future Climate: RCP 8.5 MME (2075-2099)

Composite of Inundation Area (>50 cm depth)= 1,466.1 km^2



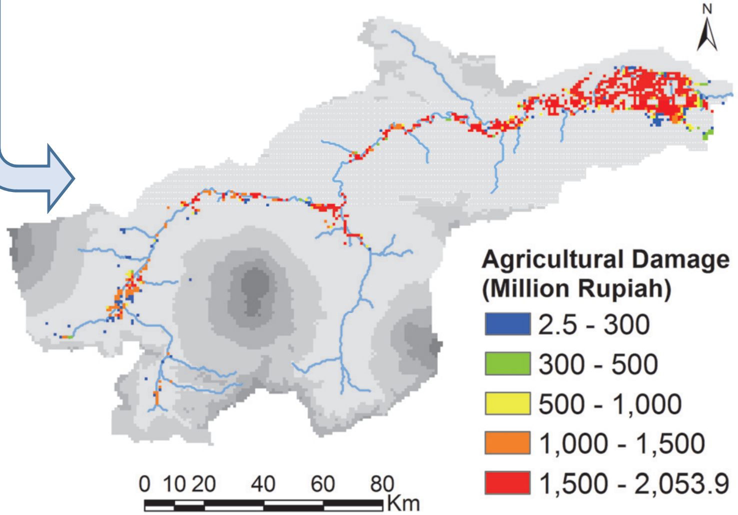
Inundation area increased by 29 %



Damage area= 60,977.3 ha
Estimated Damage= 1,127.4 billion Rupiah

Damage area increased by 28 %

Damage value increased by 27 %



Damage area= 77,868.5 ha
Estimated Damage= 1,437.3 billion Rupiah

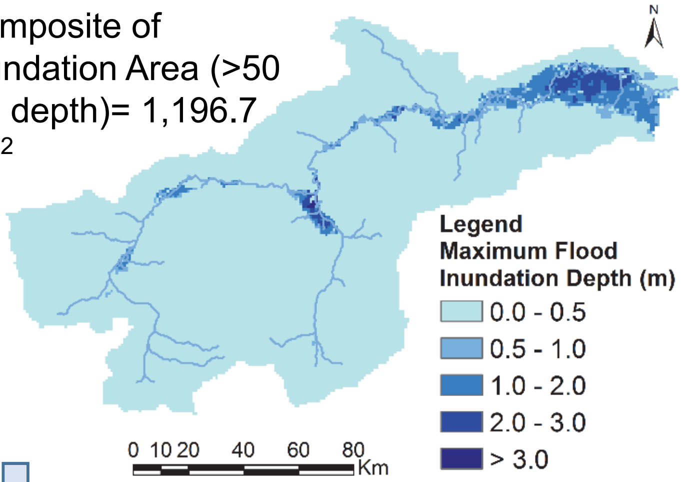
Flood Risk Assessment Under Climate Change

Comparison of agriculture damage under present/future Climate

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

Present Climate

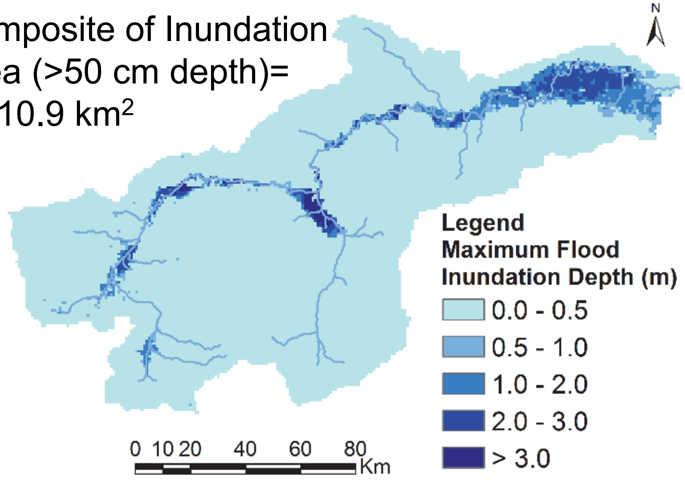
Composite of Inundation Area (>50 cm depth)= 1,196.7 km^2

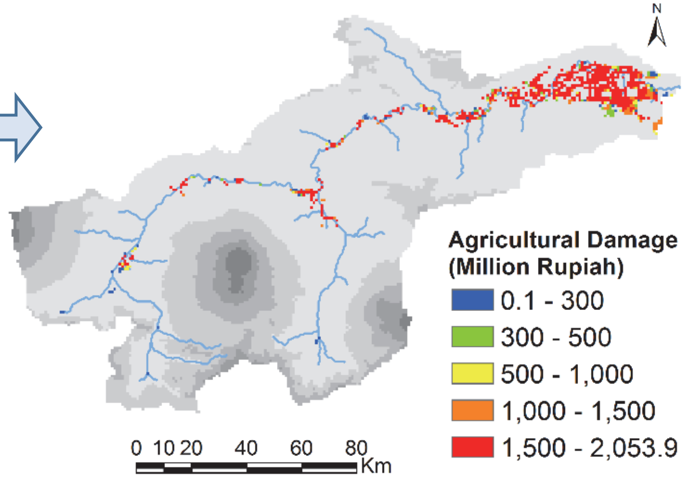


Inundation area increased by 26 %

Future Climate

Composite of Inundation Area (>50 cm depth)= 1,510.9 km^2

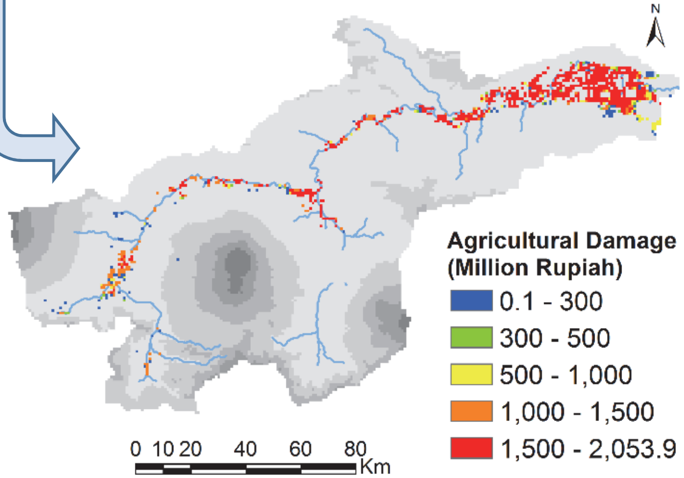




Damage area= 65,369.0 ha
Estimated Damage= 1,285.1 billion Rupiah

Damage area increased by 23 %

Damage value increased by 17 %



Damage area= 80,402.2 ha
Estimated Damage= 1,498.1 billion Rupiah

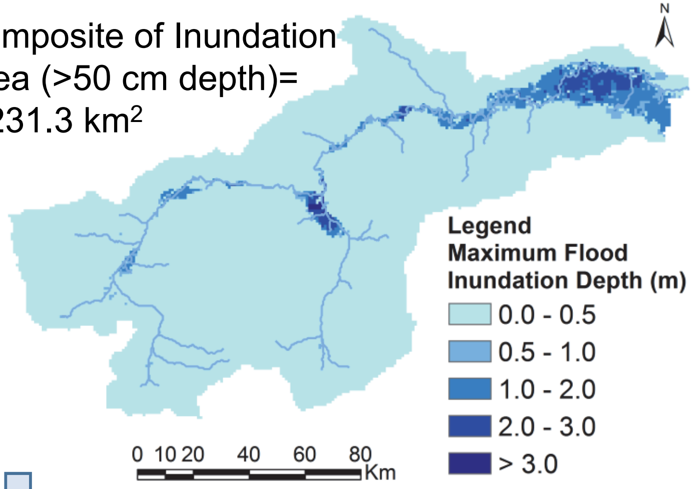
Flood Risk Assessment Under Climate Change

Comparison of agriculture damage under present/future Climate

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

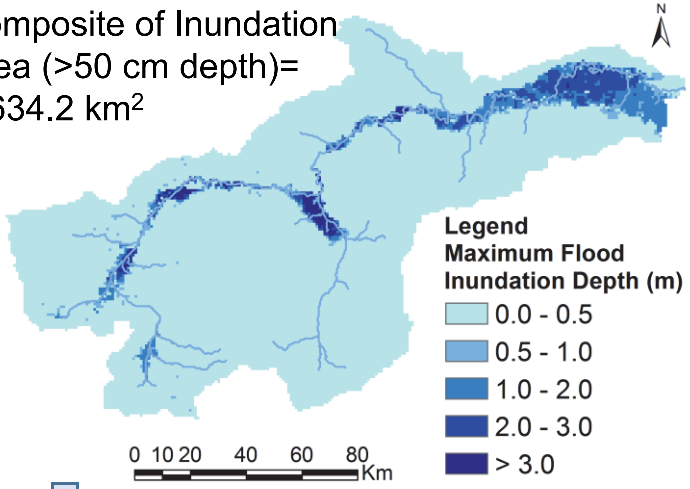
Present Climate

Composite of Inundation Area (>50 cm depth)= 1,231.3 km^2

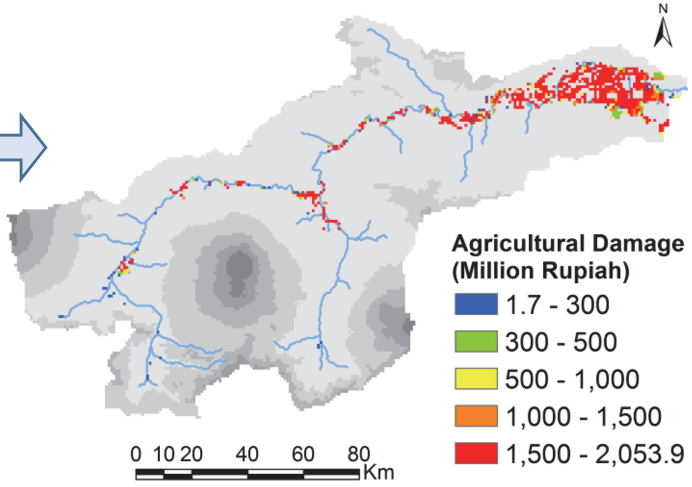


Future Climate

Composite of Inundation Area (>50 cm depth)= 1,634.2 km^2



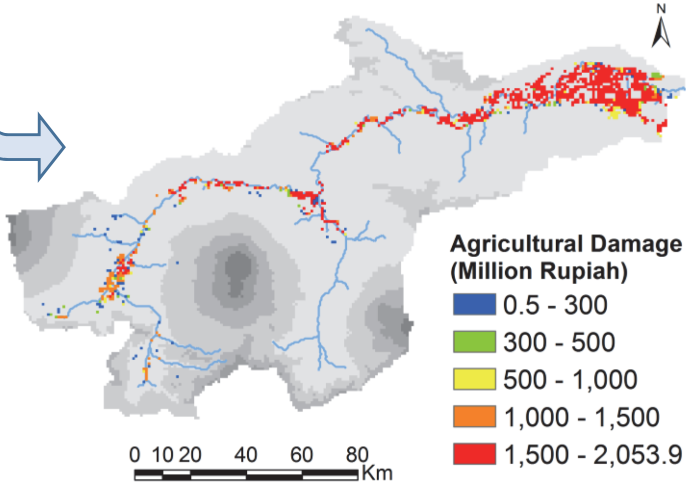
Inundation area increased by 33 %



Damage area= 67,311.5 ha
Estimated Damage= 1,326.5 billion Rupiah

Damage area increased by 29 %

Damage value increased by 25 %



Damage area= 86,989.8 ha
Estimated Damage= 1,664.5 billion Rupiah

Summary of Results

Summary : Comparison with average agricultural damage area case

Rainfall Conditions	Present Climate		Future Climate		% Increased	
	Agricultural damage area (ha)	Agricultural economic loss (bil. Rupiah)	Agricultural damage area (ha)	Agricultural economic loss (bil. Rupiah)	Agricultural damage area	Agricultural economic loss
Original	44888.4	765.4	49432.2	812.0	10	6
50-Year Return Period	51822.3	911.8	63468.8	1132.6	22	24
100-Year Return Period	53477.6	949.7	69895.9	1278.4	31	35

Summary : Comparison with worst agricultural damage area case

Rainfall Conditions	Present Climate		Future Climate		% Increased	
	Agricultural damage area (ha)	Agricultural economic loss (bil. Rupiah)	Agricultural damage area (ha)	Agricultural economic loss (bil. Rupiah)	Agricultural damage area	Agricultural economic loss
Original	60,977.3	1,127.4	77,868.5	1,437.3	28	27
50-Year Return Period	65,369.0	1,285.1	80,402.2	1,498.1	23	17
100-Year Return Period	67,311.5	1,326.5	86,989.8	1,664.5	29	25

Thank you very much !

