Recurrent Water-related Disasters in Japan

Events and Countermeasures

Oct., 2013
Izu Oshima Island (Sediment)
- 824mm/24hrs (Typhoon)
- Human Loss: 39
- *evacuation warning*

Aug., 2014
Hiroshima City (Sediment)
- 121mm/hr (Typhoon, Frontal Line)
- Human Loss: 74
- *evacuation warning, land use*

Sep., 2015
Kanto & Tohoku (Bank Breach)
- 551mm/24hrs (Typhoons)
- Human Loss: 8
- *evacuated by helicopter: 1339 and by boat: 2919*

Aug., 2016
Hokkaido & Tohoku (Bank Breach and Sediment)
- 251mm/72hrs (Typhoons)
- Human Loss: 27
- *evacuation of physical handicaps*
- *local socio-economic impact*

June, 2017
Northern Kyushu (Sediment)
- 299mm/6hrs (Frontal Line)
- Human Loss: 42
- *sediment and flood complex*

Nov., 2014
Amendment: Sediment Disasters Prevention Act

Jan., 2015:
Policy Vision: Disaster Prevention and Mitigation against a New Stage

May, 2015
Amendment: Flood Risk Management Act
- Probable Maximum Rainfall for Life-Saving

Dec., 2015
Policy Vision: Rebuilding Flood-Conscious Societies: Class A Rivers
- Raising public awareness
- Structural measures for crisis management

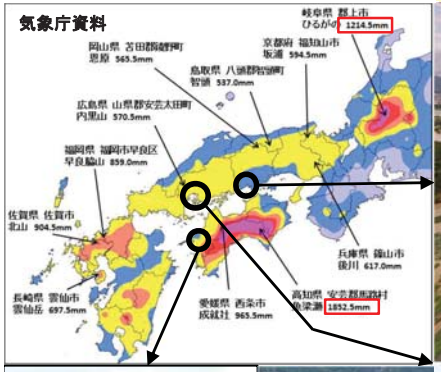
Jan., 2017
Policy Vision: Rebuilding Flood-Conscious Societies: Class B Rivers
- Life-saving of physical handicaps
- Local socio-economical continuity

May, 2017
Amendment: River Act
- Joint Stakeholder Committee for FRR
- Evacuation planning and drilling for handicap-accessible facilities
- Recovery by the national government

1

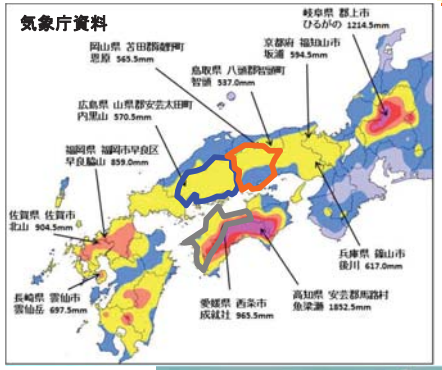
Maximum 48hrs Rainfall from June 28th to July 8th (JMA)

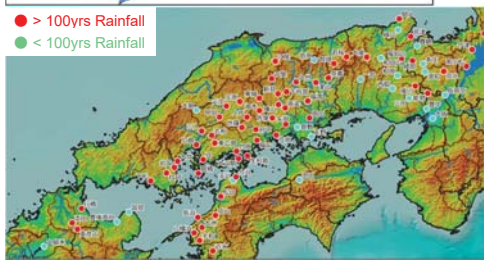
Western Japan Floods 2018



2

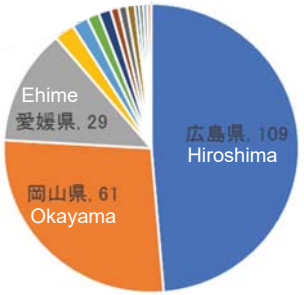
Maximum 48hrs Rainfall from June 28th to July 8th (JMA)





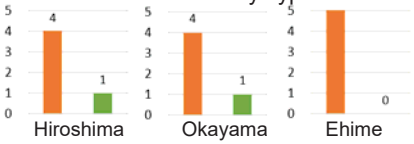
Western Japan Floods 2018

Mortality: 224
(the worst case after 1982)



by courtesy Dr. M. Ohara, ICHARM

Major River of each Prefecture
Maximum Flood by Typhoon



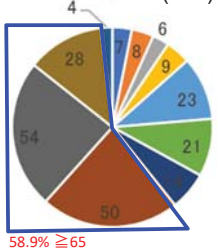
Top 5 Floods by Typhoons and Frontal Activities.

3

Recurrent Water-related Disasters in Japan

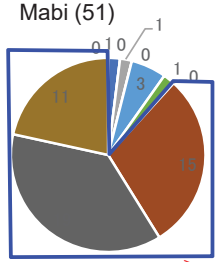
Changing Society

Nation-wide (224)



58.9% ≧65

Mabi (51)

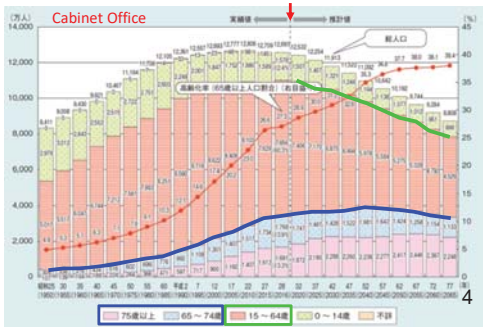


88.2% ≧65

■ 0–9 ■ 10–19 ■ 20–29
■ 30–39 ■ 40–49 ■ 50–59
■ 60–64 ■ 65–74 ■ 74–85
■ >85 ■ unknown

by courtesy Dr. M. Ohara, ICHARM

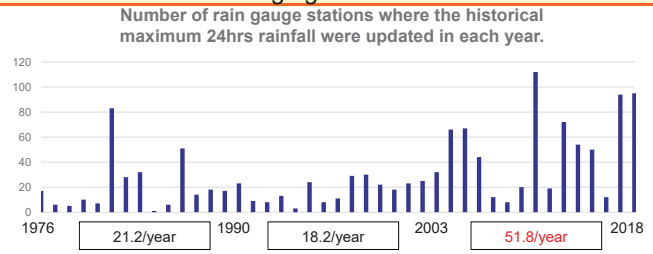
Rapid Aging:
- increase of the number of those who should be supported.
- decrease of the number of those who can support.



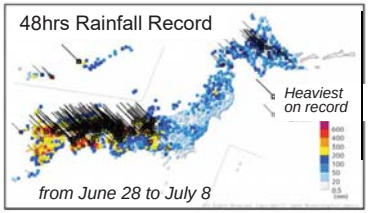
4

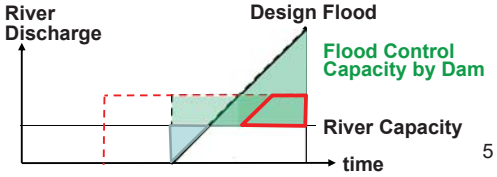
Recurrent Water-related Disasters in Japan

Changing Hazards



Torrential heavy rainfall happens everywhere more frequently. No exceptions. The areas where have not experienced heavy rainfall are likely to be seriously damaged. The June 2018 floods raised two new issues:
1) Simultaneous events in the wider area.
2) Longer duration.





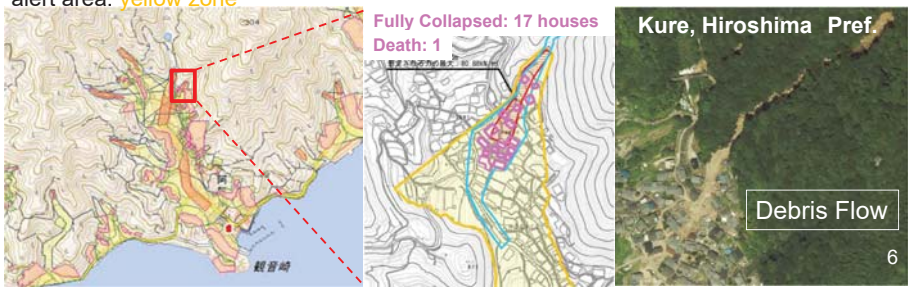
5

Recurrent Water-related Disasters in Japan

Changing Society

Sediment Disaster Prevention Act
special alert area: red zone
alert area: yellow zone

Risk has been informed but not recognized.

