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Greater Mekong Subregion Sustainable Agriculture & Food Security Program

Food and Agriculture Organization of the United Nations

Water accounting in the GMS

Policy implications for water, food and energy security in a changing climate

4-5 July 2023, Bangkok

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Greater Mekong Subregion Sustainable Agriculture & Food Security Program

Food and Agriculture Organization of the United Nations

Opening remarks

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Water Program Lead, FAO

Asia Pacific Water Scarcity Programme

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Water Program Lead
FAO Regional Office for Asia and the

Food and Agriculture Organization of the United Nations

Australian Aid

THE AUSTRALIAN WATER PARTNERSHIP

ASIA PACIFIC WATER SCARCITY Programme

ASIA PACIFIC WATER SCARCITY Programme

Develop practical capacities in routine water accounting to understand water use and demand;

Develop water allocation frameworks and processes that are based on water accounting and help share water between the various demands;

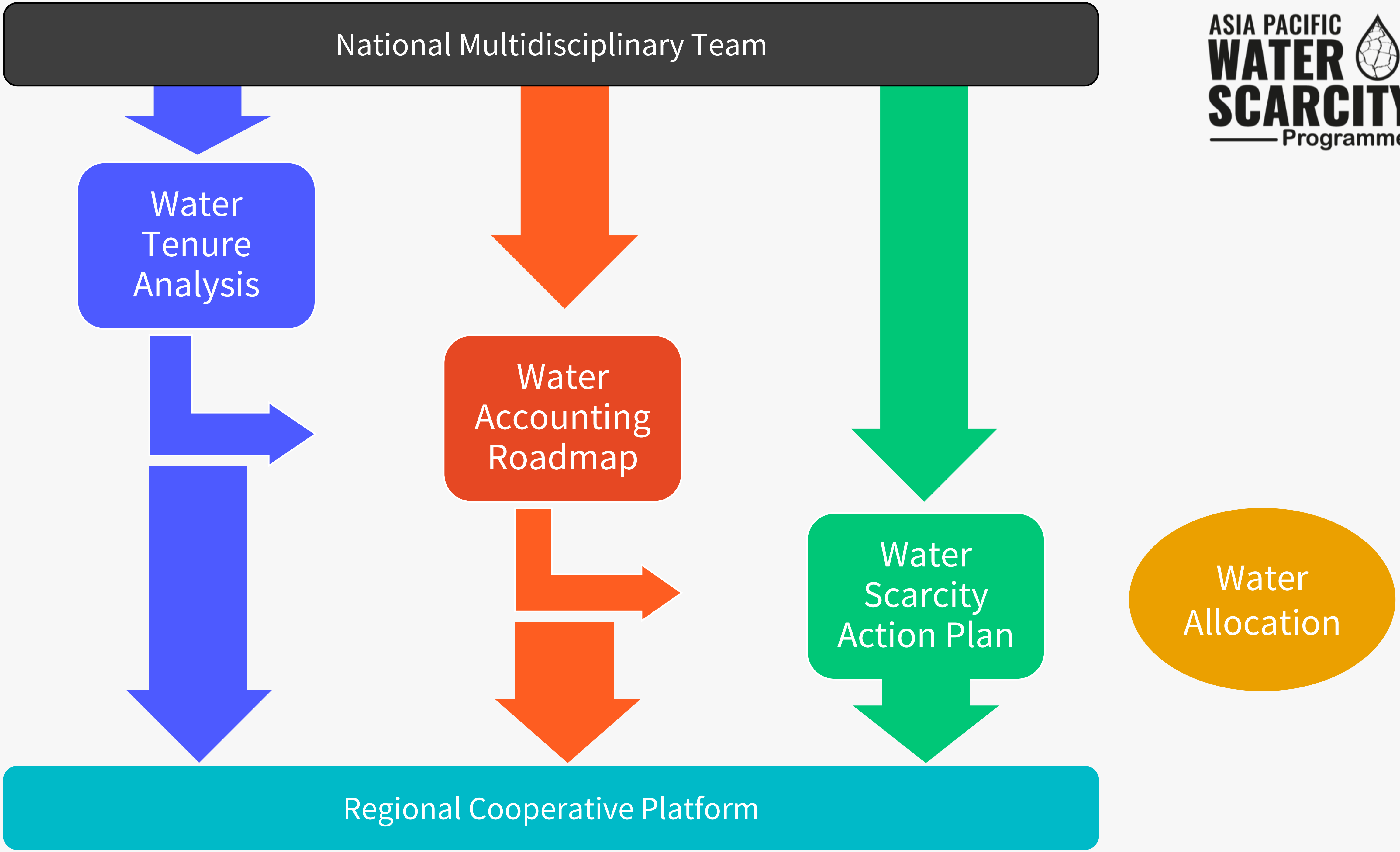
Work with farmers and water managers to adapt to water scarcity to optimise productivity with the amount of water that has been allocated; and

Establish a Regional Cooperative Platform to capture and share lessons via south south learning and exchange.

Food and Agriculture Organization of the United Nations

What is needed to implement effective water accounting and water allocation/planning?

- A thorough understanding of water tenure
- A multidisciplinary space embedded in government that considers all water using sectors
- An understanding of data capacities and shortcomings
- A plan for building national capacities and addressing policy gaps
- A progressively more accurate picture of water availability and demand (current and future)
- Opportunity to learn from success or failures in similar contexts



ASIA PACIFIC WATER SCARCITY Programme

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Greater Mekong Subregion Sustainable Agriculture & Food Security Program

Food and Agriculture Organization of the United Nations

Session 1: Water security in the GMS in a changing climate

TYPES, OCCURRENCE AND TRENDS IN WATER SCARCITY IN THE LOWER MEKONG REGION

Dr Amy Fallon
Senior Resilience Specialist
AMPERES

4 July 2023

AMPERES
Australia - Mekong Partnership
Environmental Resources & Energy Systems

alluvium

Food and Agriculture Organization of the United Nations

Australian Aid

THE AUSTRALIAN WATER PARTNERSHIP

Overview


A dead fish during drought in Tri An Lake, Dong Nai Province, Viet Nam

Regional approach to water scarcity analysis

<u>Ten countries analysed:</u>

1. Nepal
2. Bangladesh
3. Myanmar
4. **Lao PDR**
5. **Thailand**
6. **Cambodia**
7. **Vietnam**
8. Indonesia
9. Fiji
10. Australia

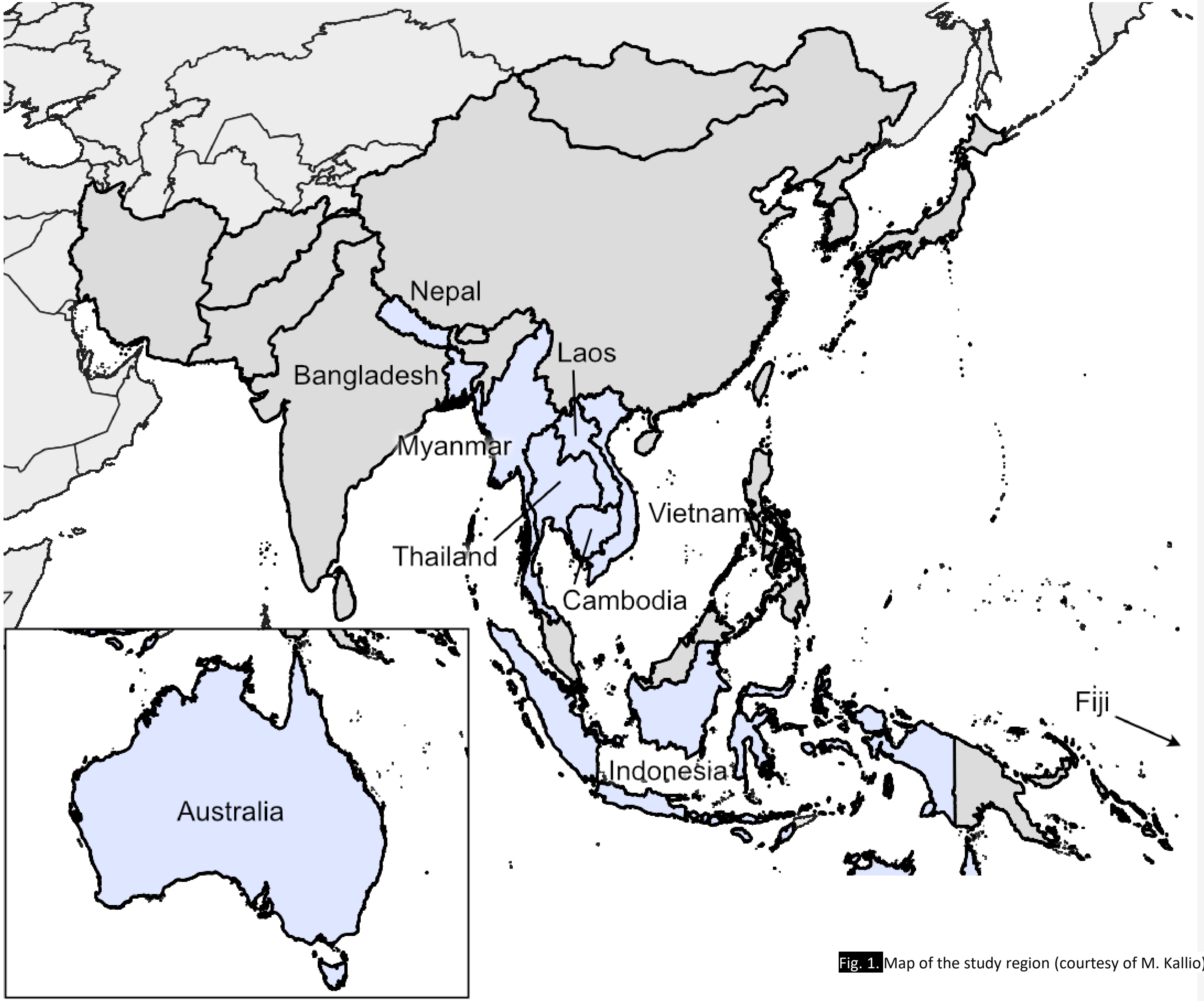
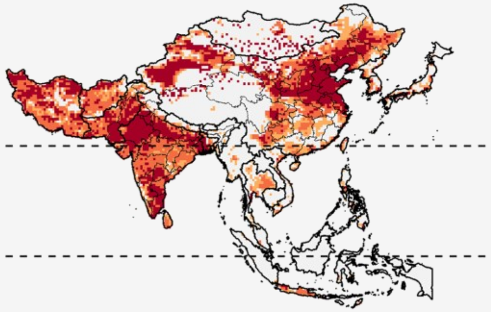