For further information:
shrestha@pwri.go.jp

4.4 Drought risk assessment in the Solo River basin

Contents

1. Introduction
2. Water resources management
   in the Upper Solo River basin
3. Simulation Method
4. Simulation Results
5. Conclusion

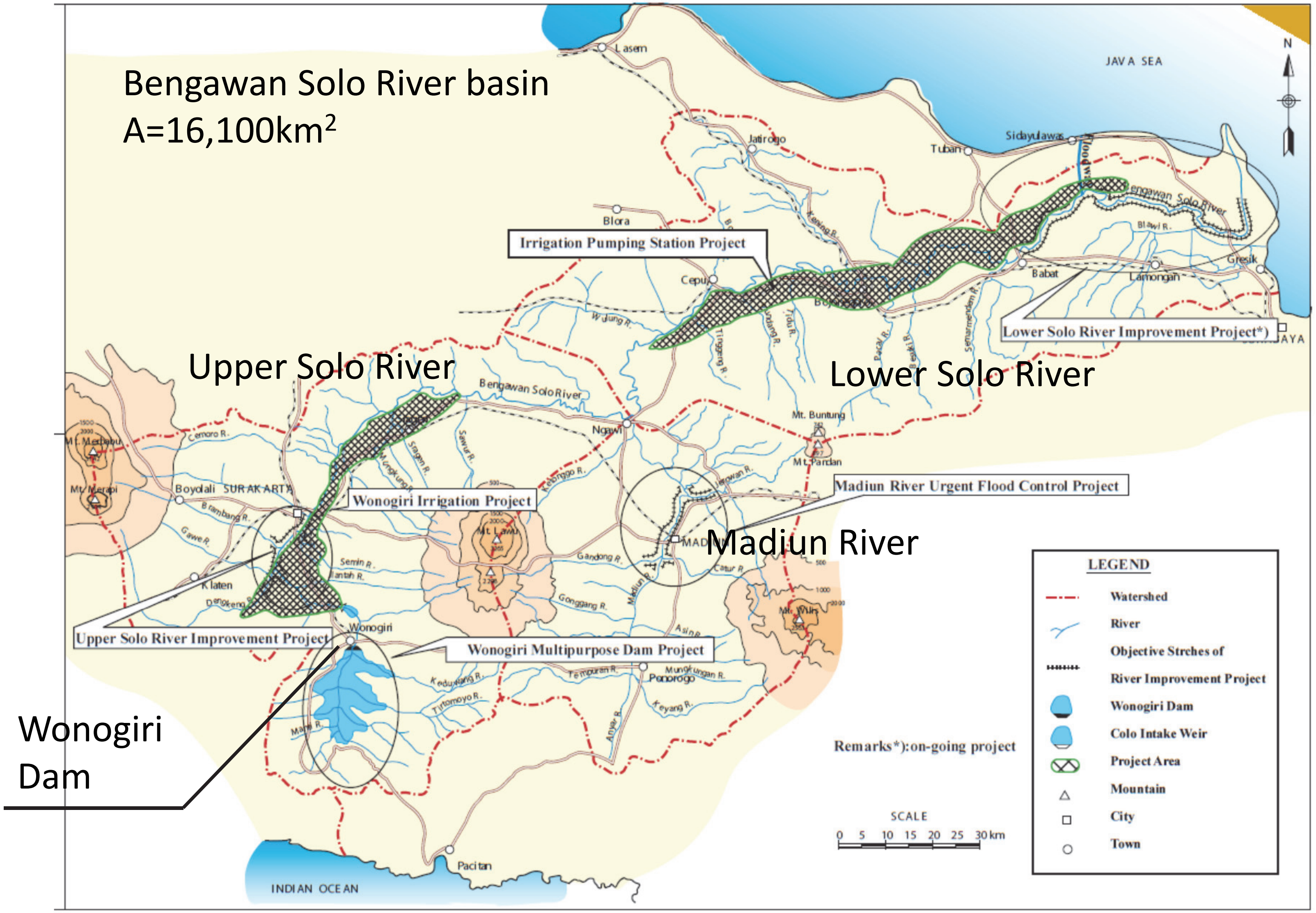
1. Introduction

Objectives of Drought Assessment

Our drought assessment has the following aims:

1) To improve the BTOP model for the drought characterization
2) To apply our drought assessment in five river basins in Asian countries

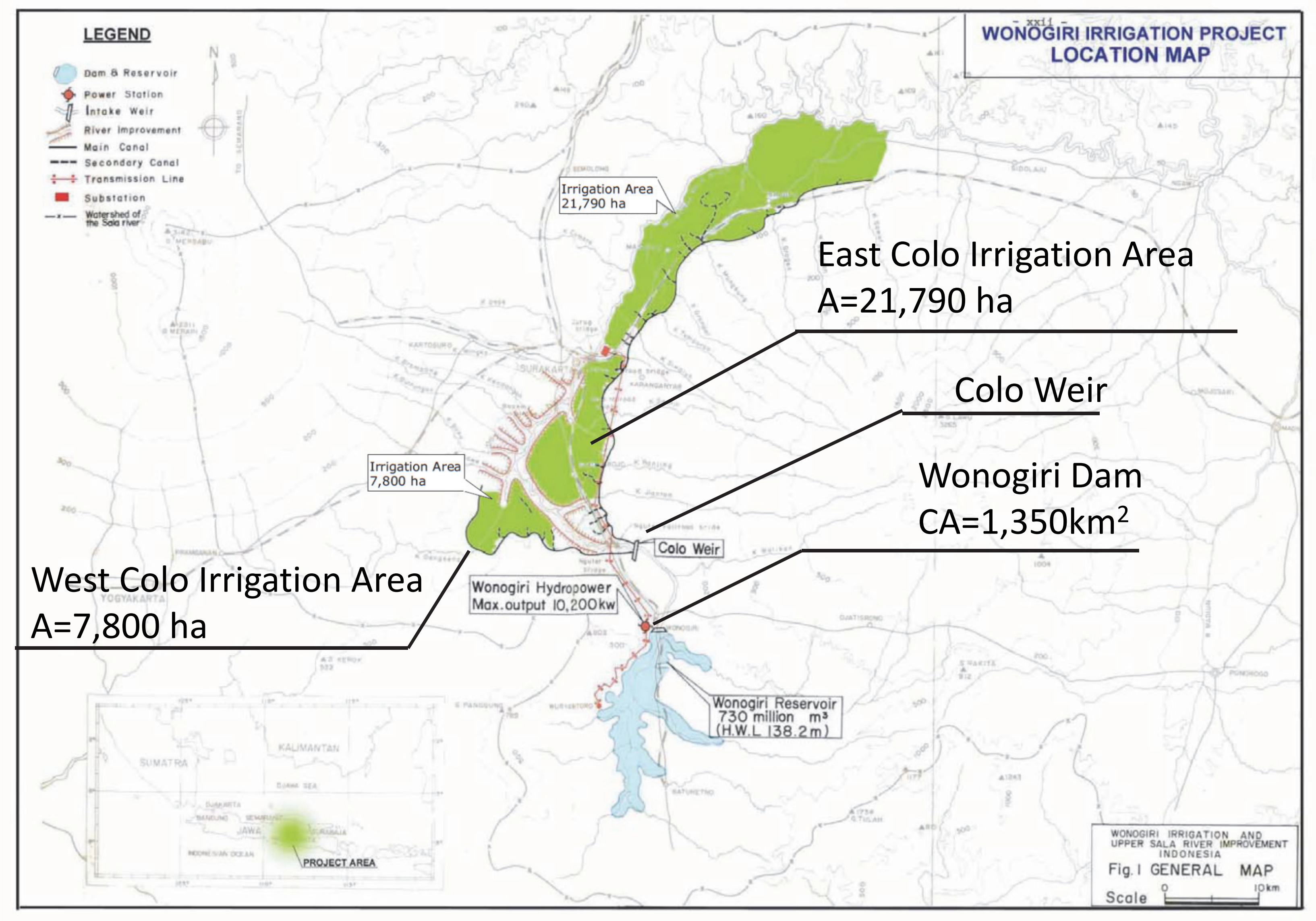
Study Area of the Bengawan Solo River Basin



Source: JICA(2001),BASIC DESIGN STUDY ON URGENT COUNTERMEASURES FOR SEDIMENTATION IN WONOGIRI MULTIPURPOSE DAM RESERVOIR IN THE REPUBRIC OF INDONESIA