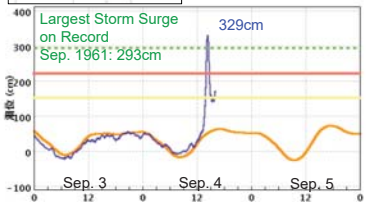


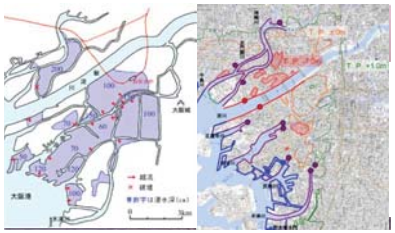
6

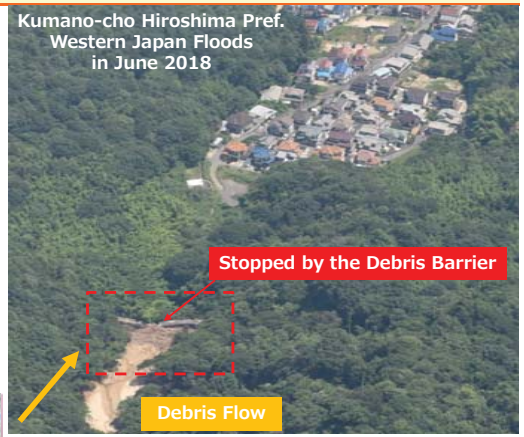
Recurrent Water-related Disasters in Japan

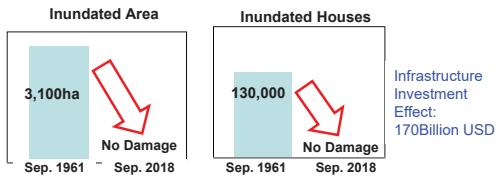
Infrastructure Investment

Typhoon 21
Sep.4, 2018





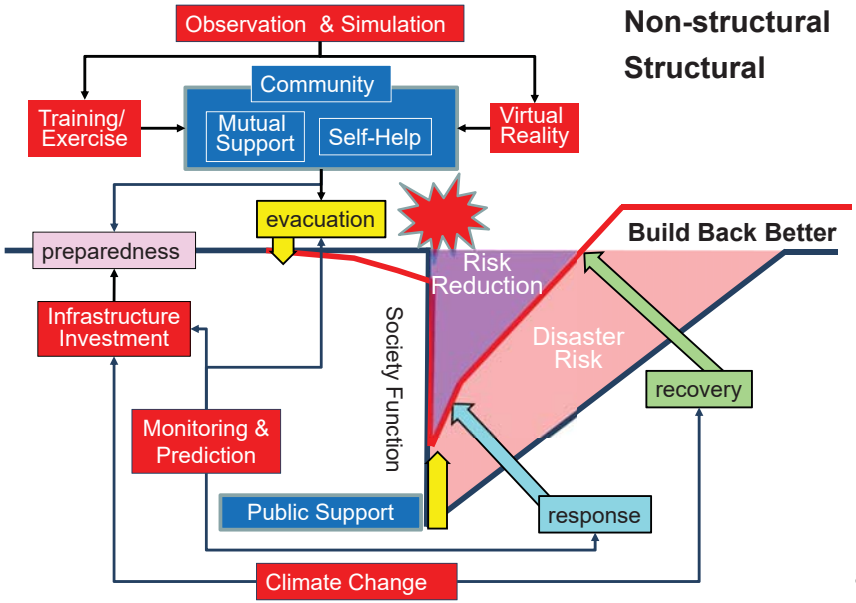




Infrastructure Investment Effect: 170Billion USD

Recurrent Water-related Disasters in Japan

Our Challenges



8

3rd Plenary Session for Platform on Water Resilience and Disasters in Sri Lanka

Review of progress

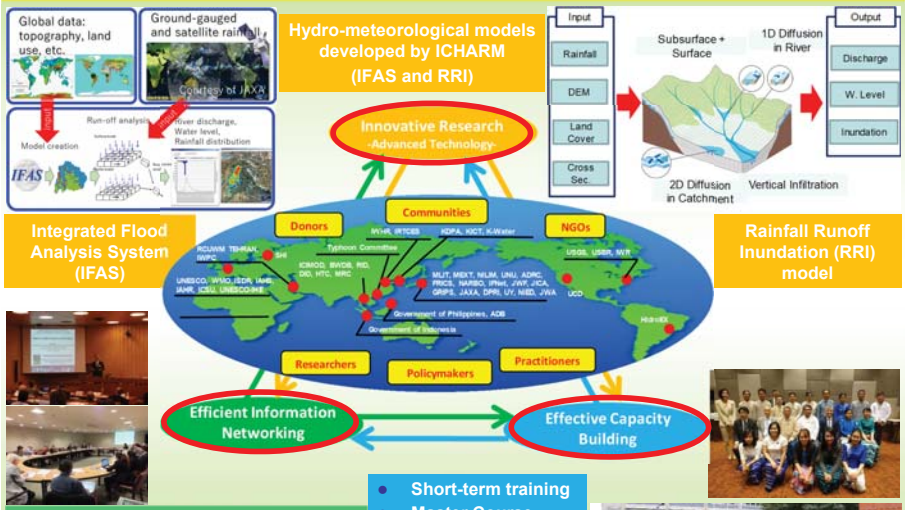
Platform on Water Resilience and Disasters in Sri Lanka

Tetsuya IKEDA, PhD

International Centre for Water Hazard and Risk Management (ICHARM)
Public Works Research Institute (PWRI), Japan

February 20, 2019

Three Pillars of ICHARM Activities

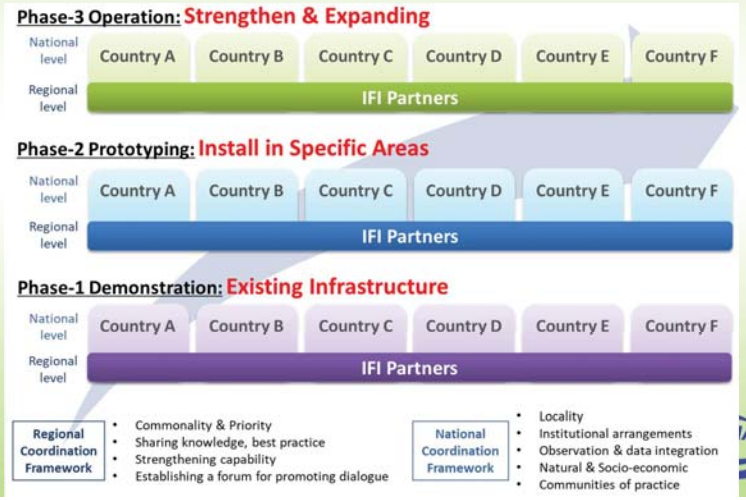


- UNESCO-IHP
- International Flood Initiative (IFI)
- UN agencies (WMO, UNISDR….)
- Typhoon Committee
- Governments, NGOs, Academia etc.

- Short-term training
- Master Course
- Ph.D. Course
- Follow-up seminars
- Local training (IFAS, ADCP)

IFI Implementation Framework 2016-2022

- IFI is a worldwide framework to promote collaboration in flood management among international organizations: UNESCO, WMO and UNISDR. ICHARM has been serving as secretariat.
- Under IFI's scheme, ICHARM supports the establishment of the "Platform on Water Resilience and Disasters", where the relevant government organizations of each country collaborate.



Regional Coordination Framework
- Commonality & Priority
- Sharing knowledge, best practice
- Strengthening capability
- Establishing a forum for promoting dialogue

National Coordination Framework
- Locality
- Institutional arrangements
- Observation & data integration
- Natural & Socio-economic
- Communities of practice

"Platform on Water Resilience and Disasters" in Sri Lanka

Post-Disaster Activities after flood and landslide of late May, 2017

Meetings for establishment of "Platform on Water Resilience and Disasters" have been held.