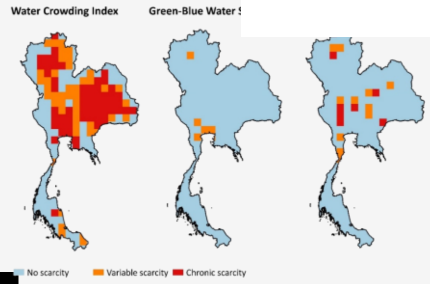
Fig. 1. Map of the study region (courtesy of M. Kallio)

Regional approach to water scarcity analysis

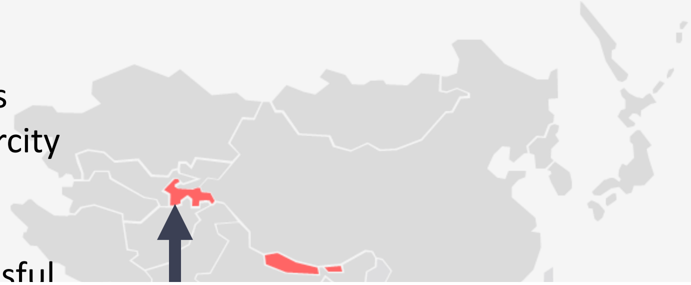
1.
How does water scarcity vary throughout Asia?



2.
What is the nature of
10 case study countri
(Bangladesh, Cambodia, Nepa
Fiji, Indonesia, Australia, Myar



4.
Which other countries face similar water scarcity problems?
How can good policy instruments & successful



GOALS:

- To better understand the **water scarcity dynamics** across the Asia–Pacific region.
- Lessons learned for **how scarcity is managed.**
- Provide insights into **policy targets** related to water scarcity.
- Highlight features for water scarcity management, such as **water accounting, allocations, and caps.**

Policy instruments

Partner organisations

Role of partners

A. WSP Program design

B. Regional water scarcity geospatial analysis

C. Cambodia policy review & water scarcity profile

D. Other case study policy reviews & profiles

What is water scarcity?

An **imbalance** between freshwater supply and demand
in a given country/region/river basin
where **demand exceeds supply**
under present institutional arrangements and infrastructure

Signs of water scarcity include

- Competition for water resources
- Groundwater over-exploitation
- Insufficient environmental water flows

(FAO, 2012)

Four types of water scarcity

Geospatial analysis of water scarcity patterns across the region between 1971 and 2010, using **three core indicators**

1. Too little water
Low natural precipitation and runoff
→ Low water availability per capita

2. Too variable water
Seasonal and interannual variability in precipitation
→ Variable water availability (incl. drought)

3. Over-utilisation of water
Water use exceeds availability or causes quality issues
→ Reduced availability for other uses

4. Poor water quality
Inadequate water quality for required uses
→ Reduced availability of water for water users

WATER SHORTAGE
- Water Crowding Index*
- Indicator of competition over water resources

GREEN-BLUE WATER SCARCITY
- Agricultural water scarcity
- Green-Blue Water Scarcity Index**
- Indicator of sufficiency of local water resources for agriculture

WATER STRESS
- Water Stress Index***
- Indicator of excessive water use compared to availability

*Falkenmark et al., 1989
** Gerten et al., 2011; Kummu et al., 2014; Rockström et al., 2009
*** Alcamo & Henrichs, 2002; Vörösmarty et al., 2000

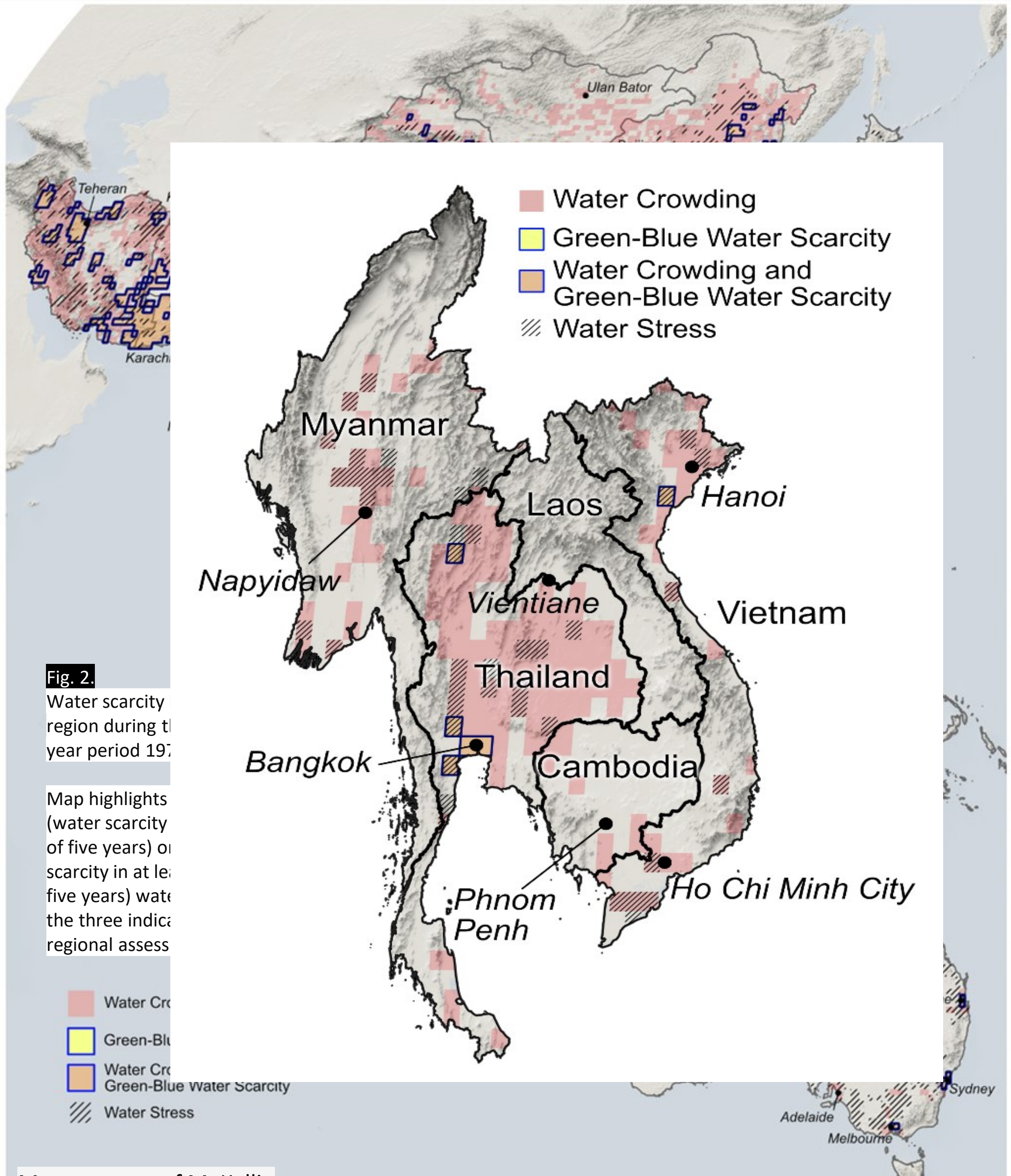
Water scarcity hotspots, 1971–2010

The population living under high or severe water scarcity **more than doubled**, from 1.1 billion to **over 2.5 billion people.**

For green-blue water scarcity (agriculture), it increased from 0.2 billion to nearly **1.5 billion people.**

Competition emerging in high-demand hotspots where water resources are either unavailable locally, or financially/technically challenging to augment.

Hotspots around **large cities** in all countries, with trends of **declining water quality** and **groundwater depletion** (e.g., Bangkok).



Map courtesy of M. Kallio

Evolution of water scarcity, 1971–2010

Every country in the region has experienced **worsening water scarcity**, especially arid countries.