2. Water resources management in the Upper Solo River basin

Area of Wonogiri Irrigation Project



East Colo Irrigation Area
A=21,790 ha

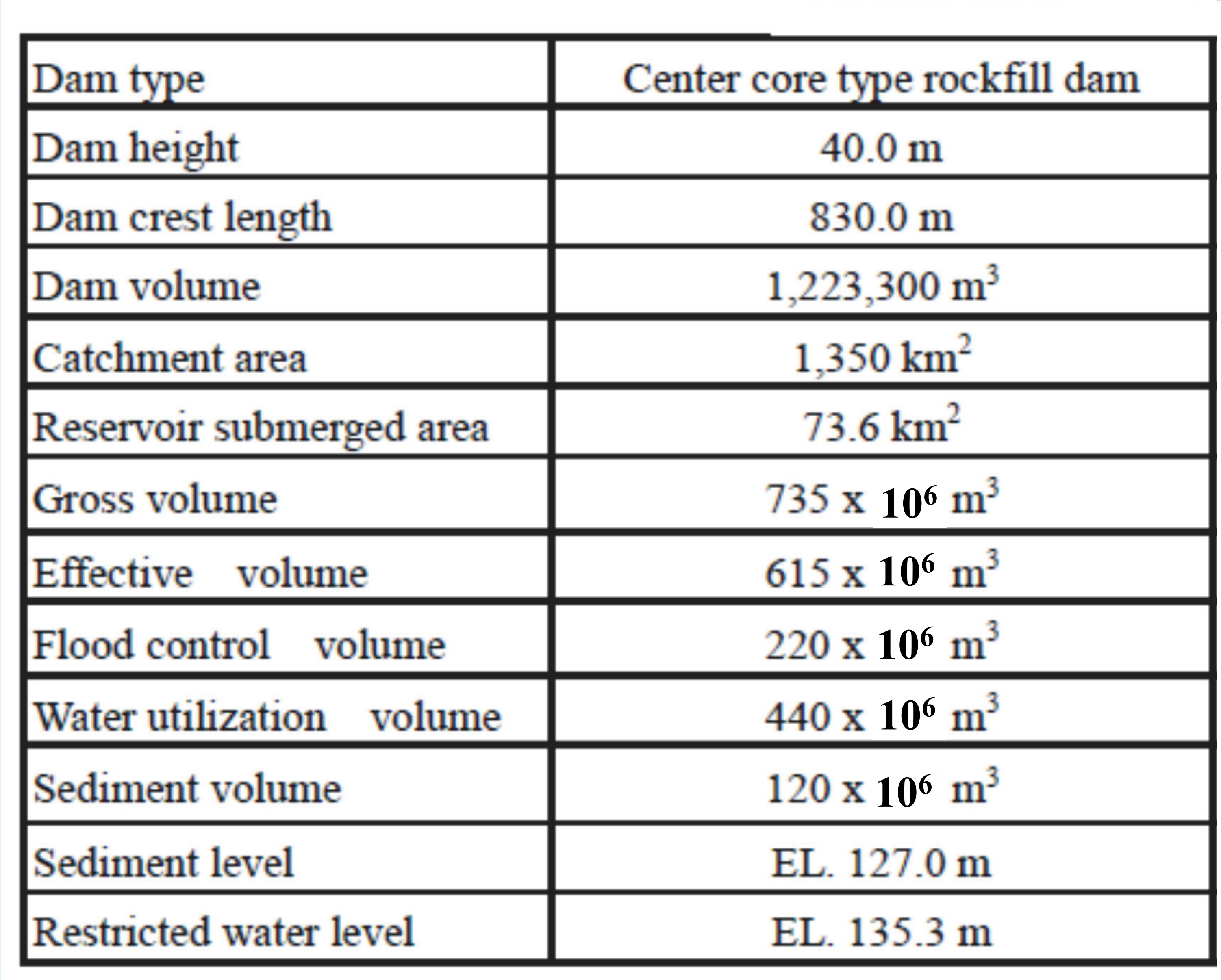
Colo Weir

Wonogiri Dam
CA=1,350km^2

West Colo Irrigation Area
A=7,800 ha

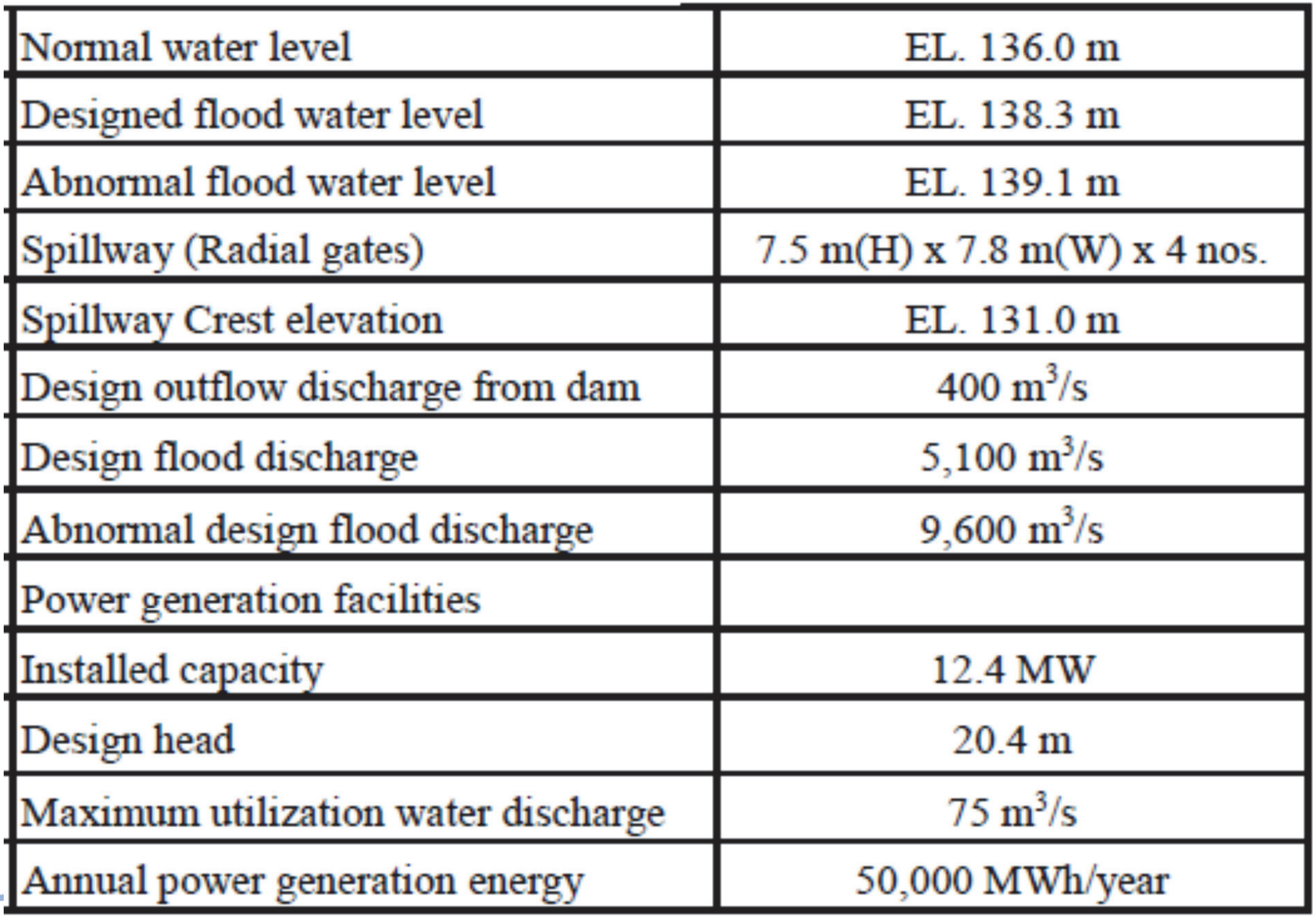
Source: JICA(2001),BASIC DESIGN STUDY ON URGENT COUNTERMEASURES FOR SEDIMENTATION IN WONOGIRI MULTIPURPOSE DAM RESERVOIR IN THE REPUBRIC OF INDONESIA

Description of Wonogiri Multipurpose Dam



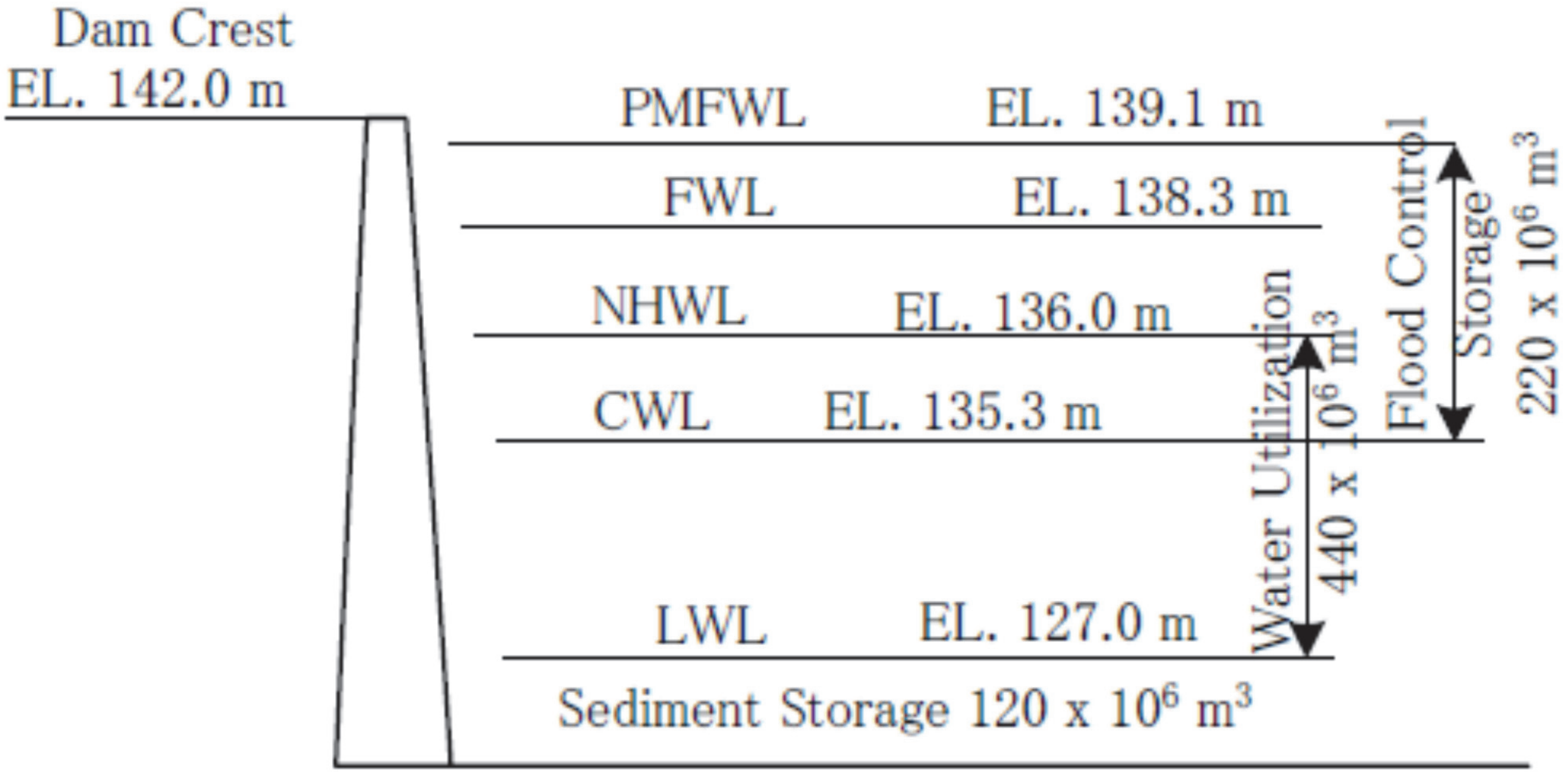
Dam type	Center core type rockfill dam
Dam height	40.0 m
Dam crest length	830.0 m
Dam volume	1,223,300 m^3
Catchment area	1,350 km^2
Reservoir submerged area	73.6 km^2
Gross volume	735 x 10^6 m^3
Effective volume	615 x 10^6 m^3
Flood control volume	220 x 10^6 m^3
Water utilization volume	440 x 10^6 m^3
Sediment volume	120 x 10^6 m^3
Sediment level	EL. 127.0 m
Restricted water level	EL. 135.3 m