- 1st Plenary Session on August 24, 2017
- 2nd Plenary Session on March 28, 2018
- **3rd Plenary Session on February 20, 2019**

Sri Lankan Minister joined at the 2nd Plenary Session

Participated Stakeholders

Irrigation	•	ID	: Irrigation Department
Disaster	•	DMC	: Disaster Management Center
Meteorology	•	MD	: Meteorological Department
Geological survey	•	SD	: Survey Department
Landslide	•	NBRO	: National Building Research Organization
Urban	•	MMWD	: Ministry of Magapolis & Western Development
Climate change	•	MMDE	: Ministry of Mahaweli Development & Environment

Progress of establishing the Platform in Sri Lanka

- **Background**
  - ✓ Large-scale flood disaster occurred in Sri Lanka in late May 2017, leaving over 300 people dead or missing.
  - ✓ The Government of Japan dispatched the Japan Disaster Relief (JDR) Expert Team to help emergency efforts upon the request of the Government of Sri Lanka, to which PWRI has contributed.
  - ✓ ICHARM and EDITORIA provide **useful information for flood management** though new Website on DIAS, and will conduct capacity development for effective use of information.
  - ✓ **Plenary Sessions** have been held two times on August 2017 and March 2018 with flood relevant government organizations.
- **Expected Outcomes**
  - ✓ Reduction of human losses and socio-economic damage
  - ✓ Effective emergency response and recovery through disseminating real-time flood forecasts & early messages.

5

Platform on Water Resilience and Disasters in Sri Lanka

Participating Organizations:

- Irrigation Department (ID) (* Coordinator and Focal point)
- National Building Research Organization (NBRO) (* Coordinator)
- Disaster Management Center (DMC) (* Focal point)
- Meteorology Department (MD)
- Ministry of Magapolis and Western Development (MMWD)
- Ministry of Mahaweli Development & Environment (MMDE)
- Survey Department (SD)

Target Actions and Coordinating Bodies

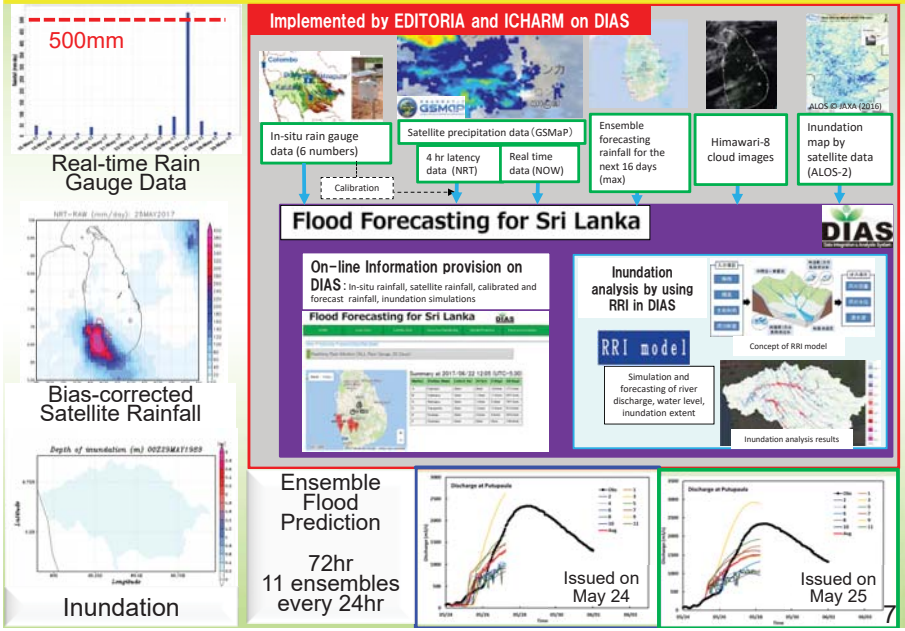
1. Early Warning: rainfall, flooding, landslide:	ID, NBRO, MD
2. Adaptation Planning for Global Change: (such as Climate Change, Urbanization)	ID, MMDE, MMWD
3. Economic Effect of Disasters:	MMDE, DMC
4. Contingency Planning and Mainstreaming DRR:	DMC

Demonstration Sites of Target Actions

1. Kalu River Basin (as rural basin)
2. Kelani River Basin (as urban basin)
3. Malvathu River Basin (as arid basin)

6

DIAS-ICHARM: Sharing Flood Information in Sri Lanka



7

Regional Cooperation among IFI implementing countries

- **Regional Cooperative Implementation Meeting** of "Platforms on Water Resilience and Disasters" was held at GEOSS Asian Water Cycle Initiative (AWCI) on October 24-25, 2018 in Kyoto, Japan.
- The high-levels and representatives from the IFI implementing countries (*) participated, notably attended by **Honorable State Minister** of the Ministry of Irrigation and Water Resources & Disaster Management of Sri Lanka.

  (*) Sri Lanka, Philippines, Myanmar and Indonesia
- During the meeting, activities and progress of each country was reported, and the future cooperation was discussed together with all the participants.

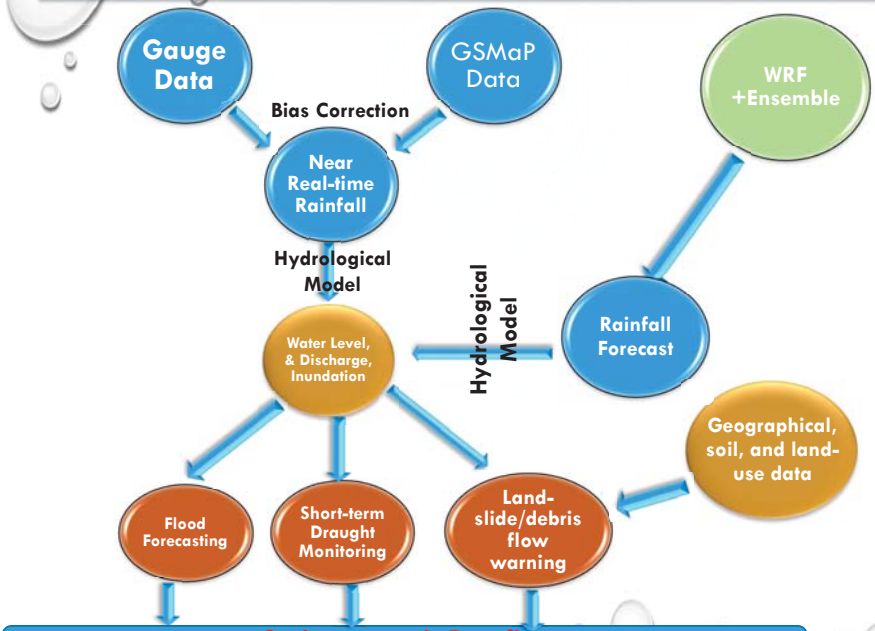
8

"ICHARM ACTIVITIES FOR A PLATFORM ON WATER RESILIENT & DISASTERS IN SRILANKA"

Real -Time Data Archiving & Integration For Effective Water Resources Management In Sri Lanka

Mohamed Rasmy
Senior Researcher, ICHARM/PWRI
Associate Professor, GRIPS

SYSTEM DEVELOPMENT & APPLICATIONS



System Development & Integration

Dissemination through DIAS

Socio-economic Benefits:
Hazard Maps & Disaster Early Warning, Assessment of Risk and Damages

Target Action #1: Monitoring & Early Warning System

- Upgrading to real-time data observing and archiving system
- Integrated data from multi-platform (insitu and Satellite)

Real-Time Data Archiving & Integration

3 Main Aspects

State of the Art Modeling System

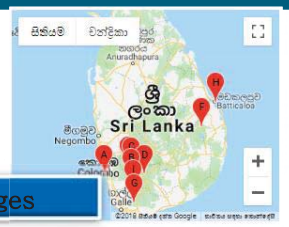
Data & Information Dissemination System

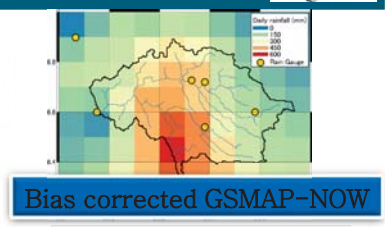
- Simulating and forecasting water related disasters

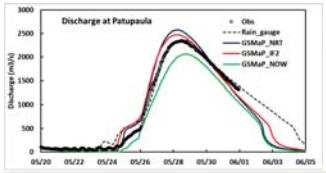
- Automated alerts & Online- data Transfer
- Dissemination from models and satellite