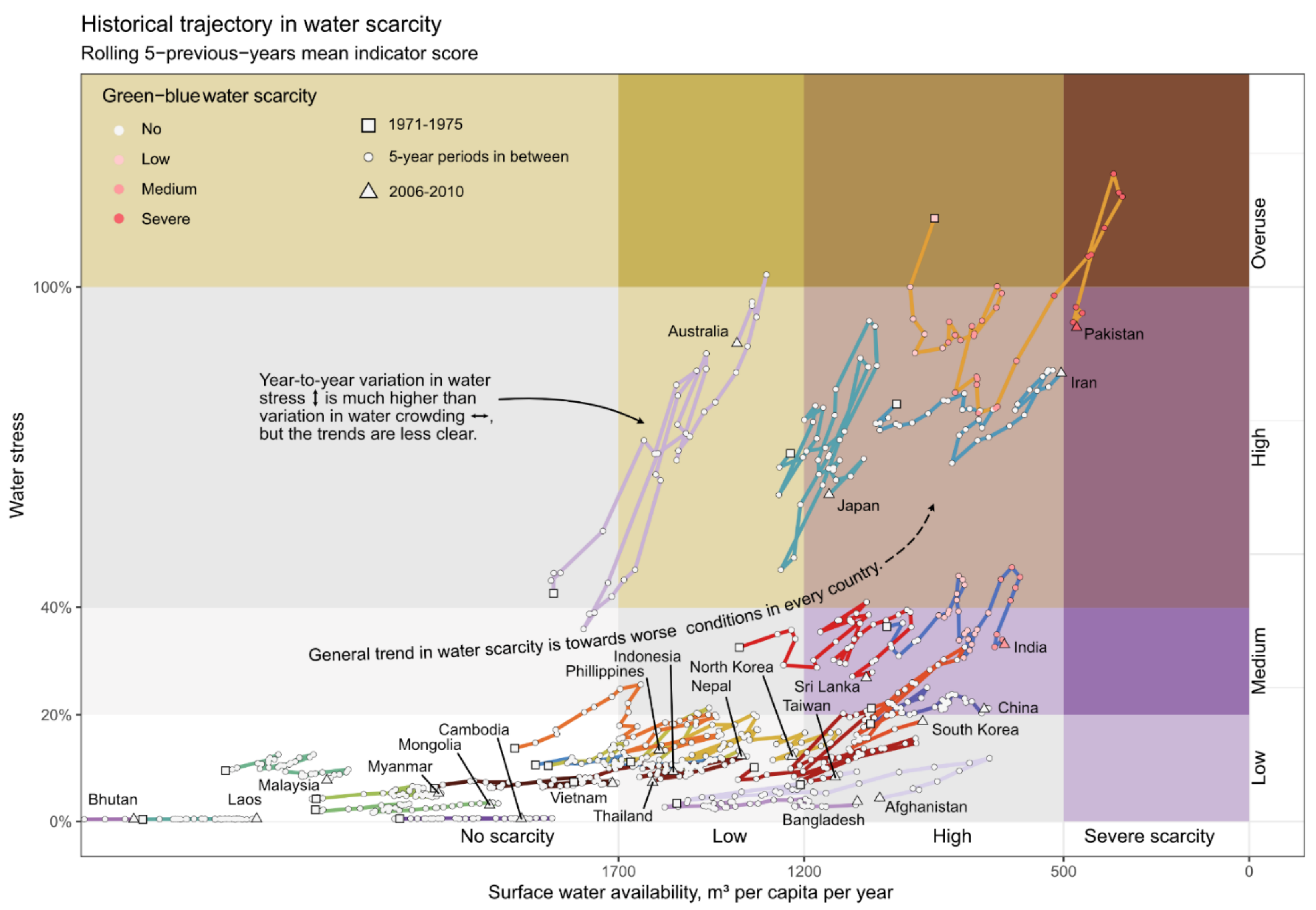


Fig. 3 Historical trajectory of water scarcity in the Asia – Pacific 1971-2010.

Highlights: Cambodia

Cambodia **experiences too variable water** and **poor water quality**, which also often interact – dry season shortages mean people in rural areas often resort to using unsafe water sources.

The country's water scarcity is particularly evident in rural areas and **agricultural activities** are the most affected by water variability and **only 16% water in rural areas is safely managed (compared to 55% in urban areas)**

Untreated wastewater is an issue in Phnom Penh and the Delta.

Climate change may worsen **intra-annual variability** – there is already evidence of longer dry season and delayed wet season. This will be an issue especially for the **Tonle Sap Lake's flood pulse system**, which supports fishing livelihoods and food security for millions of people.

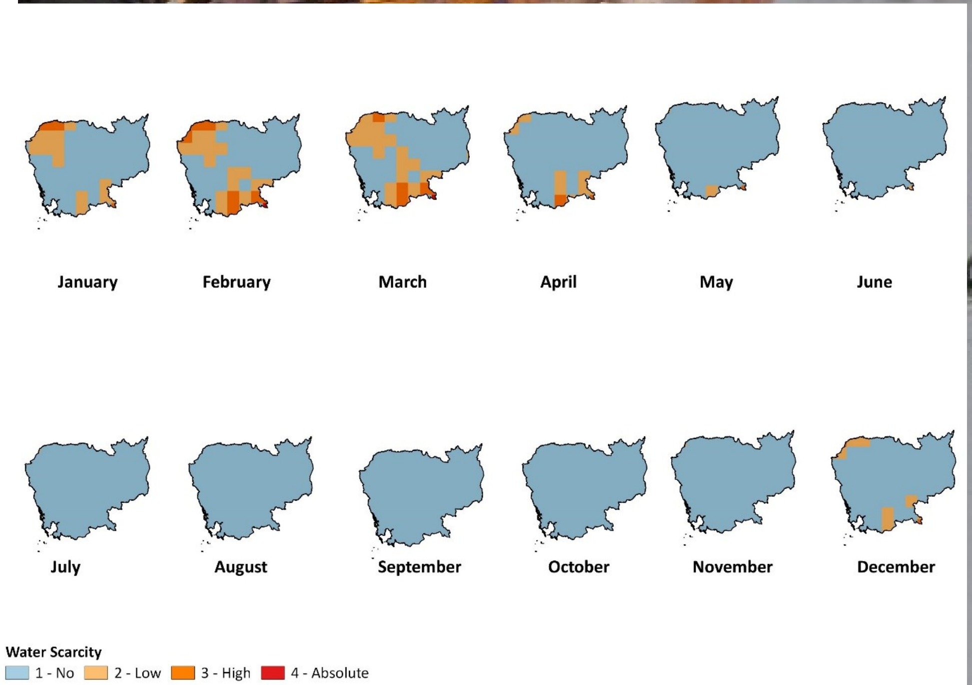


Fig. 4. Water scarcity monthly averages 1971-2010 (Kallio, 2021)

Highlights:
Thailand

Thailand experiences all four types of water scarcity: **too little water**, **too variable water**, **overutilisation**, and **poor water quality**.

Each region of the country experiences water scarcity differently – e.g., **industrial development** in the Eastern Economic Corridor has **rapidly increased water demand** and is causing **over-utilisation** of water.

Poor water quality is a widespread issue due to **industrial and agricultural pollution** and **high population density**, along with low rates of **wastewater treatment** (except in Bangkok).

Recent **droughts** have led to increased **saline intrusion** (e.g., in Chao Phraya).

Climate change may impact the country's agricultural sector due to increased **spatial and seasonal variability** of precipitation.

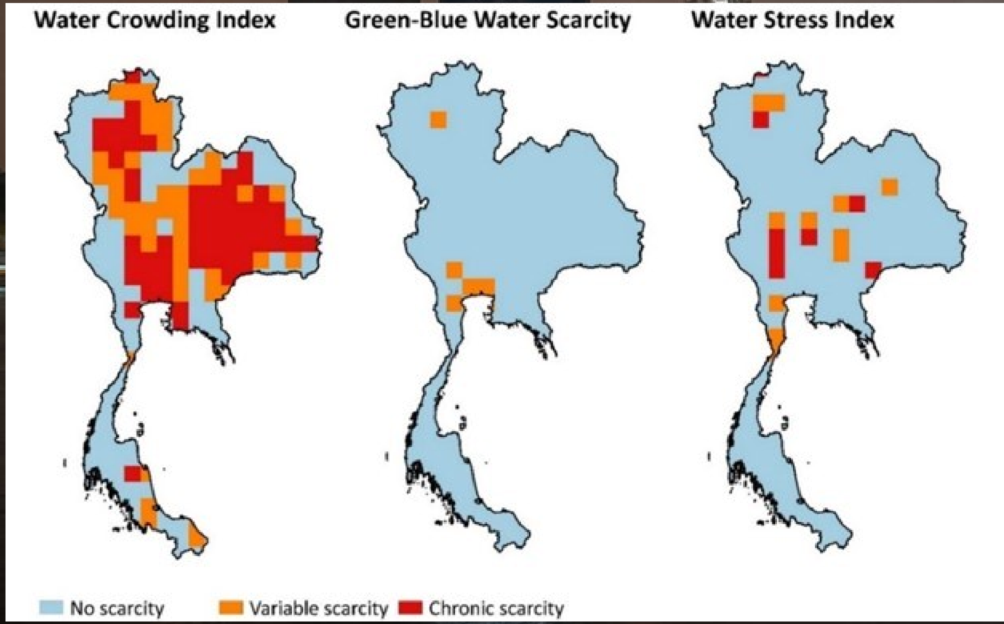


Fig. 5. Water scarcity indicators for Thailand (Kallio, 2021)

Highlights: Lao People's Democratic Republic

Lao PDR has relatively abundant water resources per capita, but **spatial and temporal variability** is causing **too variable water**, **over-utilisation**, and **poor water quality**.