Description of Wonogiri Multipurpose Dam



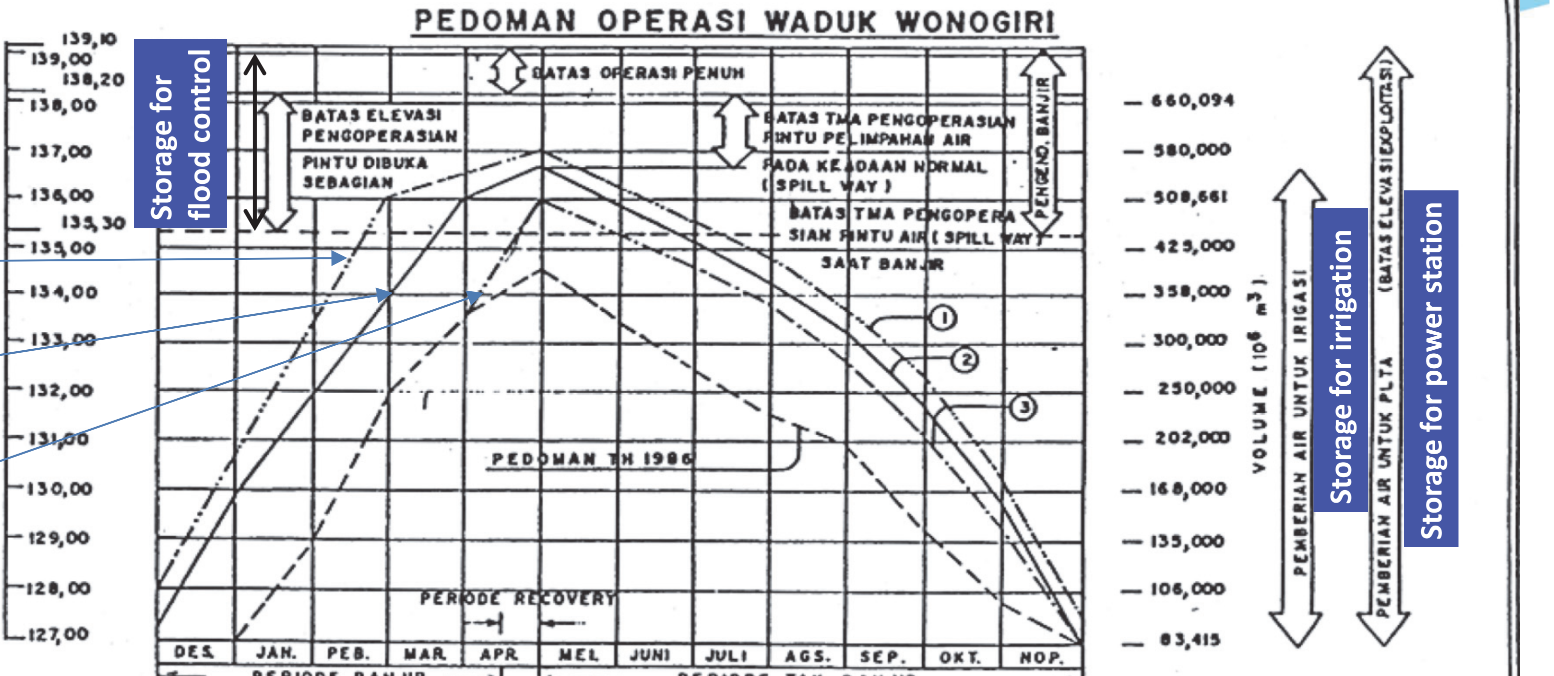
Normal water level	EL. 136.0 m
Designed flood water level	EL. 138.3 m
Abnormal flood water level	EL. 139.1 m
Spillway (Radial gates)	7.5 m(H) x 7.8 m(W) x 4 nos.
Spillway Crest elevation	EL. 131.0 m
Design outflow discharge from dam	400 m^3/s
Design flood discharge	5,100 m^3/s
Abnormal design flood discharge	9,600 m^3/s
Power generation facilities	
Installed capacity	12.4 MW
Design head	20.4 m
Maximum utilization water discharge	75 m^3/s
Annual power generation energy	50,000 MWh/year

Description of Wonogiri Multipurpose Dam



Source: JICA(2001),BASIC DESIGN STUDY ON URGENT COUNTERMEASURES FOR SEDIMENTATION IN WONOGIRI MULTIPURPOSE DAM RESERVOIR IN THE REPUBRIC OF INDONESIA

Wonogiri Reservoir Operation Guidelines


PEDOMAN OPERASI WADUK WONOGIRI

① - Maximum target water level (w.l.)

② - Normal target w. l.

③ - Minimum target w. l.

			DES.	JAN.	PEB.	MAR.	APR.	MEI	JUNI	JULI	AGS.	SEP.	OKT.	NOP.
			PERIODE BANJIR					PERIODE TAK BANJIR						
Total discharge for power station (irrigation + flow maintenance) [m³/s]	Q PLTA (m³/dt)	①	72,3	72,3	72,3	72,3	61	25	19	20	30	33	32	31
		②	60	70	70	61	50	25	21	25	21	30	30	30
		③	20	20	20	20	16	20	20	20	25	28	27	25
Discharge for irrigation [m³/s]	Q IRIGASI (m³/dt)	①	21	20	21	21	21	17	11	12	11	21	21	21
		②	20	20	20	20	20	11	11	11	11	20	20	20
		③	10	10	10	10	11	10	8	11	7	14	20	20
Discharge for river flow maintenance [m³/s]	RM. DLL. (m³/dt)	①	51,3	52,3	51,3	51,3	40	8	8	8	19	12	11	10
		②	40	50	50	41	30	12	10	14	10	10	10	10
		③	10	10	10	10	5	10	12	9	18	14	7	5
Irrigated area [ha] East Colo + West Colo	LUAS DICT+DICB (Ha)	①	30 000	20898	260 110	30 000	30000	20776	26010	30000	25 500	21000	30000	30000
		②	27382	27 382	27382	27382	27382	27382	27382	27382	27382	27382	27 382	27382
		③	15 000	15000	15000	15000	16 500	19584	25566	27 000	9796	14908	25 566	27 300

KETERANGAN

— — —	PEDOMAN OPERASI 1986
—··—	PEDOMAN TMA MAKSIMUM 1994
———	PEDOMAN TMA NORMAL 1994
—·—·—	PEDOMAN TMA MINIMUM 1994

DICT = 22 232 Ha
DICB = 5150 Ha
DI MAX = 30 000 Ha
DICT = DAERAH IRIGASI COLO TIMUR
DICB = DAERAH IRIGASI COLO BARAT
RM = RIVER MAINTENANCE

Flood season: 1 December to 15 April / Non-flood season: 1 May to 30 November

PLTA: Pusat Listrik Tenaga Air, DICT: Daerah Irigasi Colo Timur, DICB: Daerah Irigasi Colo Barat, DLL: Dengan Lain-Lain

Source: Operasi Pemantaatan Air Bendungan Serbaguna Wonogiri, Departmen Pekerjaan Umum, Directorat Jenderal Pengairan, Proyek Induk Pengembangan Wilayah Sungai Bengawan Solo, Nopember 1993

Wonogiri Reservoir Operation Guidelines

(a) Dam Operation Term

- Flood season: 1 December to 15 April
- Recovery period: 16 April to 30 April
- Non-flood season: 1 May to 30 November

(b) Target Water Level / Irrigation Plan (area, discharge)

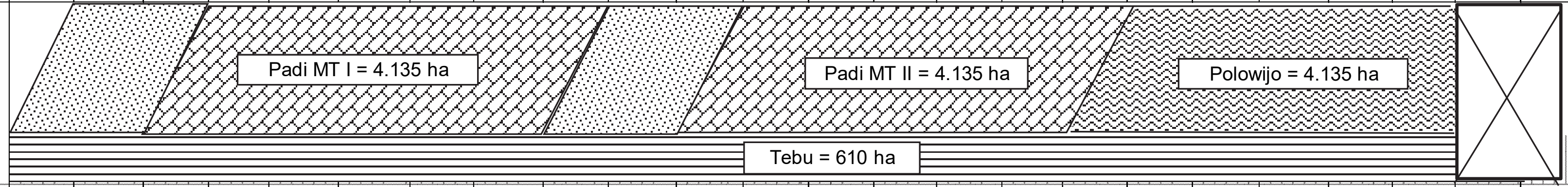
- **Three target water levels of reservoir are set up, i.e., Maximum target water level (①), Normal target water level (②) and Minimum target water level (③).**
- **The irrigation area and discharge for irrigation for each month are determined according to the water level of the reservoir.**

(c) Release Plan

- Release from the reservoir is the total value of the irrigation and the river maintenance.
- Release from the reservoir is also utilized for power generation.

Planting patterns for the calculation of water needs / Irrigation plan for MTI, MTII, MTIII

POLA TANAM DAN RENCANA TATA TANAM, PENGERINGAN SALURAN SERTA PERHITUNGAN KEBUTUHAN AIR UNTUK TANAMAN
DAERAH IRIGASI COLO TIMUR
MASA TANAM TAHUN 2011/2012



No.	Uraian	Nopember		Desember		Januari		Pebruari		Maret		April		Mei		Juni		Juli		Agustus		September		Oktober	
		1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2
1	**Golongan A** Luas`Sawah = 4.745 Ha																								
	Kebutuhan air :																								
	- Padi	7,812	7,775	4,087	4,293	4,520	4,382	1,212	0	978	2,489	618	6,050	5,568	5,431	4,950	0	0	0	0	0	0	0	0	0
	- Tebu	393	404	0	0	0	0	0	0	0	0	0	0	0	271	361	344	466	466	517	517	558	558	517	471
	- Palawija	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2,062	2,062	1,682	1,522	2,475	2,475	2,681	2,681
	Jumlah :	*8,205*	*8,249*	*5,706*	*5,608*	*4,729*	*4,538*	*4,031*	*0*	*978*	*2,489*	*618*	*6,050*	*5,568*	*5,702*	*5,311*	*344*	*2,528*	*2,528*	*2,199*	*2,039*	*3,033*	*3,033*	*3,198*	*3,152*

Keterangan :

▨ Pengolahan Tanah Tanaman Padi ▩ Pertumbuhan Tanaman Padi ▦ Tanaman Palawija ☰ Tanaman Tebu ☒ Pengeringan

MT Ⅰ : Nov. 2011 to Feb.2012, MT Ⅱ : Mar.2012 to June 2012, MT Ⅲ : July 2012 to Oct. 2012

PERHITUNGAN KEBUTUHAN AIR UNTUK TANAMAN PADI
DAERAH IRIGASI COLO TIMUR
MASA TANAM TAHUN 2011/2012

Satuan l/det

No	Uraian	B u l a n																							
		Nopember		Desember		Januari		Pebruari		M a r e t		April		M e i		J u n i		J u l i		Agusyus		September		Oktober	
		1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2
1	Golongan A Padi = 4.135 Ha																								
	(a) Satuan Kebutuhan Air (lt/dt/Ha)	1.20	1.20	0.70	0.73	0.78	0.76	0.71	0.00	1.12	1.12	0.85	0.88	0.81	0.79	0.72	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	(b) Kebt. air di petak sawah (lt/dt)	4962	4962	2895	3019	3225	3143	2936	0	4631	4631	3515	3639	3349	3267	2977	0	0	0	0	0	0	0	0	0
	(c). Hujan efektif (lt/dt)	263	285	436	436	506	507	2207	4099	4043	3134	3143	0	0	0	0	0	0	0	0	0	0	225	257	289
	(d) Kebt. Air irigasi di sawah (lt/dt)	4699	4677	2458	2582	2719	2636	729	-4099	588	1497	372	3639	3349	3267	2977	0	0	0	0	0	0	-225	-257	-289
	(e) Kebt air di pintu sadap tersier. (lt/dt)	5874	5846	3073	3228	3399	3295	911	-5124	736	1871	465	4549	4187	4083	3722	0	0	0	0	0	0	-281	-321	-361
	(f) Kebt air di jaringan utama (lt/dt)	7812	7775	4087	4293	4520	4382	1212	0	978	2489	618	6050	5568	5431	4950	0	0	0	0	0	0	0	0	0

(a) = data, (b) = 4.135 X (a), (c) = data, (d) = (b) - (c), (e) = (d) X 1.25, (f) = (e) X 1.33

Source:
Documents
from
Balai PSDA
Bengawan Solo

Planting periods / Irrigation plan

- Three planting periods, MTⅠ, MTⅡ and MTⅢ, are set up in a year.
- MT means “masa tanam (planting period)” and each MT is about 4 months.
- Starts of planting period are slightly different for each Kabpaten (Sukoharjo, Karanganyar, Sragen, Wonogiri and Klaten), mostly MTⅠ start in November.
- Rice is planted both in MTⅠ(Wet season planting) and MTⅡ(Dry season planting).
- Crops in MTⅡ greatly depend on irrigation water from a reservoir.
- There are several documents regarding Irrigation plan , i.e., “Rencana Luas Tanam per Daerah Irigasi per Masa Tanam (Plan of planting area per irrigation area for each planting period)”, “Perhitungan Kebutuhan Air Untuk Tanaman Pad (Water need calculation for the paddy fields), and etc.