TARGET ACTION #1: EARLY WARNING & CAPACITY BUILDING


Installed gauges

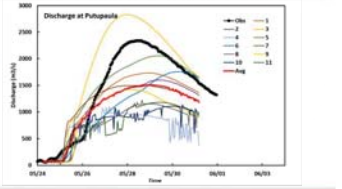



Bias corrected GSMAP-NOW



Hourly discharge at Putupaula


Inundation depth

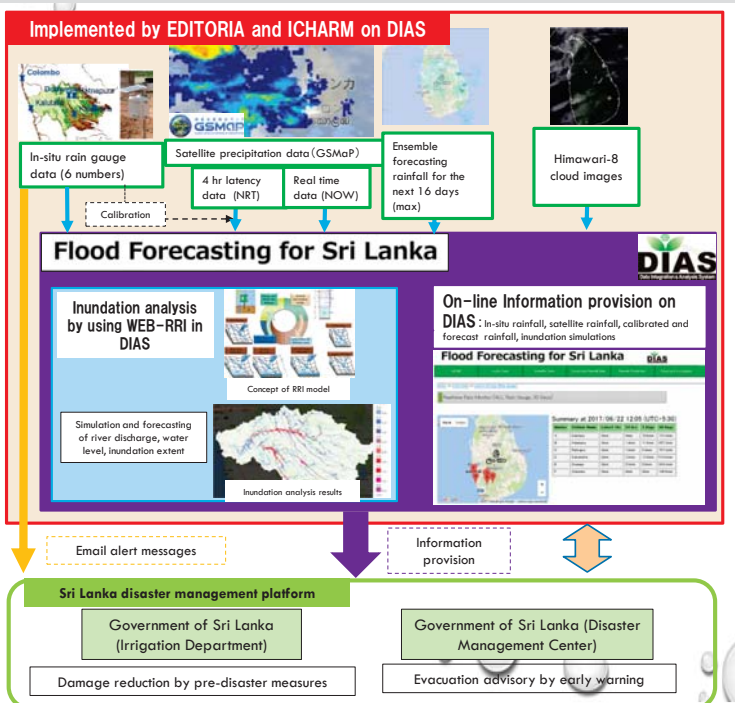

ENSEMBLE FLOOD FORECASITNG

ON-LINE DESIMINATDISSEMINATION BY DIAS


Capacity Building

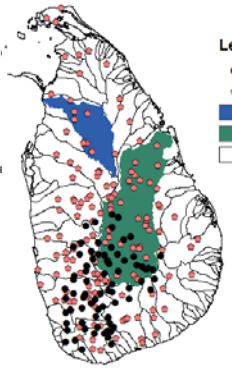
May 2018: Early Warning System: Test operation

http://ff-srilanka.diasjp.net

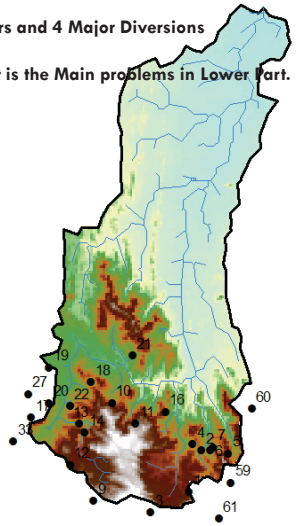


MOVING BEYOND FLOOD FORECASTING TO IWRM

- Rapid increase for water demand
- No evidence based water usage plan
  - 7 Tank and water diversion
- Flood and Drought



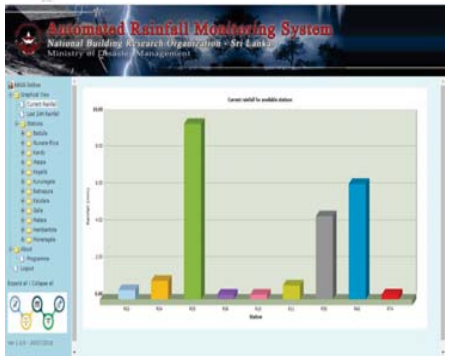
- Economically very important System (Rice Production (30-45%), Hydropower (25-35%) & Drinking Water)
- 11 Major Reservoirs and 4 Major Diversions
- Flood and Drought is the Main problems in Lower Part.



We are developing the similar system as Kalu river not only limited to flood forecasting, but also for IWRM including dam operation, hydropower generation, irrigation, agriculture, water-food-energy nexus

REAL-TIME DATA FOR FURTHER DEVELOPMENT

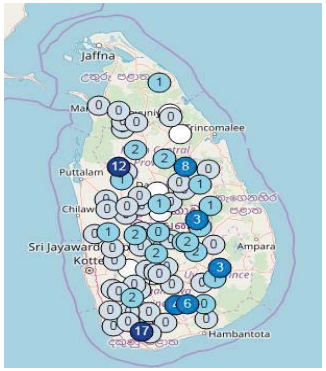
NBRO



Automated Rainfall Monitoring System - ARGS

30 min data provided direcly to ICHARM

Irrigation Department



Hydro Meteorological Information System (HMIS)

10 min data available via a public domain -

Valuable information for effective integrated water resource and eater-related disaster managements

PLATFORM ON WATER RESILIENCE & DISASTERS - ICHARM

CURRENT MISSIONS/TASKS/ACTIVITIES (EARLY WARNING) TA# 1

- REALTIME DATA ARCHIVING, FLOOD MONITORING & FORECASTING
- SYSTEM FOR DISSEMINATION OF MONITORING & FORECASTED INFORMATION
- CAPACITY BUILDING ON
  - RAINFALL DATA ARCHIVING/MONITORING, SATELLITE REMOTE SENSING, & FLOOD MODELING
- REALTIME DATA ARCHIVING FOR IWRM AND WATER-RELATED DISASTERS MANAGEMENT

FURTHER EXPECTED TASKS

- CLIMATE CHANGE IMPACT ASSESSMENT AND ADAPTATION PLANNING TA# 2
- ASSESSMENT OF DISASTER IMPACTS ON ECONOMY TA# 3
- DEVELOP A CONTINGENCY PLANNING TA# 4

FURTHER EXPECTED VALUE

- STRENGTHEN DISASTER PREPAREDNESS AND RESOURCE UTILIZATION
- ENSURE CAPACITIES OF STAKEHOLDERS AND COMMUNITIES
- CONTRIBUTE TO POLICY DESIGN AND INVESTMENT DIRECTION

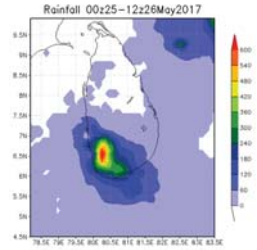
Real Time Ensemble Forecasting for Early Warning in Sri Lanka

Tomoki Ushiyama
International Centre for Water Hazard and Risk Management (ICHARM) under the auspices of UNESCO, Public Works Research Institute (PWRI)

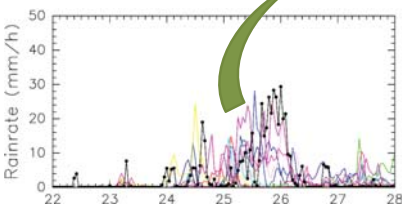
IFI meeting Feb.20th 2019

May 25, 2017 flood in Kalu River basin

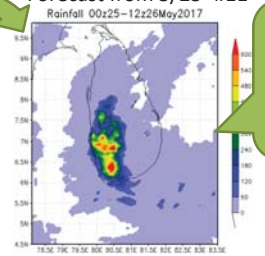
GSMaP satellite observation



Forecast from 5/23~, 11members

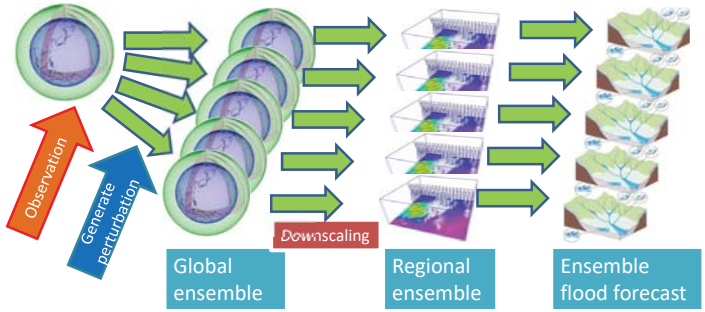


Forecast from 5/23- #11



Only one of the ensemble forecasts predicted heavy rainfall. Quite difficult to predict.