Increasing water demands from the **agricultural**, **industrial**, and **domestic sectors** are expected to worsen water scarcity. **Intensification of irrigation** is also a growing problem in many areas.

Hydropower reservoirs on the Mekong River are **fragmenting river hydrology** in many areas and **changing the timing of water availability** throughout the year by flattening seasonal variability.

Industrial and urban areas (e.g. Vientiane, Savannakhet and Pakse) face water quality issues due to **pollution**.

Highlights: Viet Nam

The Mekong Delta faces intensified saline intrusion due to decreasing transboundary water flows and deepening river channels due to sand mining, while agricultural and domestic wastewater contribute to poor water quality.

Viet Nam experiences all four types of water scarcity:

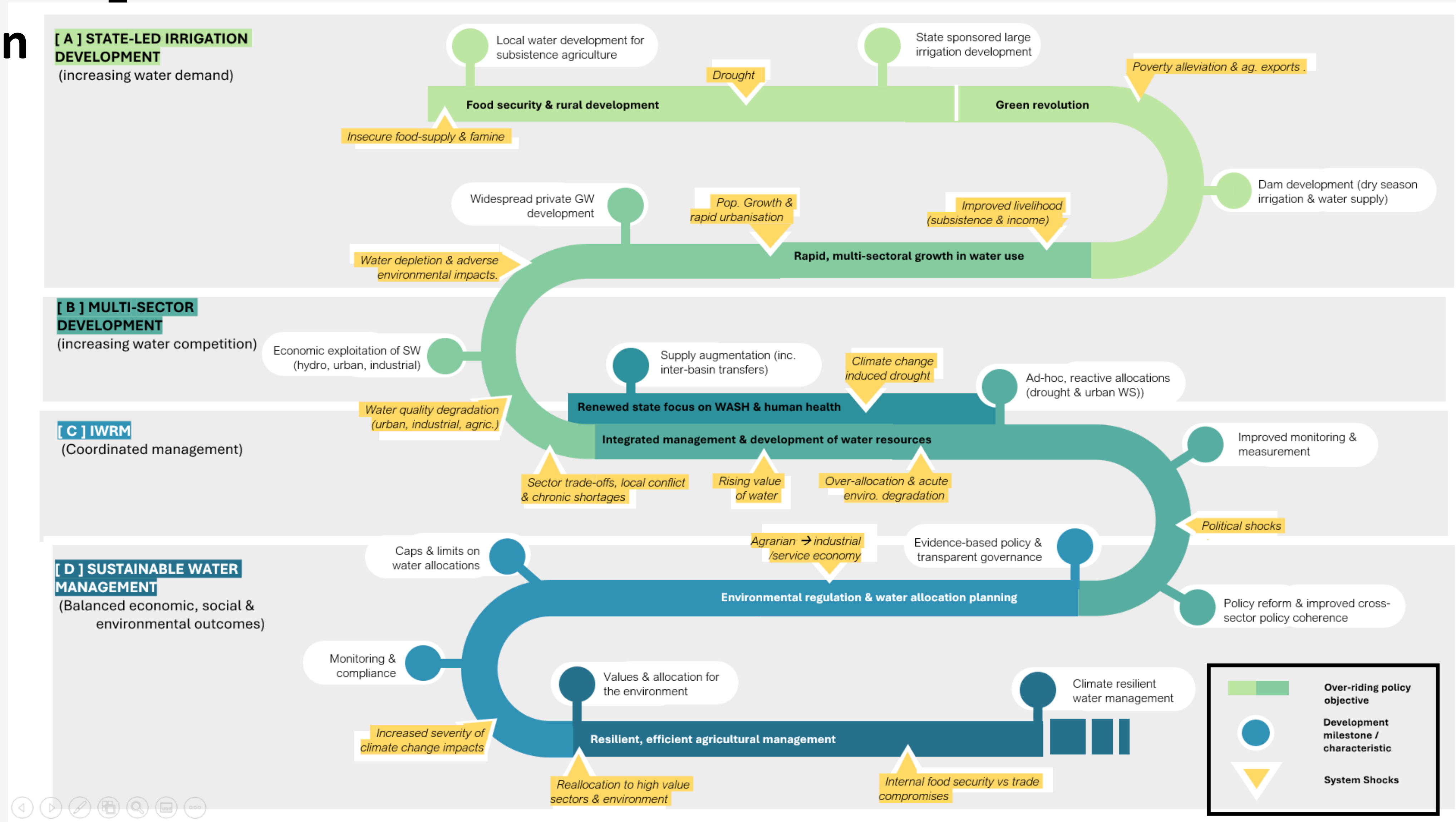
too little water, **too variable water**, **over-utilisation** and **poor water quality**.

High spatial variation in water scarcity across the country; **Mekong Delta** facing significant issues of **saline intrusion** due to impacts of **sand mining** and reduced transboundary water flows.

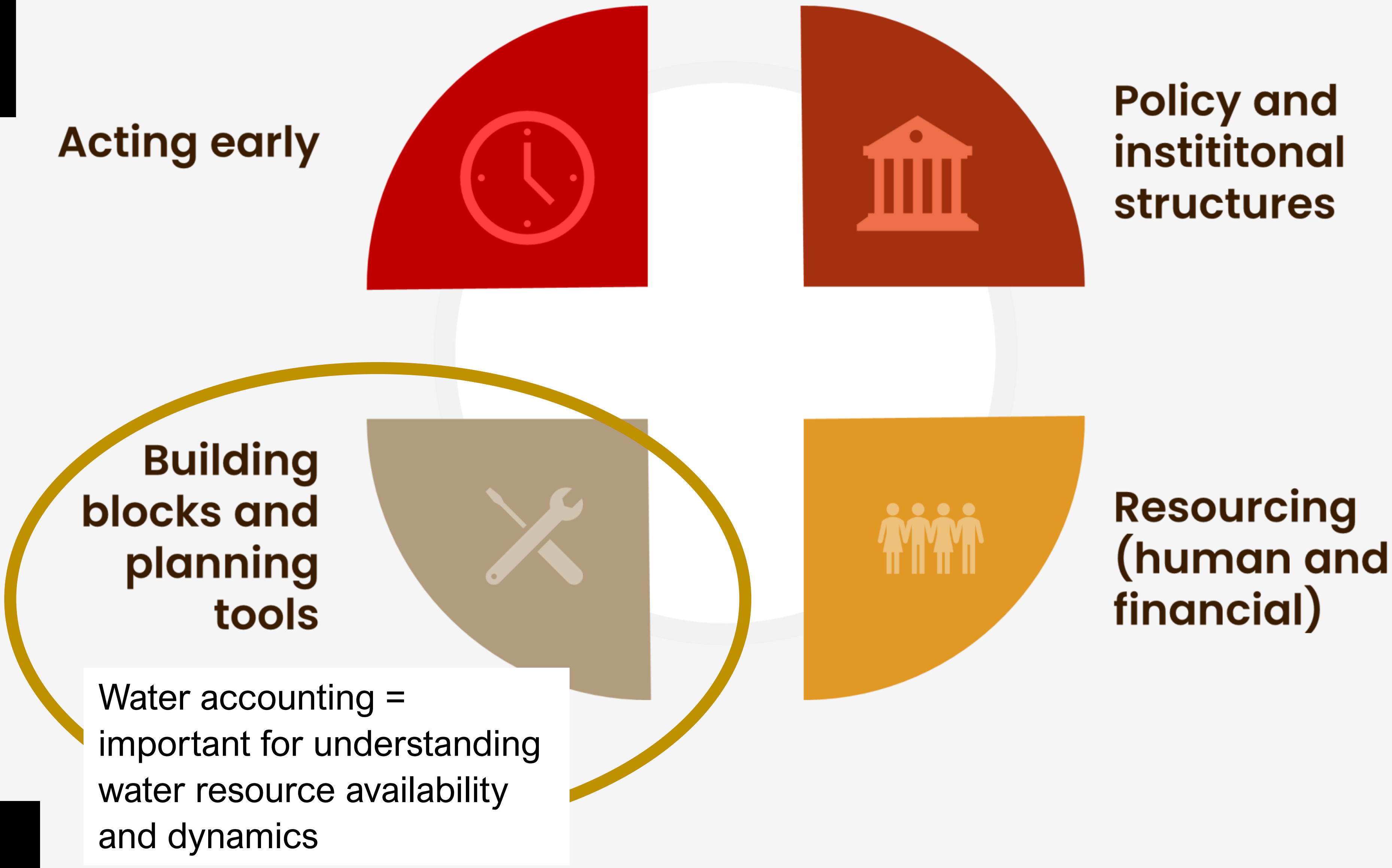
Transboundary concerns due to 63% of the country's surface water sourced from transboundary rivers.