Wonogiri Reservoir

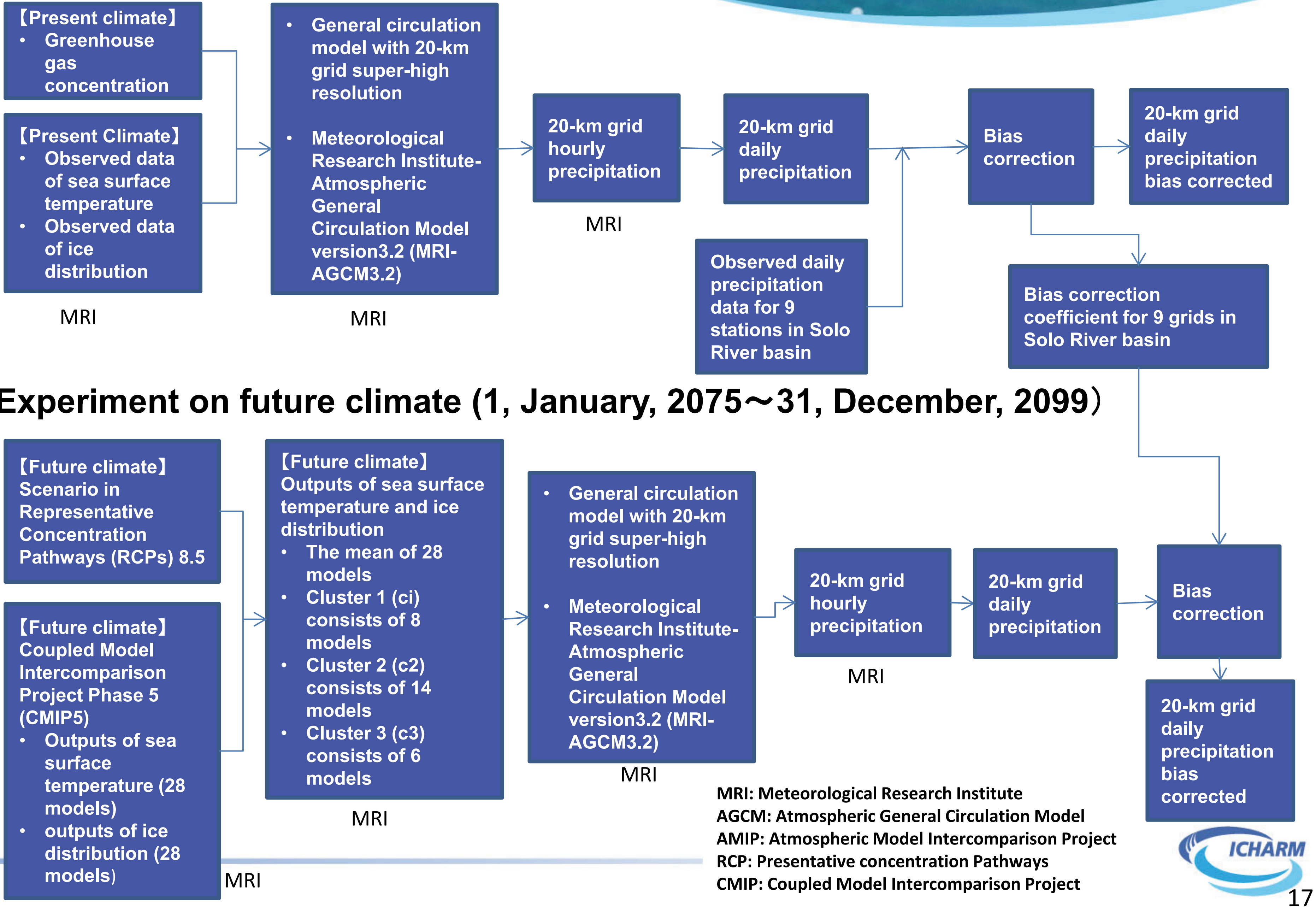
Colo Weir

Irrigated Paddy Field

Main Water Channel

3. Simulation Method

Experiment on present climate (1, January, 1979～31, December, 2003）



【Present climate】
- Greenhouse gas concentration

【Present Climate】
- Observed data of sea surface temperature
- Observed data of ice distribution

MRI

- General circulation model with 20-km grid super-high resolution
- Meteorological Research Institute-Atmospheric General Circulation Model version3.2 (MRI-AGCM3.2)

MRI

20-km grid hourly precipitation

MRI

20-km grid daily precipitation

Observed daily precipitation data for 9 stations in Solo River basin

Bias correction

20-km grid daily precipitation bias corrected

Bias correction coefficient for 9 grids in Solo River basin

Experiment on future climate (1, January, 2075～31, December, 2099）

【Future climate】
Scenario in Representative Concentration Pathways (RCPs) 8.5

【Future climate】
Coupled Model Intercomparison Project Phase 5 (CMIP5)
- Outputs of sea surface temperature (28 models)
- outputs of ice distribution (28 models)

MRI

【Future climate】
Outputs of sea surface temperature and ice distribution
- The mean of 28 models
- Cluster 1 (ci) consists of 8 models
- Cluster 2 (c2) consists of 14 models
- Cluster 3 (c3) consists of 6 models

MRI

- General circulation model with 20-km grid super-high resolution
- Meteorological Research Institute-Atmospheric General Circulation Model version3.2 (MRI-AGCM3.2)

MRI

20-km grid hourly precipitation

MRI

20-km grid daily precipitation

Bias correction

20-km grid daily precipitation bias corrected

MRI: Meteorological Research Institute
AGCM: Atmospheric General Circulation Model
AMIP: Atmospheric Model Intercomparison Project
RCP: Presentative concentration Pathways
CMIP: Coupled Model Intercomparison Project

Experiment on present and future climate

Observed sea surface temperature, ice distribution and green house gas concentration are used as the boundary conditions for the present climate(AMIP) of MRI-AGCM3.2S models.

Four outputs of sea surface temperature and ice distribution are obtained for the future climate experiments:

- Cluster 1 (c1) consists of 8 MRI-AGCM3.2S models with nearly uniform warming in the both hemispheres.
- Cluster 2 (c2) has 14 models with a larger warming over the central equatorial Pacific (so-called El Niño-like pattern).
- Cluster 3 (c3) has 6 models with a larger warming in the Northern Hemisphere than in the Southern Hemisphere.
- The mean of these 28 CMIP5 models (MME) is considered a baseline future precipitation while c1, c2 and c3 cases represent climate change uncertainty.

BTOP model cell-by-cell calculation

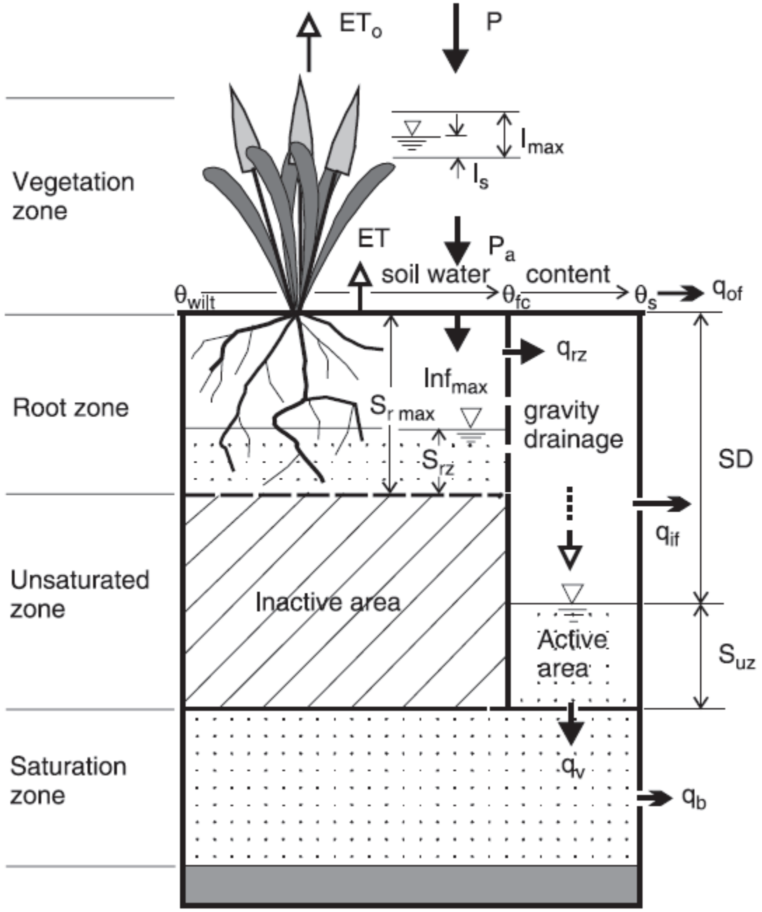


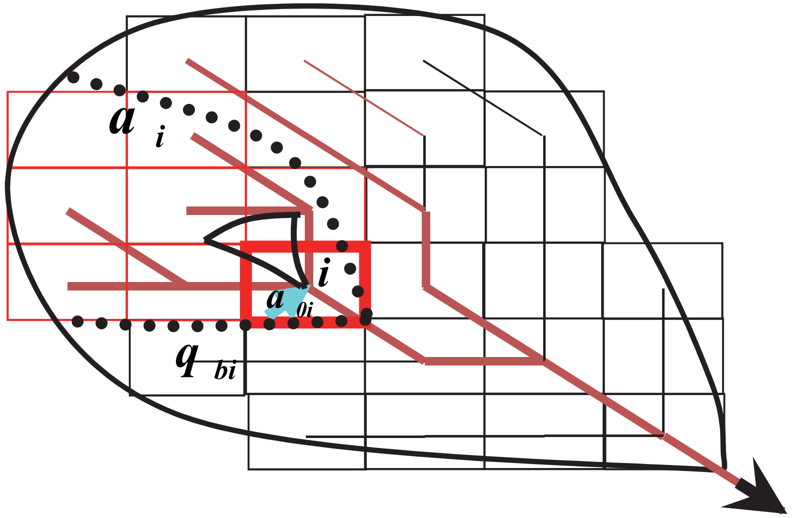
Figure 3. Runoff generation in a grid cell in the BTOP model (the vertical profile). P is the gross rainfall, ET_o is the interception evaporation, $I_{\max}$ is the interception storage capacity, I is the interception state, $Inf_{\max}$ is the infiltration capacity, P_a is the net rainfall on the land surface, ET is the actual evapotranspiration, $S_{r\ max}$ is the storage capacity of the root zone, S_{rz} is the soil moisture state in root zone, SD is soil moisture deficit in unsaturated zone, S_{uz} is the soil moisture state in unsaturated zone, q_{of} is the overland runoff, q_{if} is the saturation excess runoff, q_v is the groundwater recharge, and q_b is groundwater release. θ_{wilt}, θ_{fc}, θ_s are soil water content at wilting point, field capacity and saturation respectively

The BTOP model processes are:

- 24 hourly simulation using rainfall or precipitation
- temperature input for snow module
- calculates actual evapotranspiration
- cell-by-cell variable properties
- root and unsaturated soil moisture
- saturated flow using Darcy's law

New research:

- river water diversion points (developed by Dr. Jun Magome, University of Yamanashi),
- Irrigation water release from dams, and
- Groundwater and irrigation Water Modules.