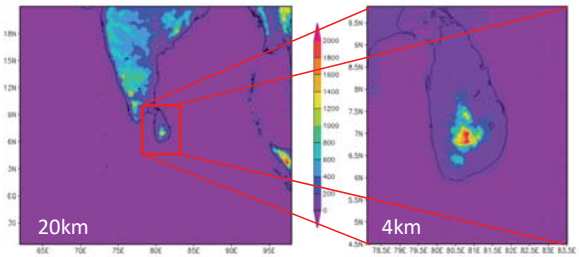
Regional Ensemble Prediction System (EPS)



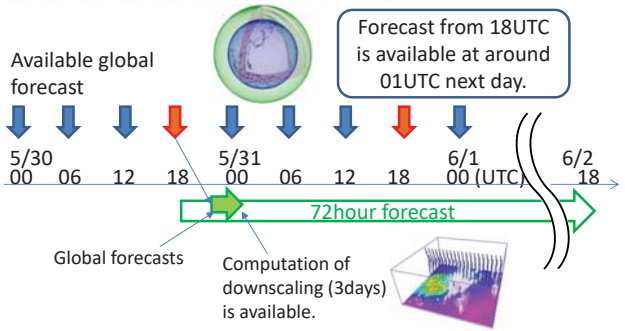
Advantages of the EPS

- EPS is often better than single (deterministic) forecasts.
- EPS can show possibility of severe rainfall in case the single forecast failed to capture.
- EPS can estimate forecast uncertainty from the width of ensemble spread.

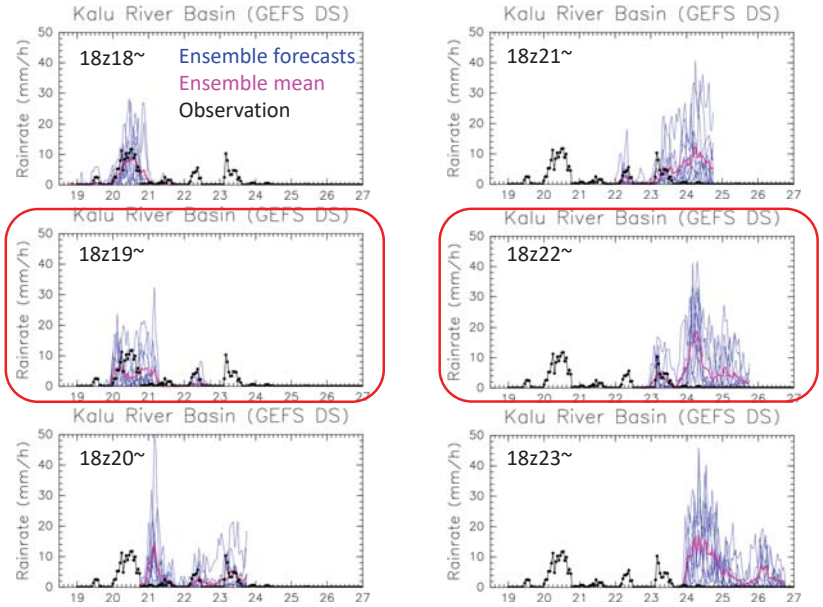
Model domain



WRF model:
Resolution: 20km/4km
Grids: 200 × 150 × 40 (outer),
151 × 151 × 40 (inner)
Cumulus parameterization:
Newer Tiedtke in outer frame
Cloud microphysics: Lin

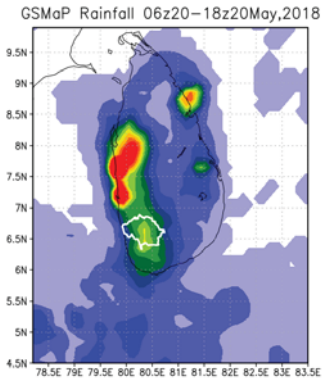


Ensemble Forecast in May 2018

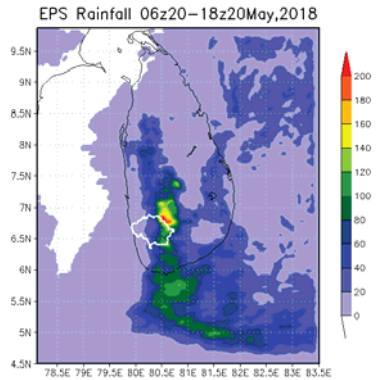


May 20 Rainfall Forecast from 18UTC19May

GSMaP satellite observation

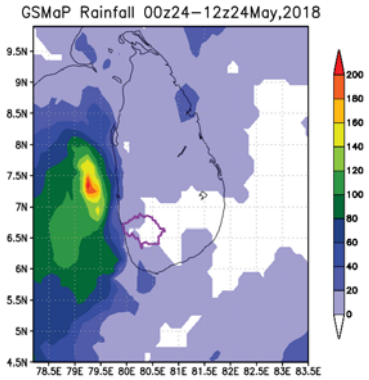


Forecast (Ensemble mean)

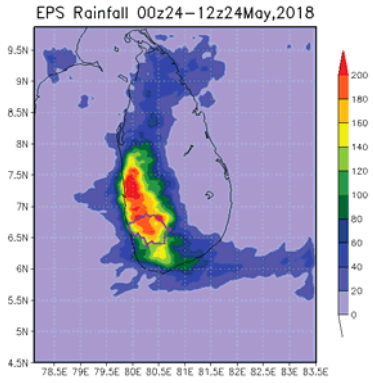


May 24 Rainfall Forecast from 18UTC22 May

GSMaP satellite observation



Forecast (Ensemble mean)



Summary

- An Ensemble Prediction System for heavy rainfall in Sri Lanka was developed and implemented in real time basis.
- This system predicted May 24, 2018 torrential rainfall two days earlier than its occurrence, although the location was not correct.
- The system worked as an early warming system for torrential rainfall.

Development of Effective Water Usage Plan for Dry zone in Sri Lanka

Case study : - Malwathuoya River Basin

Maheswaran Myuran
Irrigation Engineer
ITI - Galgamuwa

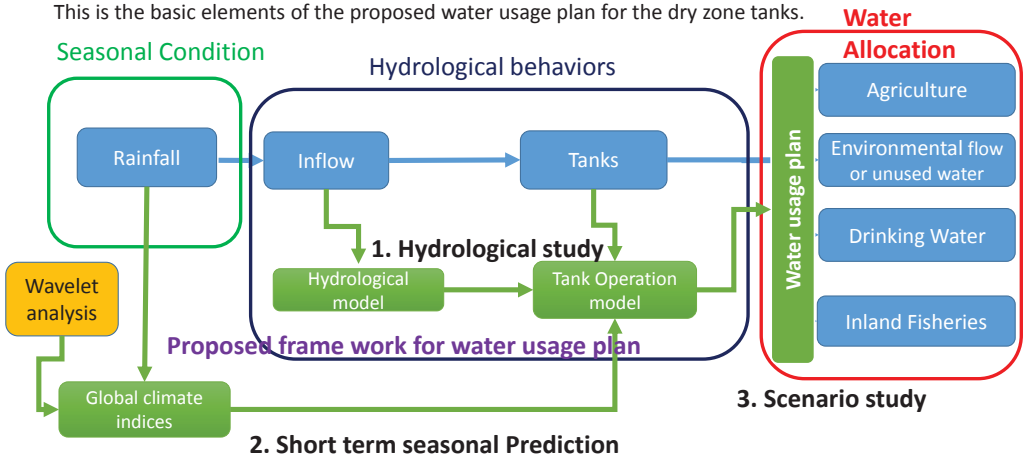
Main Supervisor : - **Prof. Toshio Koike**
Sub Supervisor: - **Dr. Mohamed Rasmy Abdul Wahid**
Dr. Mamoru Miyamoto

Objective of this study

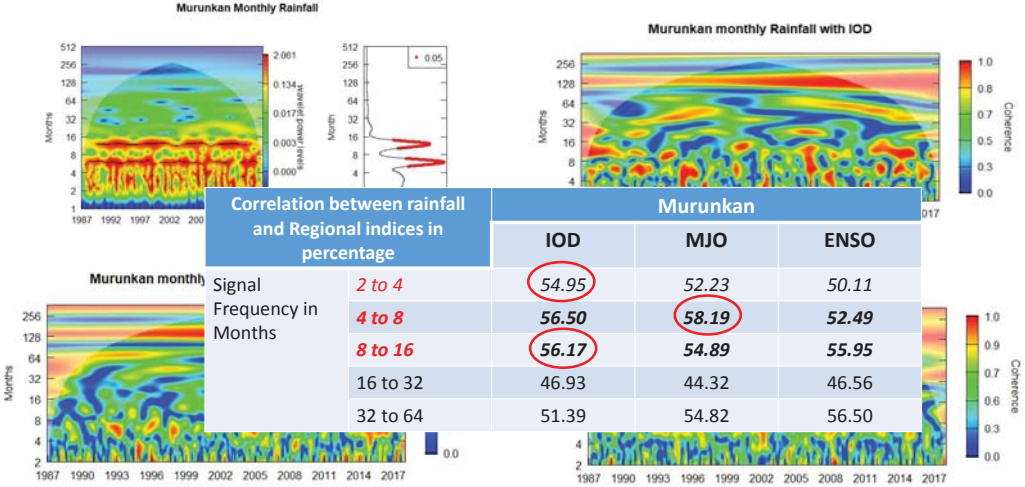
- To Formulate some **best scenario** of **integrated water usage (IWUP)** in this Basin with respective of **Giant's Tank**.
- To develop a **Short term seasonal prediction of rainfall** for Murunkan region to help decision making in choosing scenario
- To understand the **Possible income** of these scenario

Proposed Framework of the water usage plan

This is the basic elements of the proposed water usage plan for the dry zone tanks.