Groundwater overexploitation in some areas is leading to **land subsidence** and poor water quality.

There is a common pattern to water resources development, including water scarcity…

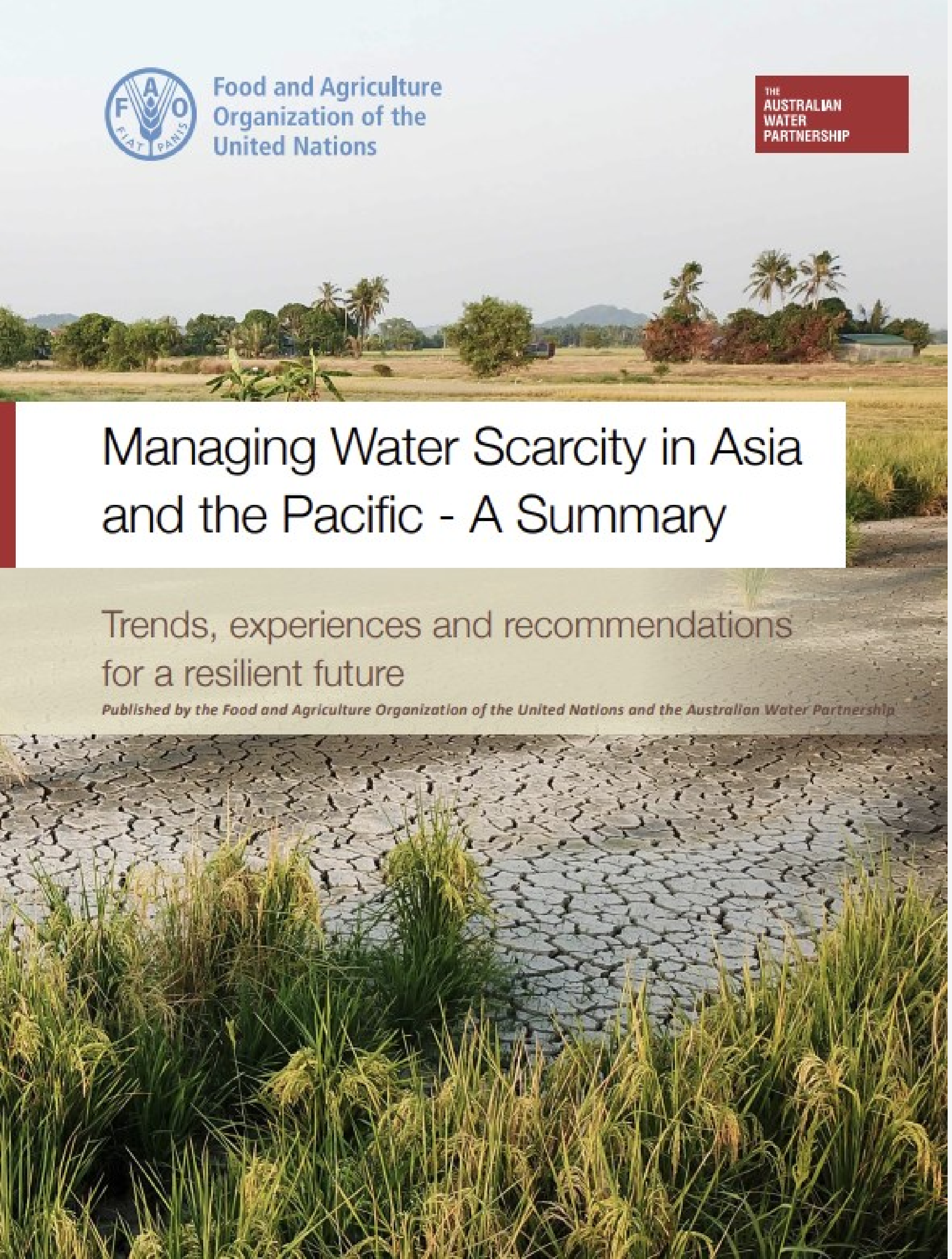


This trajectory helps to identify four categories of insights for management of water scarcity



Concluding remarks

- Growing pressures such as **population growth**, increasing **water demands and competition**, and **pollution** continue to **worsen water scarcity** across the Asia and Pacific.
- Water scarcity challenges in the **Lower Mekong** countries tend not to be about chronic scarcity, but rather **‘too much’ or ‘too little’** (i.e., too variable) water.
- This often manifests as **drought** and **seasonal scarcity**, which may worsen in some countries due to limited seasonal water storage (e.g., Cambodia and Lao PDR).
- **Water quality is deteriorating** due to **industrial** and **agricultural pollution**, with serious implications for **human health**, **ecosystems**, and **food security** across the region.
- **Water scarcity has no easy fix, but acting early is vital** and we have many tools available to us to move towards more sustainable water management.



Thank you for listening!

Cảm ơn

ขอบคุณ

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ຂອບໃຈ

ASIA PACIFIC WATER SCARCITY Programme

Contact me: amy.fallon@amperes.com.au

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Food and Agriculture Organization of the United Nations

Session 1: Water security in the GMS in a changing climate

Climate change and water scarcity

Dr Jerasorn Santisirisomboon

RU-CORE, Ramkumhaeng University

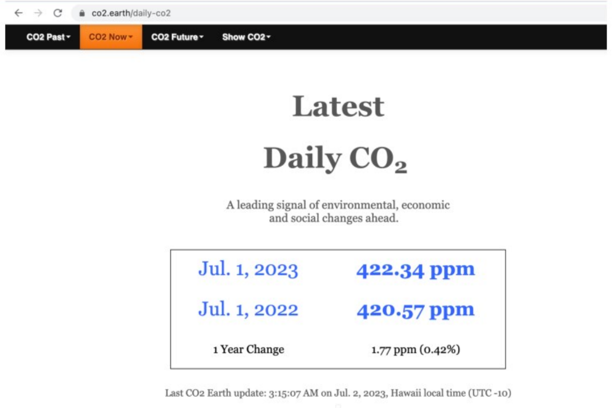
Climate change and water scarcity

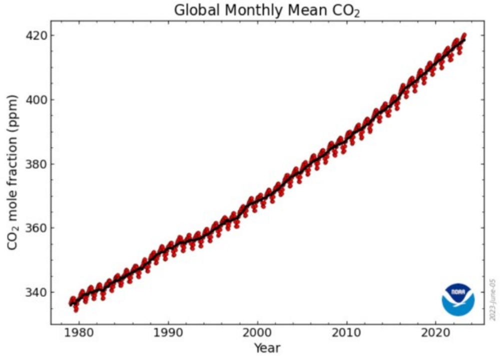
Asst.Prof.Dr Jerasorn Santisirisomboon

Ramkhamhaeng University Center of Regional Climate Change and Renewable Energy

RU-CORE Ramkhamhaeng University Center of Regional Climate Change and Renewable Energy