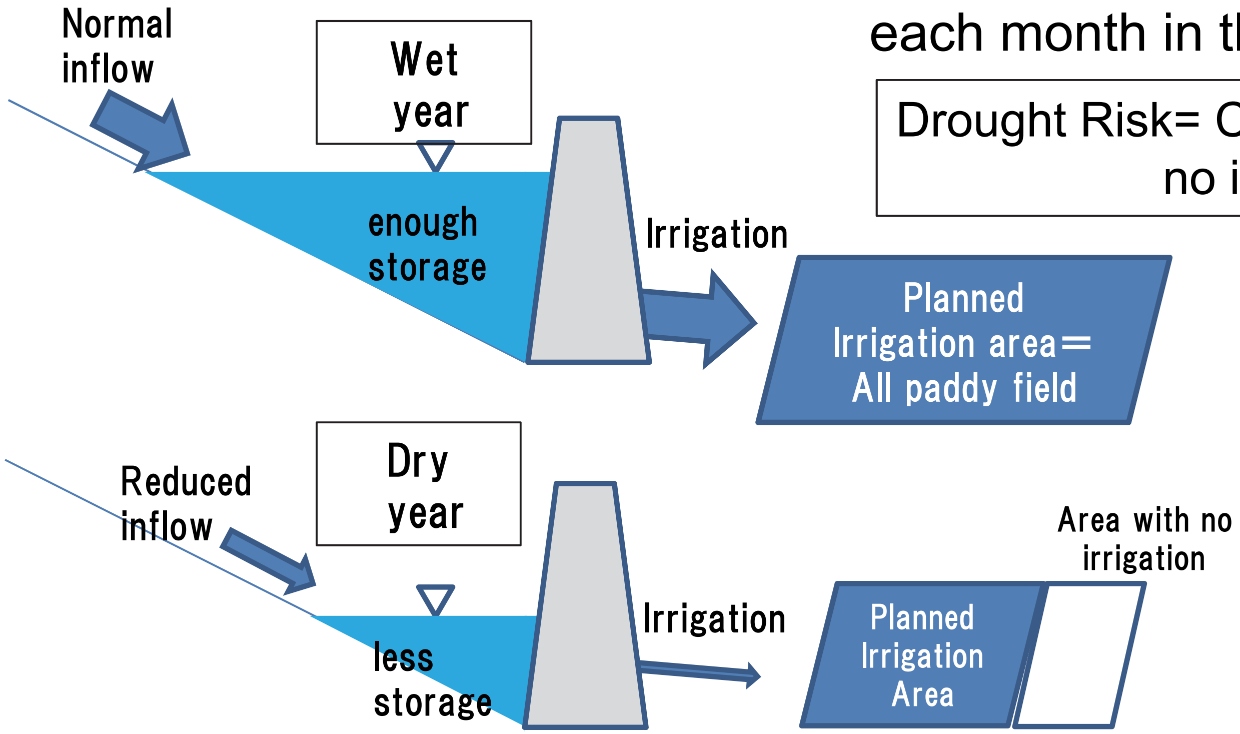


Reference: Takeuchi et. al. (2008) A BTOP model to extend TOPMODEL for distributed hydrological simulation of large basins, Hydrological Processes, 22, 3236-3251, http://onlinelibrary.wiley.com/doi/10.1002/hyp.6910/abstract

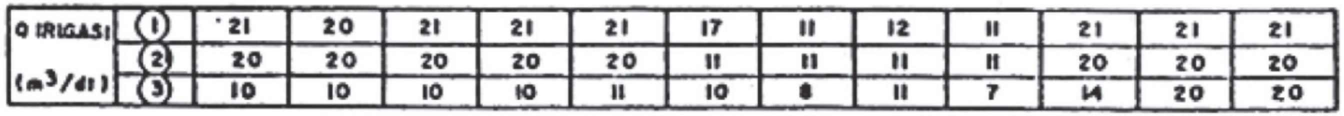
Proposed Method for Drought Risk Assessment

Irrigated area in dry season is determined by considering the reservoir water level at the 1st day of each month in this model.

Drought Risk= Crop Loss due to no irrigation

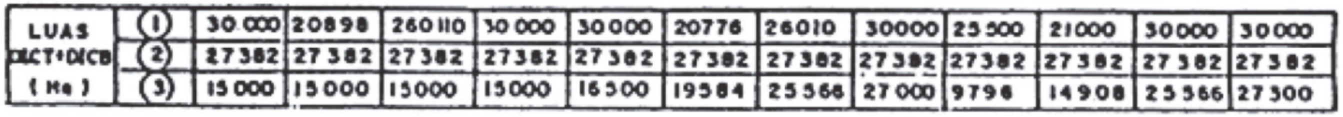


Discharge for irrigation [m³/s]



Q IRIGASI (m³/dt)	①	˙21	20	21	21	21	17	11	12	11	21	21	21
	②	20	20	20	20	20	11	11	11	11	20	20	20
	③	10	10	10	10	11	10	8	11	7	14	20	20

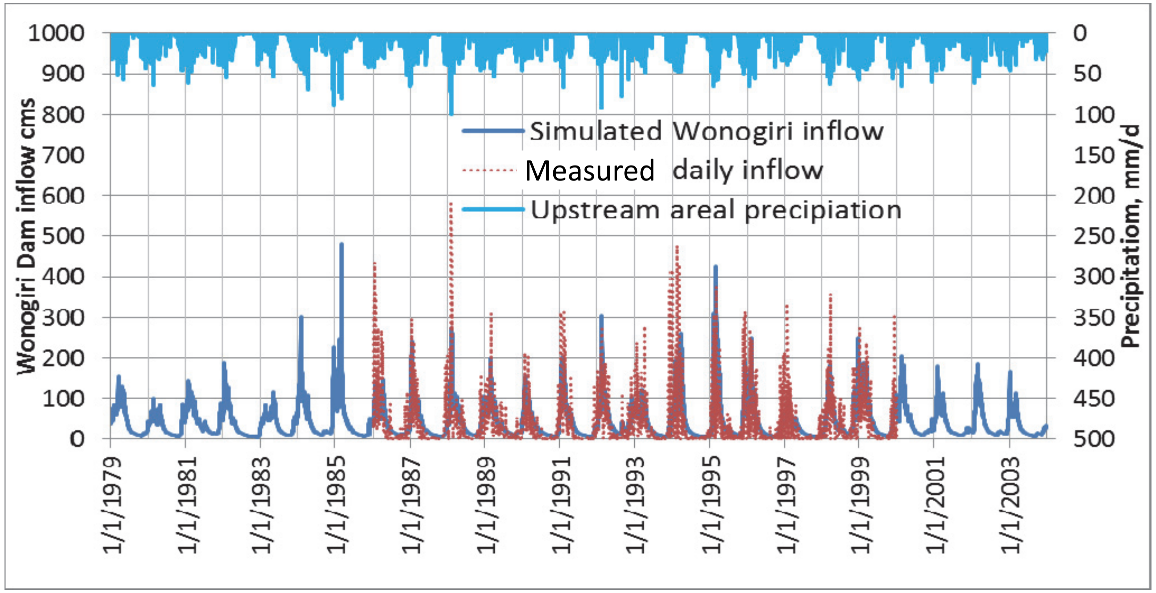
Irrigated area [ha]
East Colo + West Colo



LUAS DICT+DICB (Ha)	①	30 000	20898	260 110	30 000	30000	20776	26010	30000	25 500	21000	30000	30000
	②	27382	27 382	27382	27382	27382	27382	27382	27382	27382	27382	27 382	27382
	③	15 000	15 000	15000	15000	16500	19584	25566	27 000	9796	14908	25566	27300

4. Simulation Results

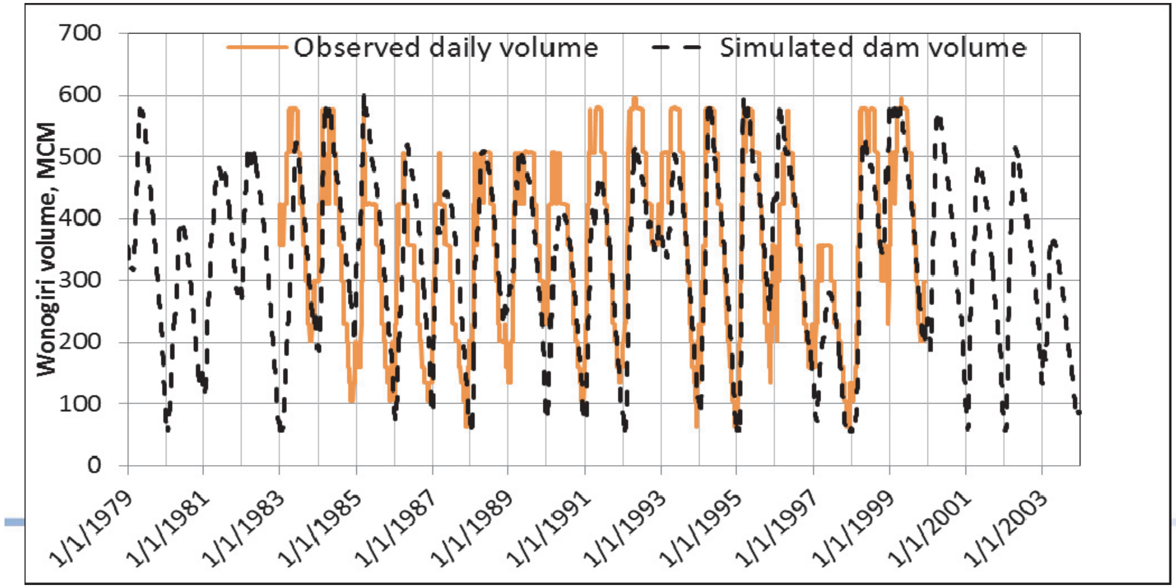
Measured and BTOP simulated Wonogiri Dam inflows with observed precipitation



1)

Wonogiri Dam (WD) daily inflows:

- BTOP model simulated with observed precipitation;
- Measured from the WD water balance.

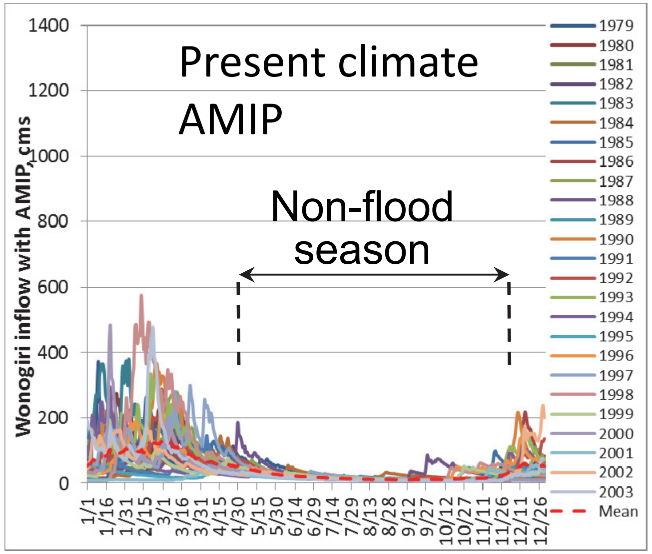


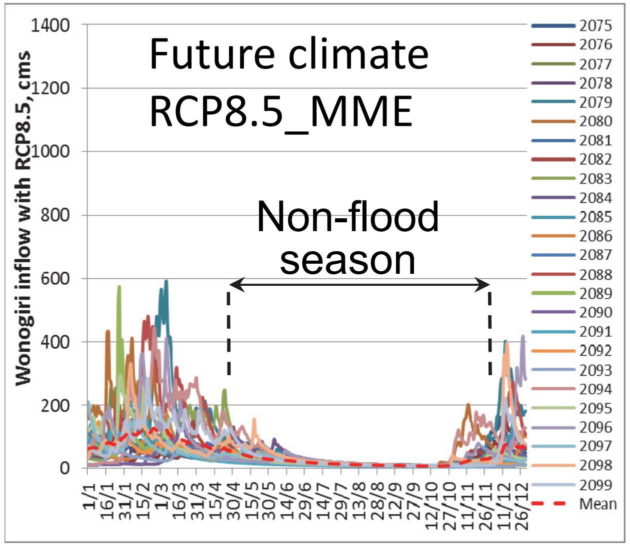
2)

BTOP simulated daily WD reservoir volume using operation guidelines.