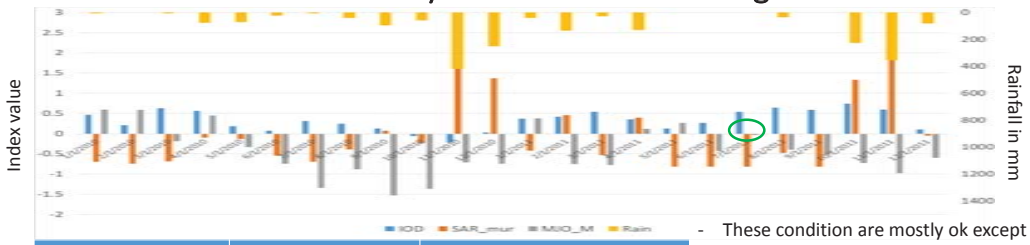
Wavelet Coherence Analysis of the Variability at Station 3 (Murunkan) With IOD. MJO and ENSO For Period from 1987 to 2017



Correlation between rainfall and Regional indices in percentage		Murunkan		
		IOD	MJO	ENSO
Signal Frequency in Months	*2 to 4*	*54.95*	*52.23*	*50.11*
	4 to 8	***56.50***	***58.19***	***52.49***
	8 to 16	***56.17***	***54.89***	***55.95***
	16 to 32	46.93	44.32	46.56
	32 to 64	51.39	54.82	56.50

Source:- Irrigation Department of Sri Lanka, Metrological department of Sri Lanka , https://www.esrl.noaa.gov/ , http://www.cpc.ncep.noaa.gov/

Global Indices and Std. Anomaly rain indices correlating to Prediction



IOD	MJO	Std. Anomaly Index
Positive and > 0	Positive and < 0.1	Positive
Positive and > 0	Positive and > 0.1	Negative
Positive and >0	Negative and < -0.25	Positive
Positive and >0	Negative and > -0.25	Negative
Negative	Positive	Positive not Applicable
Negative	Positive	Negative
Negative and < -0.25	Negative < -0.5	Positive
Negative and > -0.25	Negative < -0.5	Negative

- These condition are mostly ok except the green circulated month in 2010 to 2011.
- Checked for 2010 to 2017
- Positive means rainfall above average
- Negative means rainfall below average
- Extrema event is shown in RED.

Source:- Irrigation Department of Sri Lanka, Metrological department of Sri Lanka , https://www.esrl.noaa.gov/ , http://www.cpc.ncep.noaa.gov/

Sector 3 Scenario study

Selection of Scenario study depending on Prediction

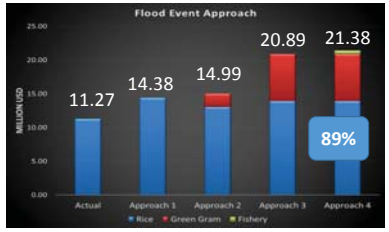
Scenarios

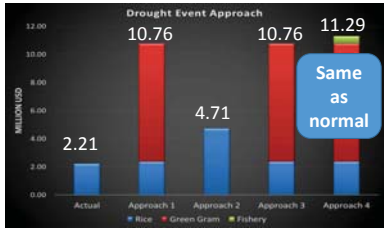
Flood Event Approach (2010-2011)	1. Full Pad in Maha and Yala Pad
	2. Full Pad in Maha and 60% pad + 40 % GG in Yala
	3. Full Pad in Maha and Yala GG
	4. Inland fishier + Full Pad in Maha and which ever high in Yala
Normal Event Approach (2007 -2008)	1. ID registered Area Pad in Maha and 60% pad + 40% GG in Yala
	2. Full Pad in Maha and Yala Pad
	3. Full Pad in Maha and 60% pad + 40% GG in Yala
	4. Full pad in Maha + inland fishier and Which ever high Yala
Drought Event Approach (2013-2014)	1. 40% GG in Maha and Yala Pad
	2. No Maha and Yala Pad + intermediate Pad
	3. No Maha and Yala Pad + intermediate GG
	4. Inland Fishier in Maha and Yala Pad + Intermediate GG
Hypothesis Approach (2010-2011)	1. Full pad in Maha and 70% Yala pad
	2. Full Pad in Maha and 60% pad +40% GG in Yala (85%)
	3. Inland fishery + Full Pad in Maha and which ever high Yala pad

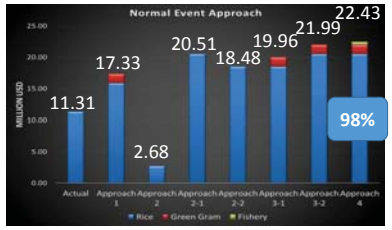
- These Approaches were used in RRI model and TOM model to find the feasibility of success.
- With those output, possible income generated from the scenarios are studied.

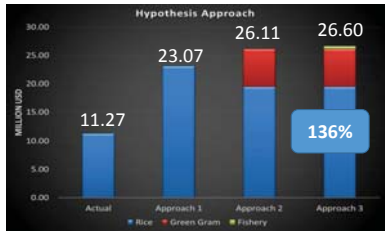
- **GG – Green Gram**
- **Pad - Paddy**

Selection of Best Scenario comparing the possible income









- Approach 4 is the best Scenario of IWUP in every events.

For this Study following Data were taken from the sources
- Yield Per ha
- Farm –gate price of rice and green gram in USD/ha
- Inland fish export value for Sri Lanka is taken assumed 5% contribution from GT

Sources :- Agricultural department and Department of Census and Statistics and National Aquaculture Development Authority of Sri Lanka

Results

- The best Scenario for IWUP for the Giant's tank is to collaborate Paddy and Green Gram Cultivation with Inland Fishers including coordinated tank operation.
- The percentage of Collaboration is depends on the short term Seasonal Prediction.
- Additional outcome is that if there is a tank in upstream of Thekkam then the possible income can increased more than 100%
- With this case study it is proven that the proposed frame work is a good tool to develop effective water usage plan for dry zone in North part of Sri Lanka

Development of Integrated Water Resource Plan for a Complex Watershed System

Case Study - Mahaweli River Basin

2017 -2018 ICHARM Master Group

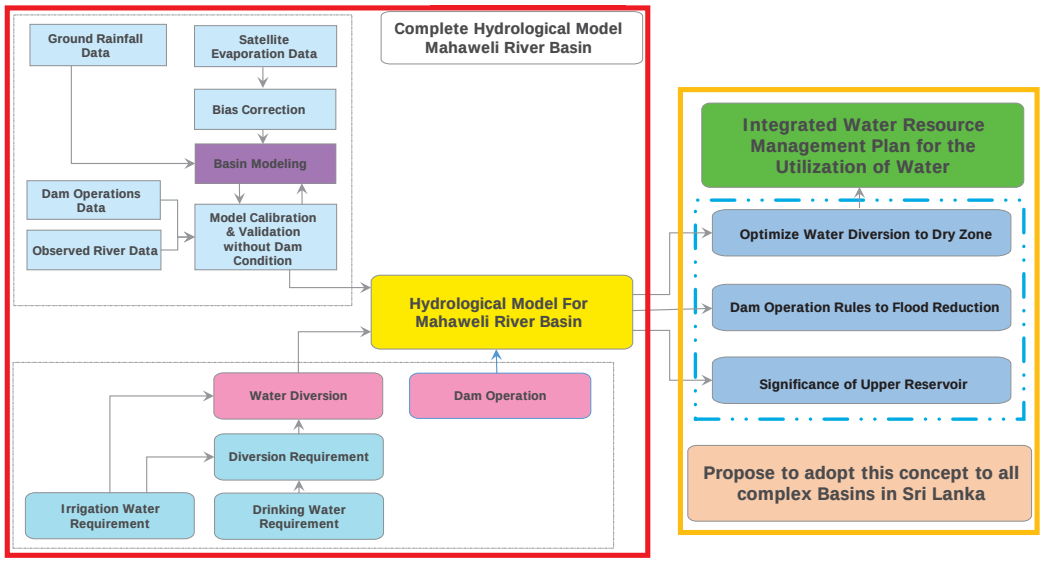
Supervisors : Asso. Prof. Mohomad Rasmy, Prof. Toshio Koike