CO_2 Now/Global Temperature





Global monthly means since 1980

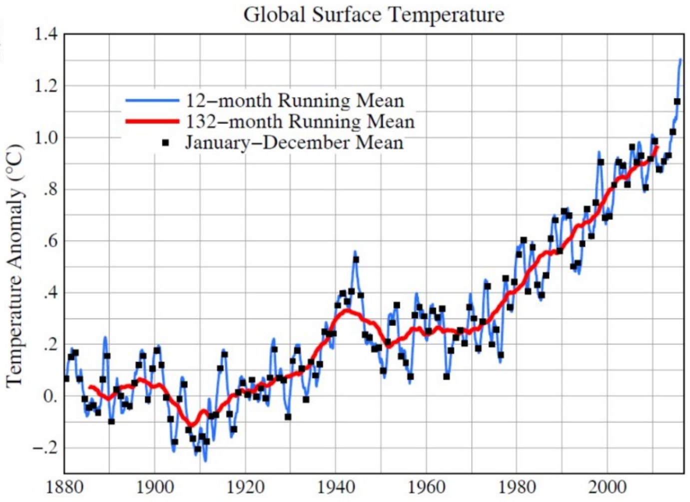
Global Temperatures

May 2023 Global Temperatures

+1.22°C

3rd warmest May since 1880

CSAS / GISS update: June 16, 2023

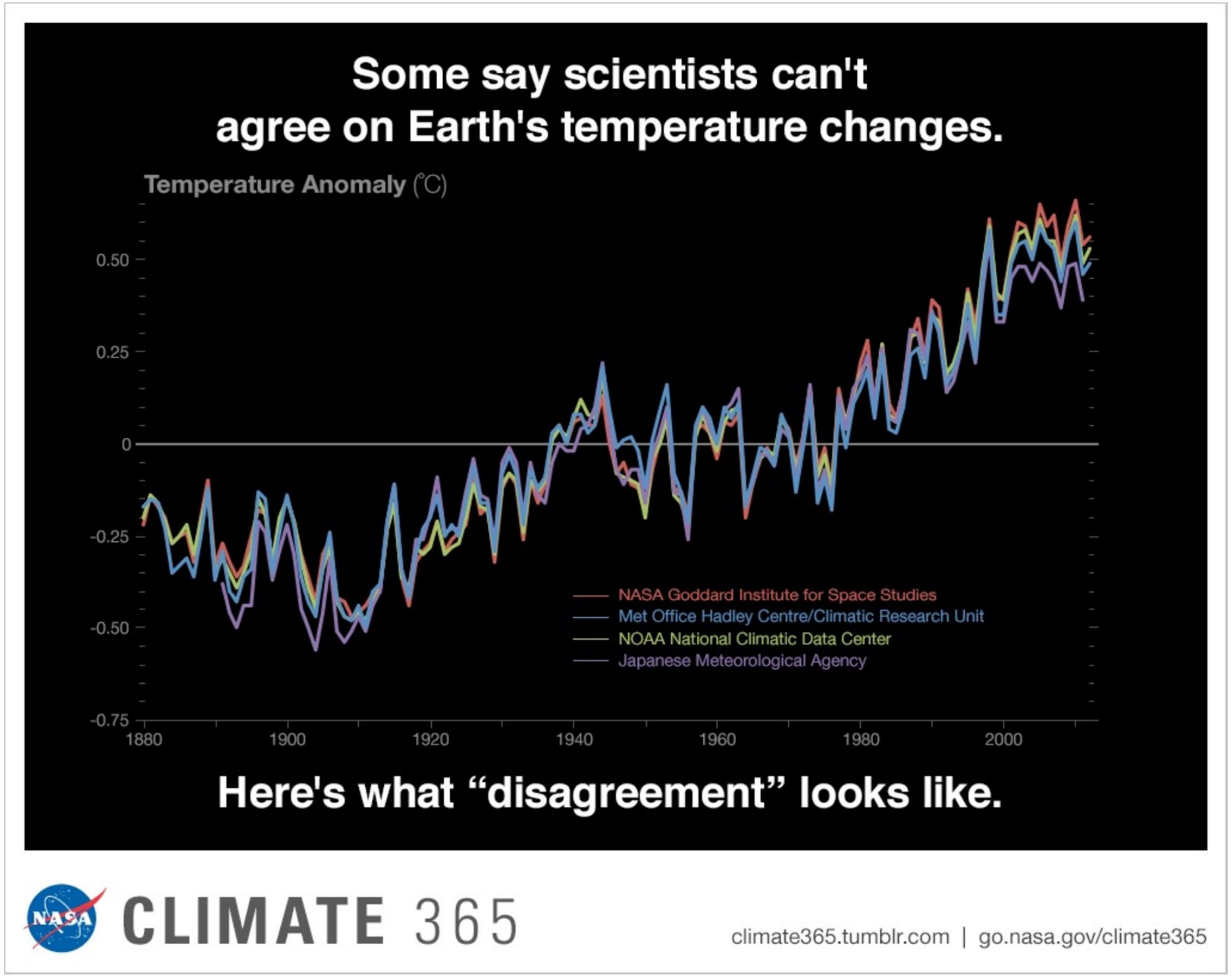


Credit: National Snow and Ice Data Center

Muir Glacier, Glacier Bay, Alaska in 1941, 1976, and 2004.

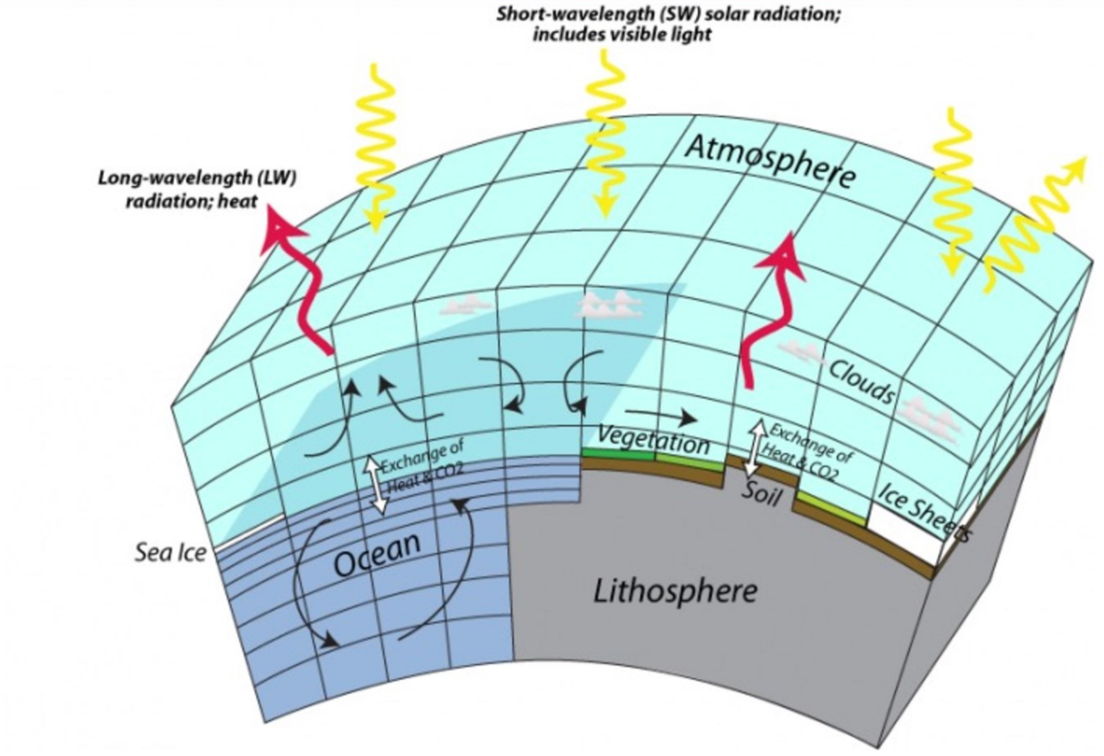
Each year, four international science institutions compile temperature data from thousands of stations around the world and make independent judgments about whether the year was warmer or cooler than average.

"The official records vary slightly because of subtle differences in the way data analyzed. But they also agree extraordinarily well."



Downscaling GCMs : CORDEX Southeast Asia

General Circulation Model (GCM)

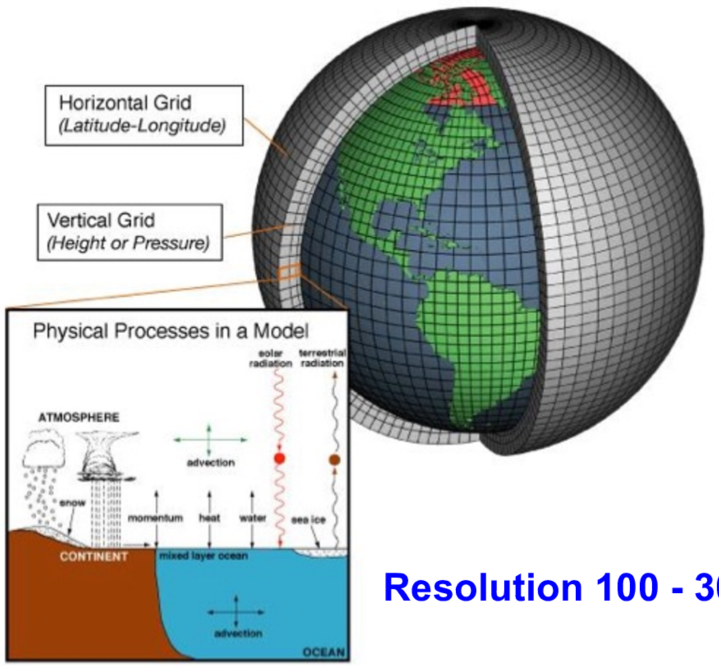


Credit: David Bice © Penn State University

Global Circulation Model (GCM) is a model that simulates general circulation of planetary atmosphere or oceans. The term general circulation is used to indicate large-scale atmospheric or oceanic motions with its persistent as well as transient features on various scales. GCM employs a combination of mathematical expressions that represent governing physics of circulations processes and empirical calculations which replicate processes based on data.

Modeling Future Climate Using GCMs

FIGURE 3. CONCEPTUAL STRUCTURE OF A GCM

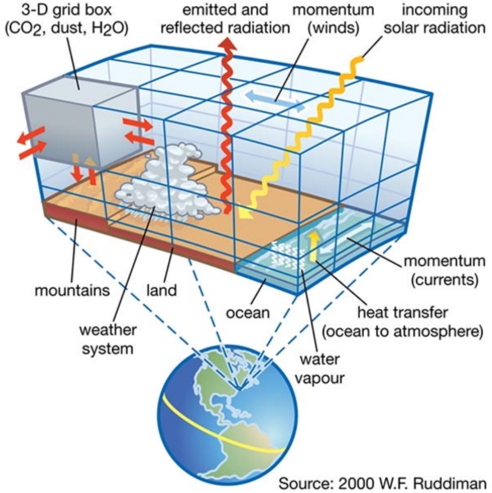


Source: National Oceanic and Atmospheric Administration (NOAA), 2012

Resolution 100 - 300 km

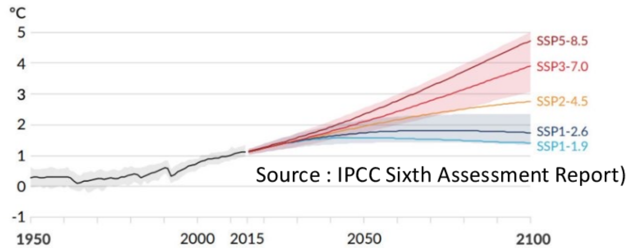
- Numerical simulation of important physical processes involving the land, atmosphere, ocean, ice, etc, of the globe.
- For scientific understanding.
- Results are given also where and when there is no monitoring.