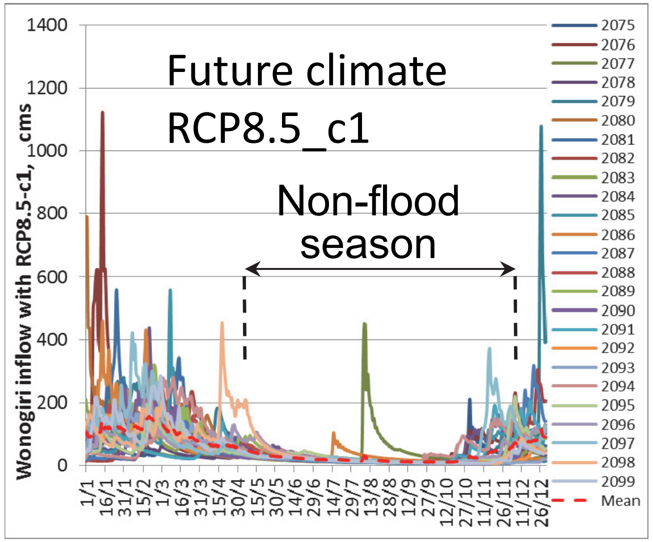
BTOP demonstrated good performance in simulating Wonogiri inflows and volume

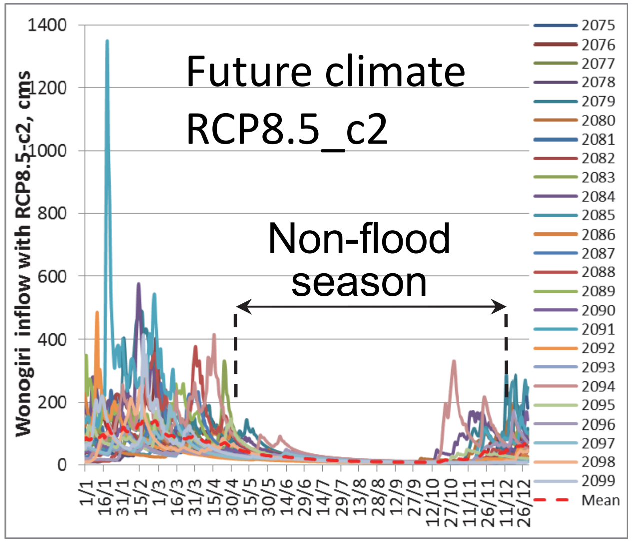
Comparison of daily Wonogiri Dam inflows for the present and the future climate experiments

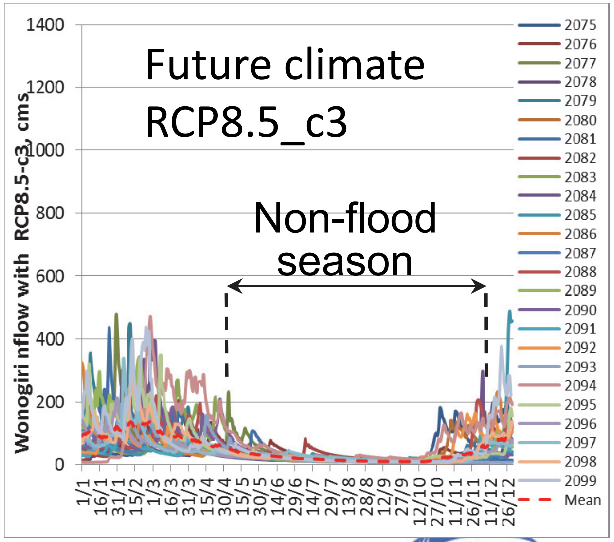




25 years of daily Wonogiri Dam inflows from the BTOP model simulation for the present (AMIP) and four RCP8.5 future climates.







ICHARM

Comparison of inflow into Wonogiri Dam for the present and the future climate

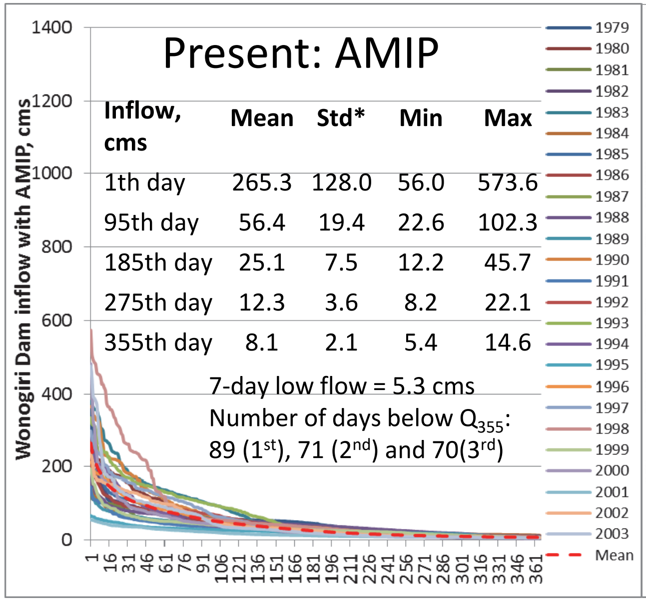
【Characteristics of the future climate】

- In the future climate, there is a possibility of large rainfall and flood even in the non-flood season (especially RCP8.5_c1).
- Compared to the present climate, the climate in the future has a tendency of an early start and prolonged duration of the flood season, so that a non-flood season may be shorten.
- There is a possibility that a very large inflow may occur in the flood season and could be a danger of causing a large water related disaster.
- Therefore, it is necessary to secure the flood control capacity as much as possible during the flood season by changing the operation of the dam.

Comparison of inflow regime of Wonogiri Dam for the present and the future climates

Sorted daily Wonogiri Dam inflows from largest to smallest for each year of the 25-year BTOP model simulation for the present (AMIP) and four RCP8.5 future climates.

*Std: Standard deviation

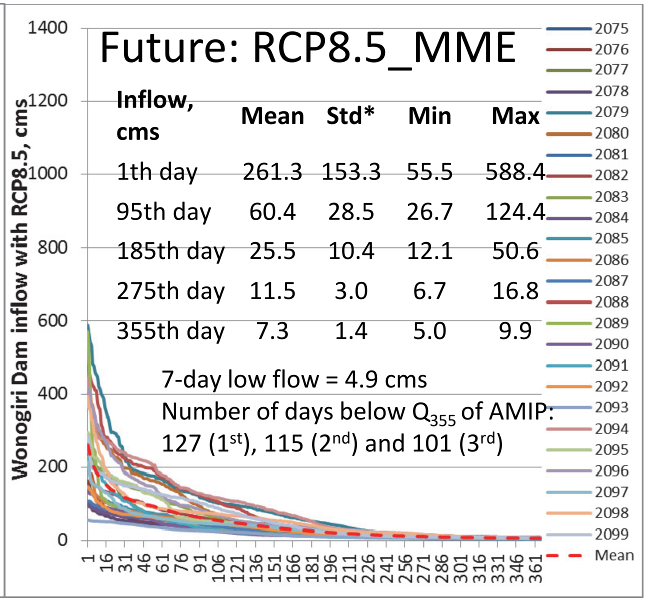


Present: AMIP

Inflow, cms	Mean	Std*	Min	Max
1th day	265.3	128.0	56.0	573.6
95th day	56.4	19.4	22.6	102.3
185th day	25.1	7.5	12.2	45.7
275th day	12.3	3.6	8.2	22.1
355th day	8.1	2.1	5.4	14.6

7-day low flow = 5.3 cms

Number of days below Q_{355}: 89 (1st), 71 (2nd) and 70(3rd)

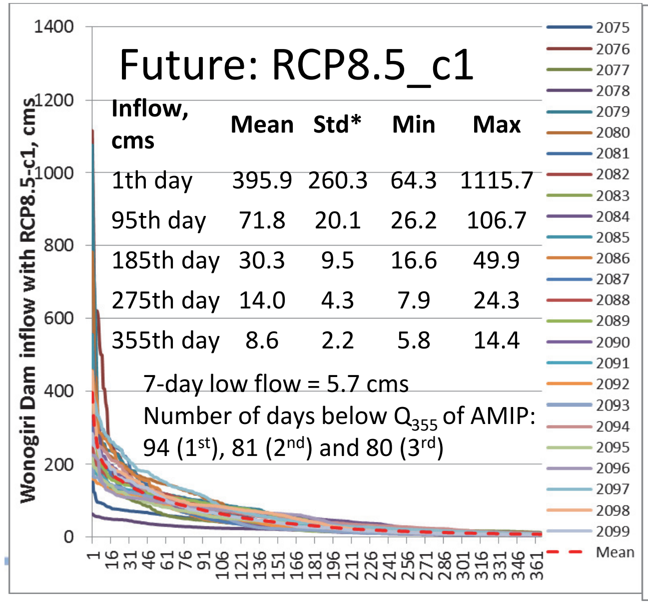


Future: RCP8.5_MME

Inflow, cms	Mean	Std*	Min	Max
1th day	261.3	153.3	55.5	588.4
95th day	60.4	28.5	26.7	124.4
185th day	25.5	10.4	12.1	50.6
275th day	11.5	3.0	6.7	16.8
355th day	7.3	1.4	5.0	9.9

7-day low flow = 4.9 cms

Number of days below Q_{355} of AMIP: 127 (1st), 115 (2nd) and 101 (3rd)

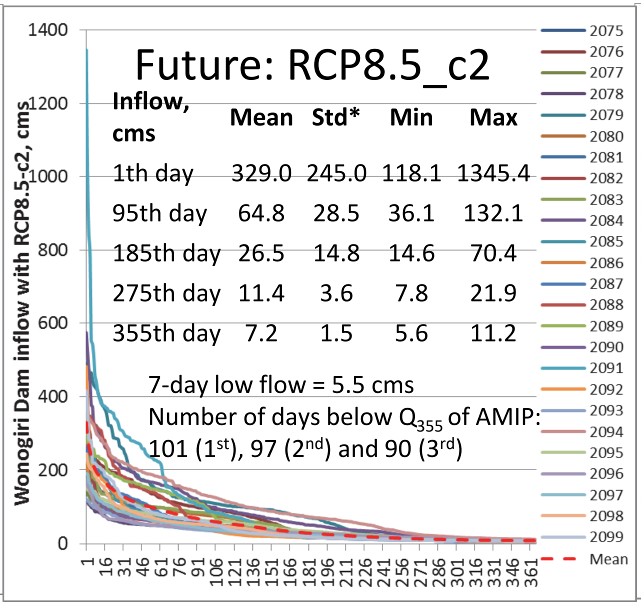


Future: RCP8.5_c1

Inflow, cms	Mean	Std*	Min	Max
1th day	395.9	260.3	64.3	1115.7
95th day	71.8	20.1	26.2	106.7
185th day	30.3	9.5	16.6	49.9
275th day	14.0	4.3	7.9	24.3
355th day	8.6	2.2	5.8	14.4

7-day low flow = 5.7 cms

Number of days below Q_{355} of AMIP: 94 (1st), 81 (2nd) and 80 (3rd)

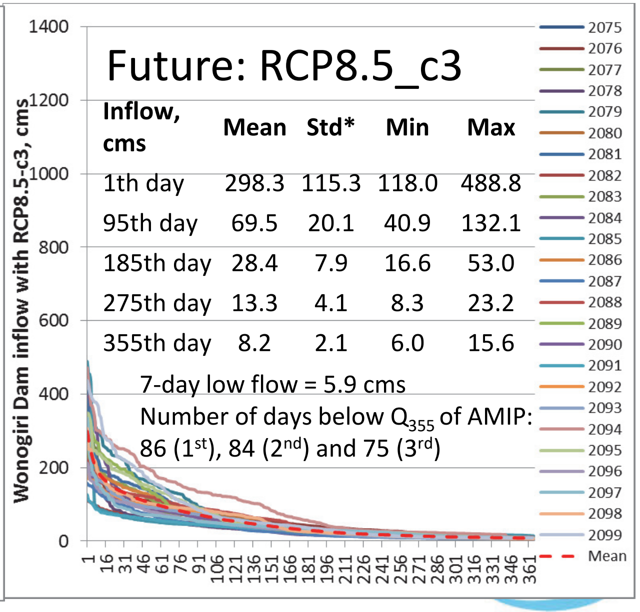


Future: RCP8.5_c2

Inflow, cms	Mean	Std*	Min	Max
1th day	329.0	245.0	118.1	1345.4
95th day	64.8	28.5	36.1	132.1
185th day	26.5	14.8	14.6	70.4
275th day	11.4	3.6	7.8	21.9
355th day	7.2	1.5	5.6	11.2