Name: Roshan Indika Jayasinghe
Organization: Department Of Irrigation
Country: Sri Lanka
Index No: MEE17729

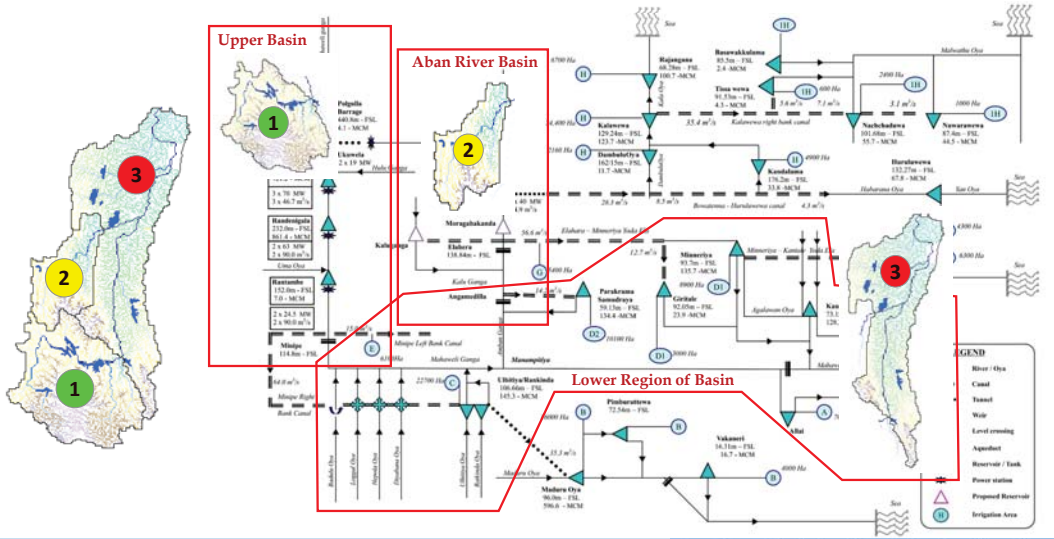
Objectives of the Research

- Development of Integrated Water Resource Management Plan for the Utilization of Water in Mahaweli River Basin to reduce the Flood and Drought in Downstream area.
  - Reliable Hydrology Model for the Basin to Simulate Actual Condition.
  - Optimization of Water Diversion Capacity to Dry Zone.
  - Dam Operation Rules to Minimize the flood in Downstream.

Methodology



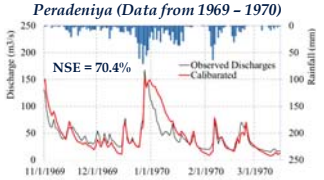
Simplified of Complex System By considering Topographic and Climatology Zone



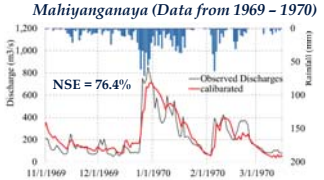
Source: Mahaweli Authority and Irrigation Department Annual Reports

RRI Model Calibration and Validation – Simple Model

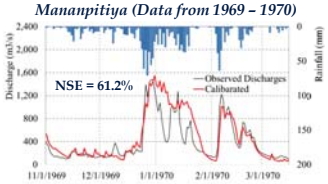
Peradeniya (Data from 1969 – 1970)



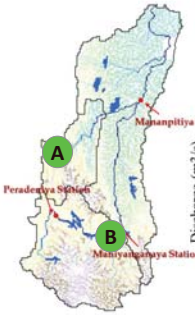
Mahiyanganaya (Data from 1969 – 1970)



Mananpitiya (Data from 1969 – 1970)

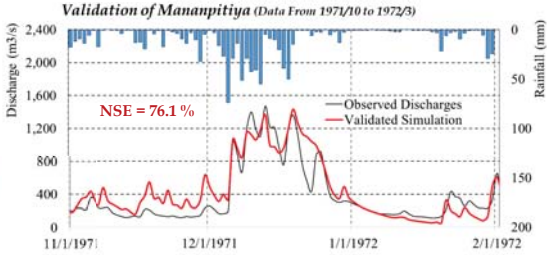


Data Used, Before Construction of Dams

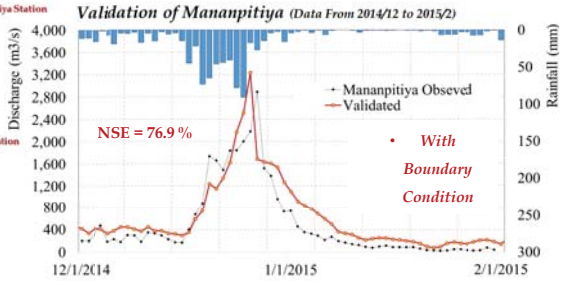


- *Before Dam Construction*

Validation of Mananpitiya (Data From 1971/10 to 1972/3)



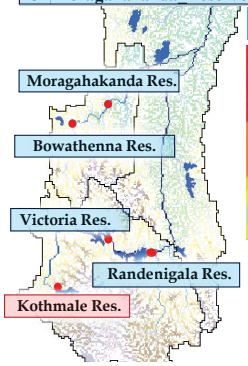
Validation of Mananpitiya (Data From 2014/12 to 2015/2)

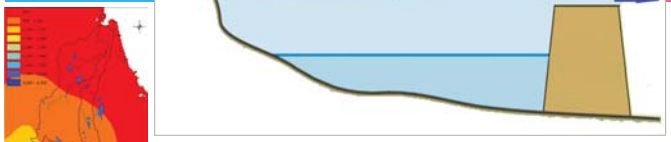


- *With Boundary Condition*

Proposed Dam Operation Rules for Flood Operation

		APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR
1	Kothmale_Reservoir	6%	10%	15%	20%	20%	15%	10%	6%	6%	6%	6%	6%
2	Victoria_Reservoir	6%	6%	6%	6%	10%	15%	20%	20%	20%	15%	10%	6%
3	Randenigala_Reservoir	6%	6%									10%	6%
4	Bowathenna_Reservoir	6%	6%									10%	6%
5	Moragahakanda_Reservoir	6%	6%									10%	6%





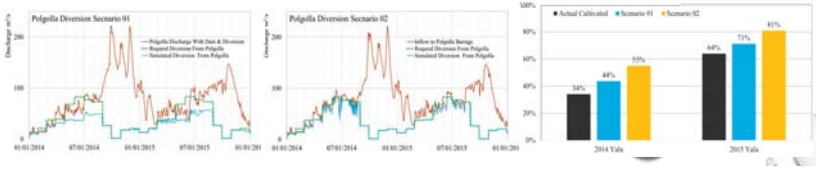
- *Four Main Stages considered to Control Dam for Flood*
  - *Pre –Flood Operation Stage*
  - *Flood Operation Stage*
  - *Pre – Emergency Operation Stage*
  - *Emergency Operation Stage*
- *New Dam Module introduced to RRI by considering all above*
- *Monthly Basis New Diversion Module introduced to RRI by considering all above*

System Performance and its applications

- *Both Dam Operation & Diversion*

Flood Reduction in lower part due to Dam Operation Rules

Two Scenarios Checking to Optimize the Water Diversion



Conclusion

Conclusion

- Complex system Approach was Developed & Apply to Mahaweli System
  - Simplified the complex System
  - Introduced the Water Diversion and Reservoir Operations
- Model Was Calibrated and Validated With and Without Reservoir and Diversions
- Monthly Basis 20% flood Storage is very effective to reduce the flood in downstream area.
- If it increase tunnel Capacity by 60%, Cultivation extend can increase(17-20 %) in the dry zone
- Cultivation Decision is very important to increase the Farmer Income.
- First Priority should be given for Irrigation water Demand in Kothmale Reservoir.
- Coordinated Reservoir Operation & Management Between Institutions is Very Important.