Concept diagram of climate modeling

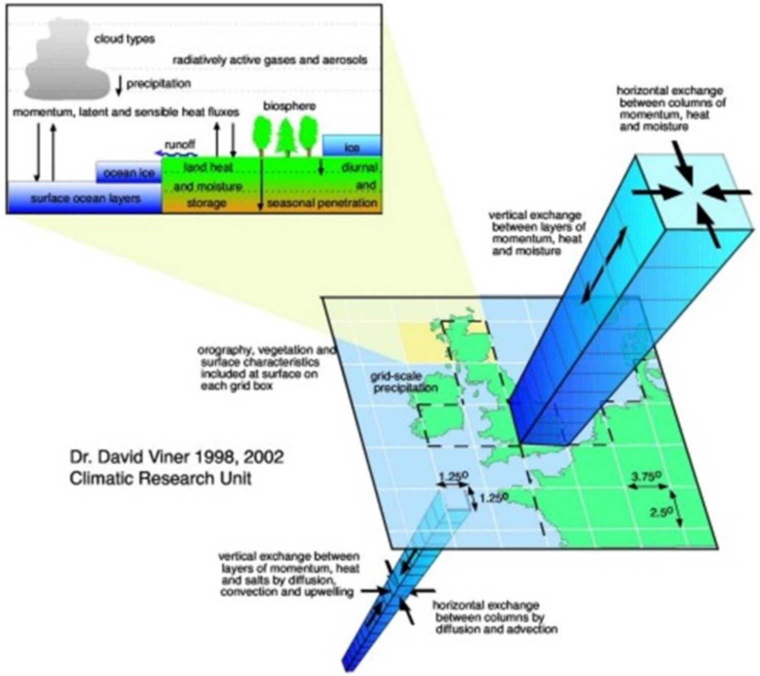


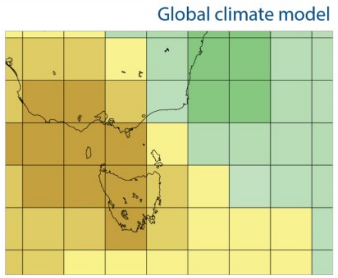
Source: 2000 W.F. Ruddiman

a) Global surface temperature change relative to 1850-1900



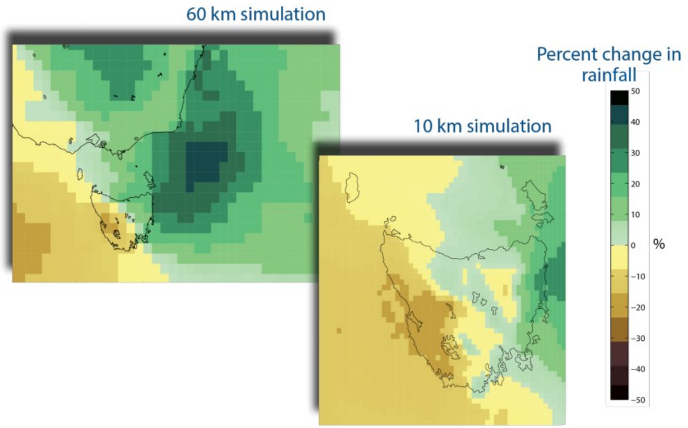
Downscaling GCMs



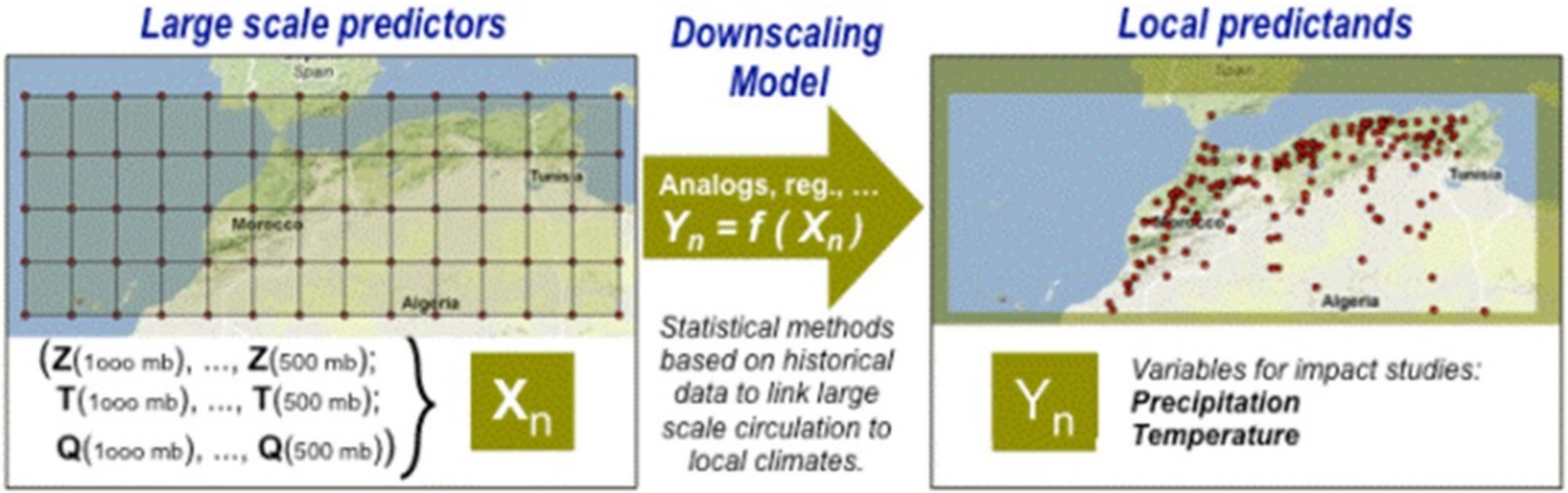


Approaches in downscaling GCMs
- Statistical Approach
- Dynamical Approach

https://climatefutures.org.au/projects/what-is-downscaling/

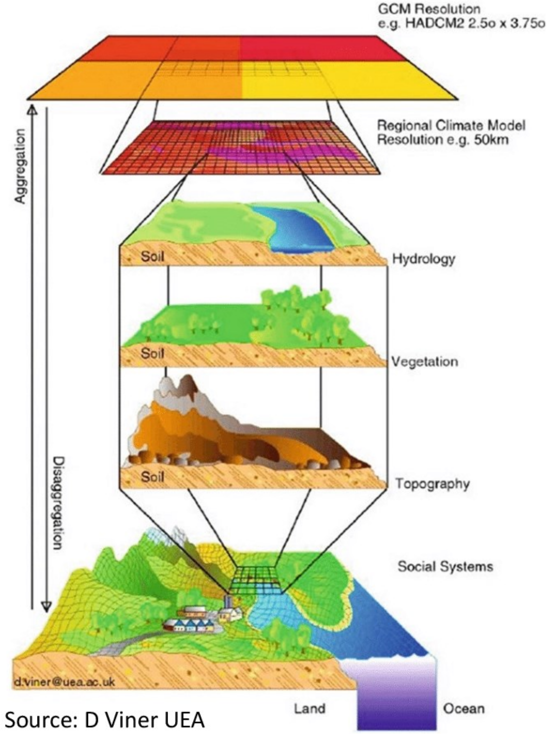


Statistical Approach



Dynamical Approach

Dynamical Climate Downscaling

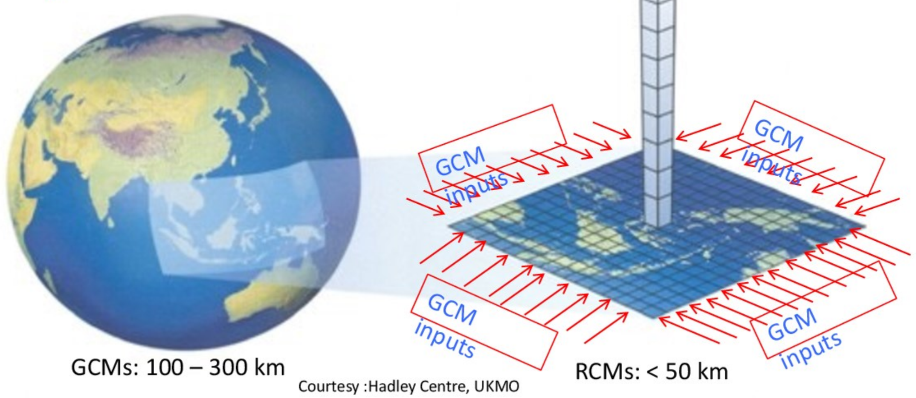


Source: D Viner UEA

RCM is forced at the boundary with inputs from GCMs (Specific humidity, air pressure, air temperature, U wind and V wind) at 6-hourly interval

The RCM is integrated to create its own weather and climate

With the requirement of having multiple GCMs, multiple RCMs and multiple scenarios for robust climate projections, regional climate downscaling is a resource-expensive and extremely time consuming exercise.



Courtesy :Hadley Centre, UKMO

Schematic diagram of the resolution of the Earth's surface and the atmosphere in the Hadley Centre regional climate model.