7-day low flow = 5.5 cms

Number of days below Q_{355} of AMIP: 101 (1st), 97 (2nd) and 90 (3rd)



Future: RCP8.5_c3

Inflow, cms	Mean	Std*	Min	Max
1th day	298.3	115.3	118.0	488.8
95th day	69.5	20.1	40.9	132.1
185th day	28.4	7.9	16.6	53.0
275th day	13.3	4.1	8.3	23.2
355th day	8.2	2.1	6.0	15.6

7-day low flow = 5.9 cms

Number of days below Q_{355} of AMIP: 86 (1st), 84 (2nd) and 75 (3rd)

Comparison of inflow regime of Wonogiri Dam for the present and the future climates

【Flow Regime】

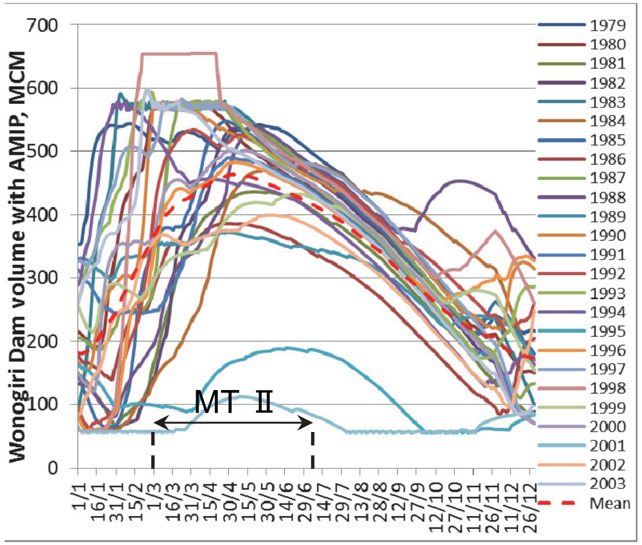
- Four symbolic order of daily inflows were set up for flow regime analysis besides annual maximum inflow.
- Q_{95} is the plentiful discharge, Q_{185} is the ordinary discharge, Q_{275} is the low water discharge and Q_{355} is the drought river discharge.
- These values represent flow regime of a river.

【Characteristics of the future climate】

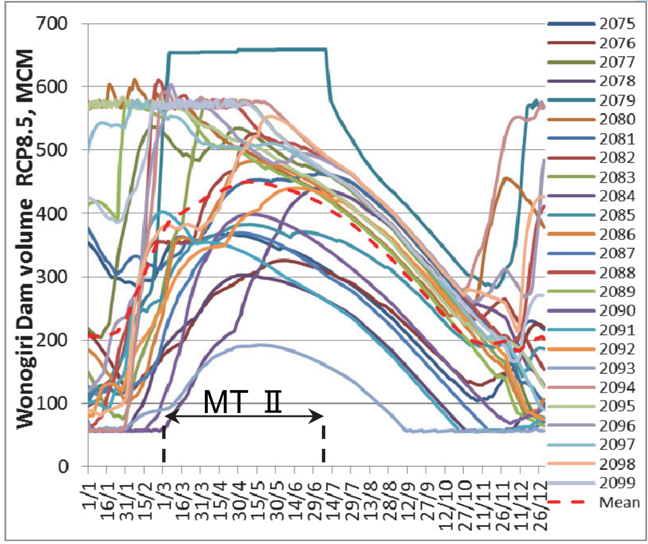
- The averaged annual maximum inflow tends to increase greatly in RCP8.5_c1.
- The averaged 95th inflow tends to increase.
- The number of days below Q_{355} (=8.1m^3/s) of the present(AMIP) tends to increase in the future climate, so that there is a concern of the occurrence of low water in a river.

Comparison of the Wonogiri Dam Water Storage change

Present: AMIP

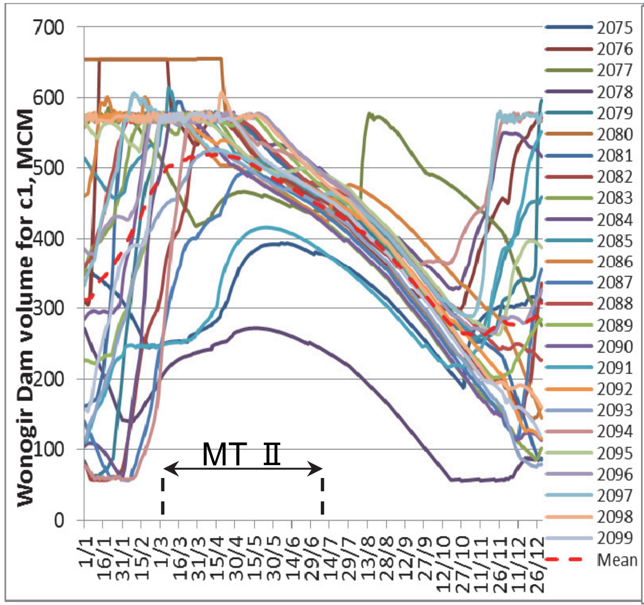


Future: RCP8.5_MME

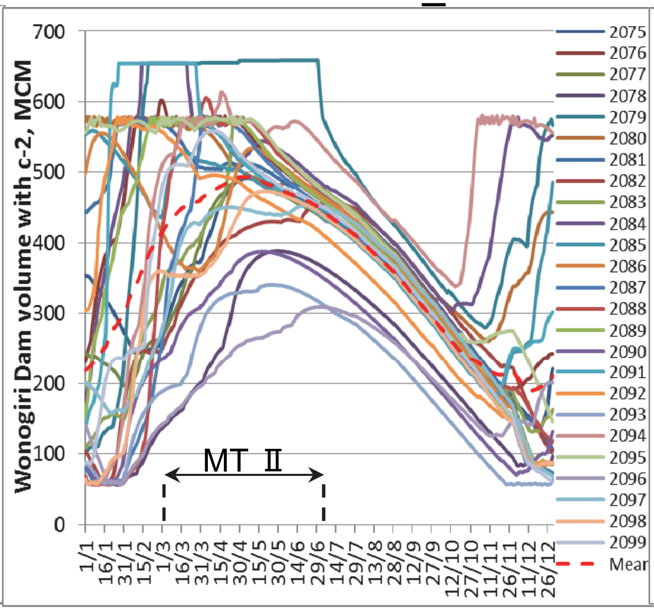


25 years of daily Wonogiri Dam water storage from the BTOP model simulation for the present (AMIP) and four RCP8.5 future climates.

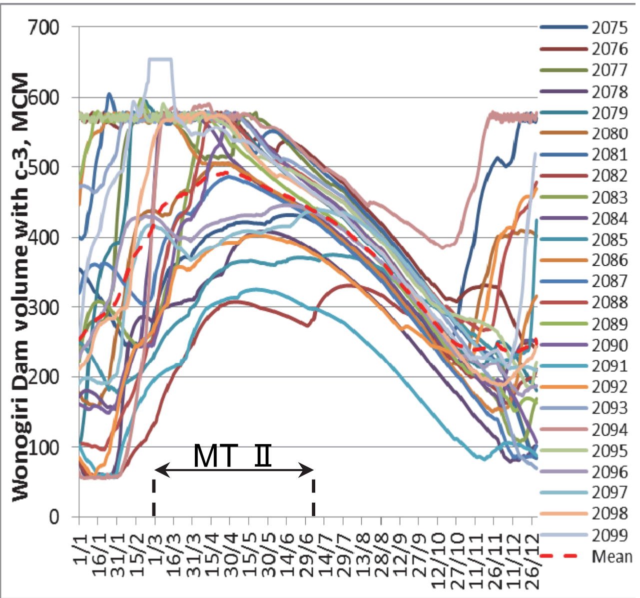
Future: RCP8.5_c1



Future: RCP8.5_c2



Future: RCP8.5_c3



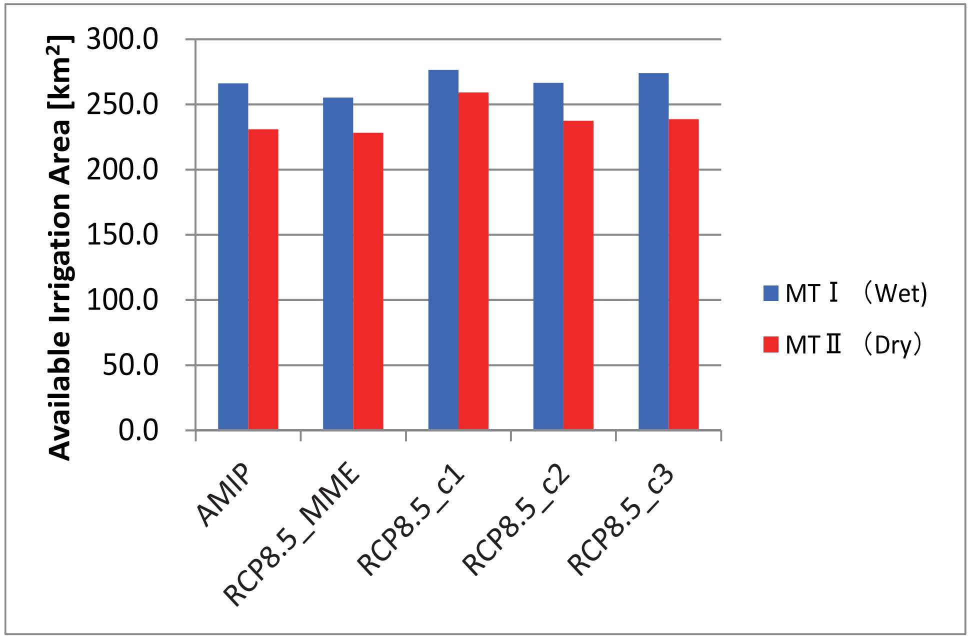
Comparison of the Wonogiri Dam Water Storage change

【Characteristics of the future climates】

- In all cases of present and future climates, the reservoir will not be empty during MTⅡ.
- In some cases, the reservoir will be empty in late MT Ⅲ but it will not affect the rice crop.
- In the present climate, there is a little ineffective release from reservoirs, but in future climates there will be a period of ineffective release in each case.
- It is possible to increase the water discharge by changing the dam operation rule, moreover it raises an importance of the flood control function.

Comparison of Available Irrigation Area for the present and the future climate

	MT Ⅰ（Wet)		MT Ⅱ（Dry）	
	Area [km^2]	Ratio	Area [km^2]	Ratio
AMIP	266.7	1.00	230.8	1.00
RCP8.5_MME	255.2	0.96	228.2	0.99
RCP8.5_c1	276.5	1.04	259.0	1.12
RCP8.5_c2	266.5	1.00	237.4	1.03
RCP8.5_c3	274.0	1.03	238.6	1.03



Available irrigation area
for the present and the future climate

- The available irrigation area in MT I (Wet) is almost same between the present and the future.
- On the other hand, the available irrigation area in MT II (Dry) tends to increase both c1, c2, and c3, and in MT II (Dry), which is heavily dependent on reservoirs, the drought risk is expected to decrease in the future.

5. Conclusion

1) In the future climate, there is a possibility of large rainfall and flooding even in the non-flood season.
2) There is a possibility that a very large inflow may occur in the flood season and there is a danger of becoming a large water related disaster.
3) In the present climate, there is a little ineffective release of water resources, but in future climates there will be a period of ineffective release.
4) In the future climate, it is possible to increase the water discharge by changing the dam operation rule, moreover it raises an importance of flood control function.
5) The available irrigation area in MT II (Dry) tends to increase in future and the drought risk is expected to decrease.

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2) Hasegawa A., Gusyev M. A., and Y. Iwami (2016). Meteorological Drought and Flood Assessment using the Comparative SPI Approach in Asia under Climate Change. Journal of Disaster Research 11(6): 1082-1090, doi: 10.20965/jdr.2016.p1082

Trima kasih !

PWRI and Mt. Tsukuba