PhD. Research Theme

A Proposal for Science and Policy Implications for the Integrated Water Resources Management in Mahaweli River Basin

Hemakanth Selvarajah
Irrigation Engineer, Irrigation Department
PhD. Student at GRIPS/ICHARM

Integrated Water Resources Management

According to UNESCO

The IWRM approach endorses an efficient, equitable and sustainable development and management of the limited water resources and coping mechanisms for conflicting demands

On a basin level IWRM

Sustainable Management of Water Resource requires;

Systematic, Integrated decision making that recognizes several interdependences.

Land use-Water-Environment
Food-Energy-Water
Economic-Social-Hydrologic
International-National-Local
Upstream-Instream-Downstream
And many more…

Administration in Sri Lanka

IWRM Stakeholders in a River Basin of Sri Lanka

- ✓ Department of Irrigation
- ✓ Mahaweli Authority
- ✓ Department of Agriculture
- ✓ Department of Animal Production & Health
- ✓ Provincial Irrigation Departments
- ✓ Ceylon Electricity Board
- ✓ Water Resources Board
- ✓ National Water Supply and Drainage Board
- ✓ Wildlife Department
- ✓ Department of Meteorology
- ✓ Disaster Management Centre
- ✓ Forest Department
- ✓ Ministry of Industrial Development
- ✓ Ministry of Fisheries and Aquatic Resources
- ✓ Land Commissioners Department
- ✓ Coast Conservation Department
- ✓ Department of Agrarian Development
- ✓ Central Environmental Authority

and

- ✓ Public

Mahaweli River Basin

Basin Detail

- ✓ Largest River Basin in Sri Lanka
- ✓ Covers **10,300 sqkm** out of **65,610 sqkm**
- ✓ 11,000 MCM of annual water yield in 335 km long river
- ✓ The volume is about 20% of the discharge of all the river basins of Sri Lanka
- ✓ 40% of land area of the Island is planned to develop under Mahaweli System

Mahaweli was Developed To;

- ✓ Food for increasing Population
- ✓ Reduce imports of agricultural goods
- ✓ Improve the economic conditions
- ✓ Irrigation for Agriculture
- ✓ Hydropower for household & industry
- ✓ Reduce unemployment
- ✓ Improved food security

Current Issues in IWRM

Tradeoff Between Food Production and Energy Generation.

Drought and Flood as Climate change impact.

Complex system within different climatic zones and rapid stream flow changes.

Different stakeholders.

Degraded Irrigation Efficiency.

Alarming increase in Water pollution.

Review of IWRM Case Studies

Mahaweli river basin has been operated by various stakeholders in different socio economic and environmental characteristics.

- ✓ Integrate a number of stakeholders by compromising various components in water usage of the system.
- ✓ Integrating varieties of water use, geographic and hydrologic, agricultural and social and economic patterns have to be divided into sub systems.
- ✓ Addressing the nexus between the water and energy and food, the tradeoff between these trilemma has to be considered.

Three approaches were selected based on the relevance of the study

1. **Compromise Programing Approach**
   IWRM in Polurd Irrigation System in Iran., ***Mahdi Zarghaami**, International Journal on Water Resources Management*
2. **Domain Decomposition Approach**
   Integrated Hydrologic-Agronomic-Economic Model for Syr Darya River Basin Management in Central Asia, ***Ximing Cai** et al. Journal of Water Resources Planning and Management*
3. **Tradeoff Frontiers Approach**
   Frontiers of the food–energy–water trilemma: Sri Lanka as a microcosm of tradeoffs, ***Debra** et al, Environmental Research Letters*

Review of IWRM Case Studies

Compromise Programing Approach

A Compromise Programming approach is used in Poluard Irrigation System to ensure efficient water regulation and to plan the multi-criterions such as

- ✓ Efficient distributing water among users
- ✓ Sharing patterns within different crop varieties
- ✓ Drought management
- ✓ Planning environmental releases

Mahdi Zarghaami, International Journal on Water Resources Management

Domain Decomposition Approach

An Integrated hydrologic-agronomic-economic model was developed based on decomposition of Syr Darya river basin network in Central Asia

✓Multiple-source nodes (reservoirs, aquifers, river reaches, etc.)
✓Multiple demand sites, with a number of crops considered in each demand site.

Multi-period network model of the river basin, ranging from crop root zones to the river system to Maximize total water use benefit from irrigation, hydropower generation, and ecological water use

Ximing Cai et al. Journal of Water Resources Planning and Management

Tradeoff Frontier Approach

A Tradeoff Frontier approach is used to show the compromise between two outputs given a set number of inputs in the Mahaweli River Basin.

And

To visualizing system-level tradeoffs among Water-Energy-Food trilemma, especially when water scarcity is driving the nexus.

Debra et al, Environmental Research Letters

Proposal for Science and Policy Implications

Data integration for characterizing the water resources

Damage

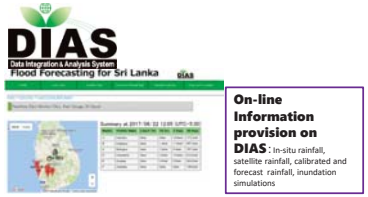
Data	Source of information
Num. of affected people	MASL,DMC
Agricultural damage	MASL, AD, ADD,DMC
Direct economic loss other than agricultural loss	MASL,DMC

Hazard

Data	Source of information
Rainfall	MASL,ID,NBRO, MD, GSMaP, 3B42RT,
River water level and Discharge	MASL, ID,
Dam inflow and outflow discharge	MASL, ID,
Diversion Discharge	MASL, ID,
Evaporation	MASL,ID,MD,
Inundation depth	DMC, web,
DEM	HydroSHEDS

Socio-economic

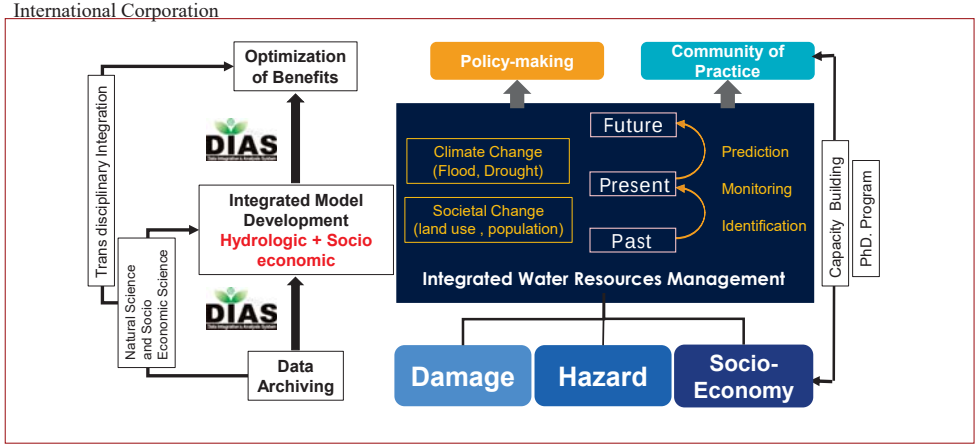
Data	Source of information
Land use	MASL,ID
Agriculture	MASL,ID,AD,ADD
Population	MASL,
Water Demand	NWS&DB,
Crop Yield	AD,ADD,MASL,ID,
Crop cost & Price	ADD,PMB,
Infrastructure	MASL,ID
Hydropower station Data	CEB,MASL,ID



In Sri Lanka, through the Platform of Water Resilience and disaster, DIAS has already started integrating ground and satellite precipitation data, rainfall forecasting data, results of flood inundation analysis and forecasting, and satellite observation data on cloud development, as well as ongoing floods and inundations.

Proposal for Science and Policy Implications

International Corporation



Platform of Water Resilience and disaster

Proposal for Science and Policy Implications

The end to end approach of climate change adaptation can be used for developing a comprehensive Integrated Water Resources Management for future adaptation under varying climate by integrating natural science, engineering and technology and social science to enable dynamic policy making.