Southeast Asia Region

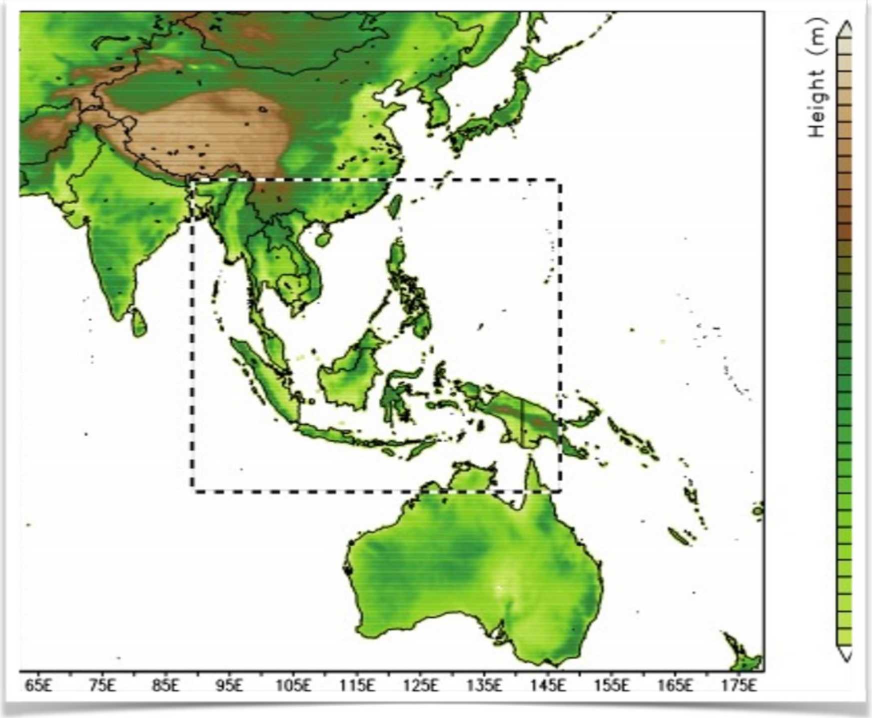
could be affected in the future ?

- Warmer temperature ✓
- More intense precipitation events ✓
- Large variations of rainfall and temperature associated with ENSO ✓
- Changes in monsoon ✓
- Sea level rise ✓
- Warmer ocean & acidification ✓

- > ½ billion people
- High exposure, higher vulnerability
- No coordinated regional climate downscaling
- No freely available downscaled regional climate change scenarios
- Could be a contributing factor to lack of IAV studies in the region

Southeast Asia Region

- With multiple GCMs, RCMs, and emission scenarios, regional climate downscaling requires large computing resources
- We have a number of institutions with regional climate modeling expertise but limited resources
- Collaboration and sharing resources are the way to move forward
- CORDEX provides a good platform for regional collaboration



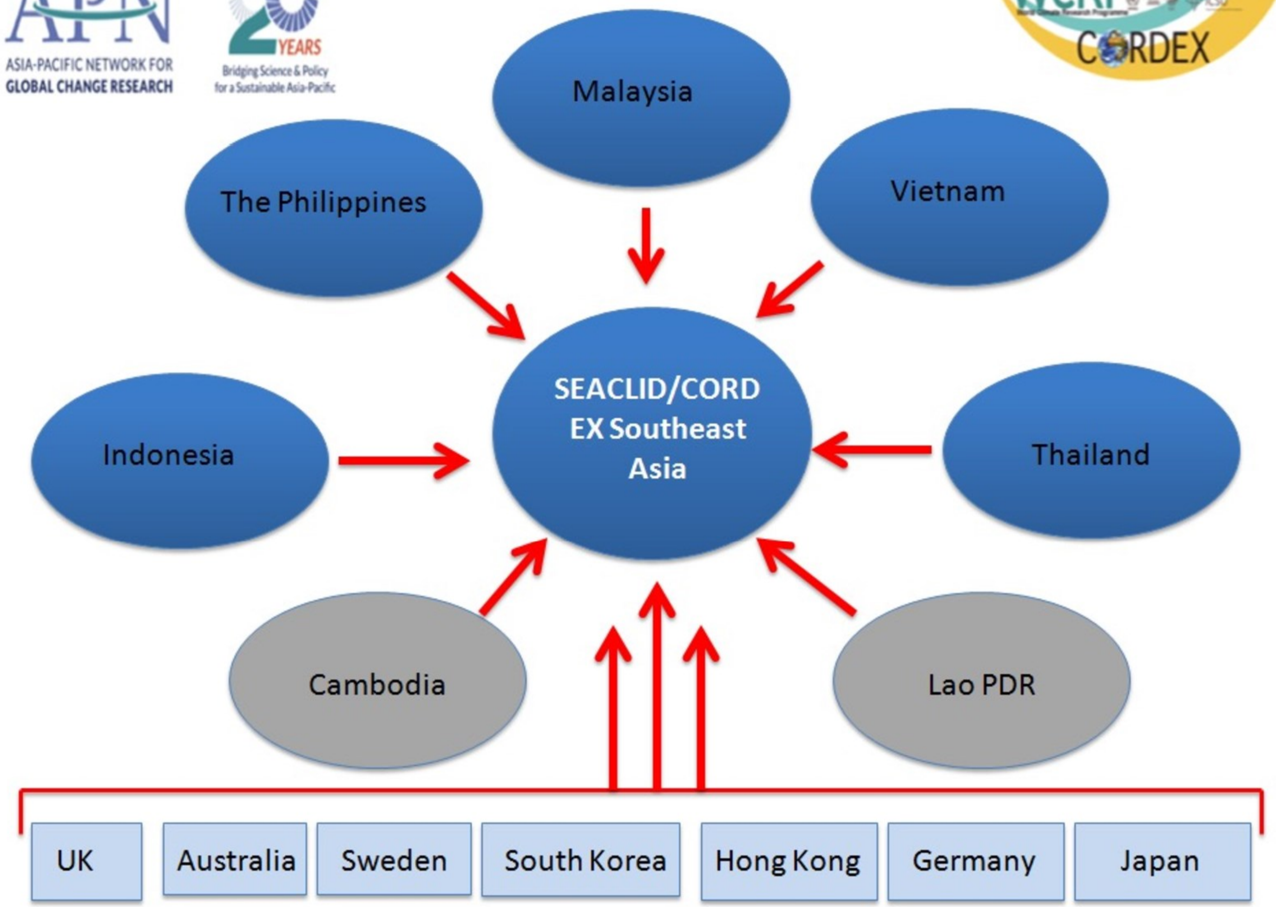
Southeast Asia Regional Climate Downscaling (SEACLID)

APN ASIA-PACIFIC NETWORK FOR GLOBAL CHANGE RESEARCH — 20 YEARS Bridging Science & Policy for a Sustainable Asia-Pacific

Initial Member Countries: Malaysia, Indonesia, Vietnam, Philippines, Thailand
First Workshop hosted by VNU Hanoi University of Science, Vietnam, 2-3 Aug 2012

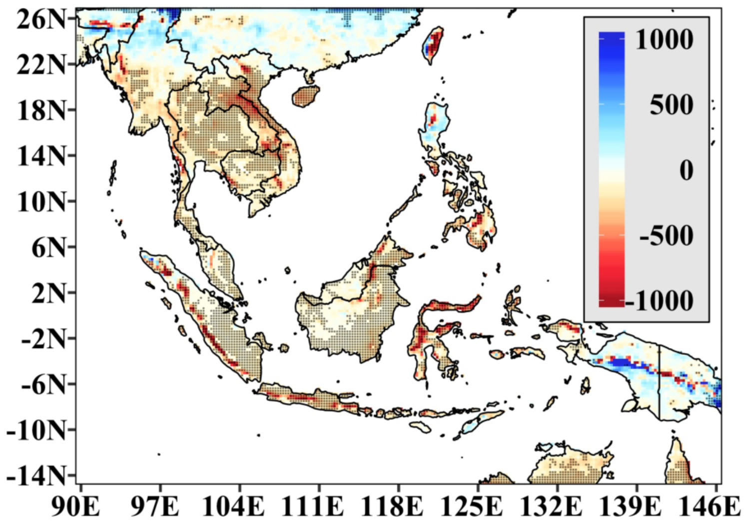
SEACLID/CORDEX Southeast Asia Objectives

- Create a platform for scientists (especially young scientists) within and outside the SEA region to collaborate on issues related to regional climate downscaling;
- On a task-sharing basis, carry out a joint regional climate downscaling activity over a common SEA domain with RegCM4 (and other RCMs) using a number of CMIP5 GCMs and RCP scenarios;
- Collectively analyze model performances, create an ensemble of regional climate projection scenarios for the SEA region, and establish a web portal and data center for efficient data dissemination (ESGF);
- Narrow knowledge gaps related to regional climate change in SEA by increasing peer-review scientific and policy-relevant publications and strengthen research capacity and capability, particularly in numerical regional climate modeling.


Malaysia
The Philippines
Vietnam
SEACLID/CORD EX Southeast Asia
Indonesia
Thailand
Cambodia
Lao PDR
UK
Australia
Sweden
South Korea
Hong Kong
Germany
Japan

Needed for High Resolution Climate Data Set

Yearly Precipitation Change :
2081 – 2099 compared to 1970 - 2005

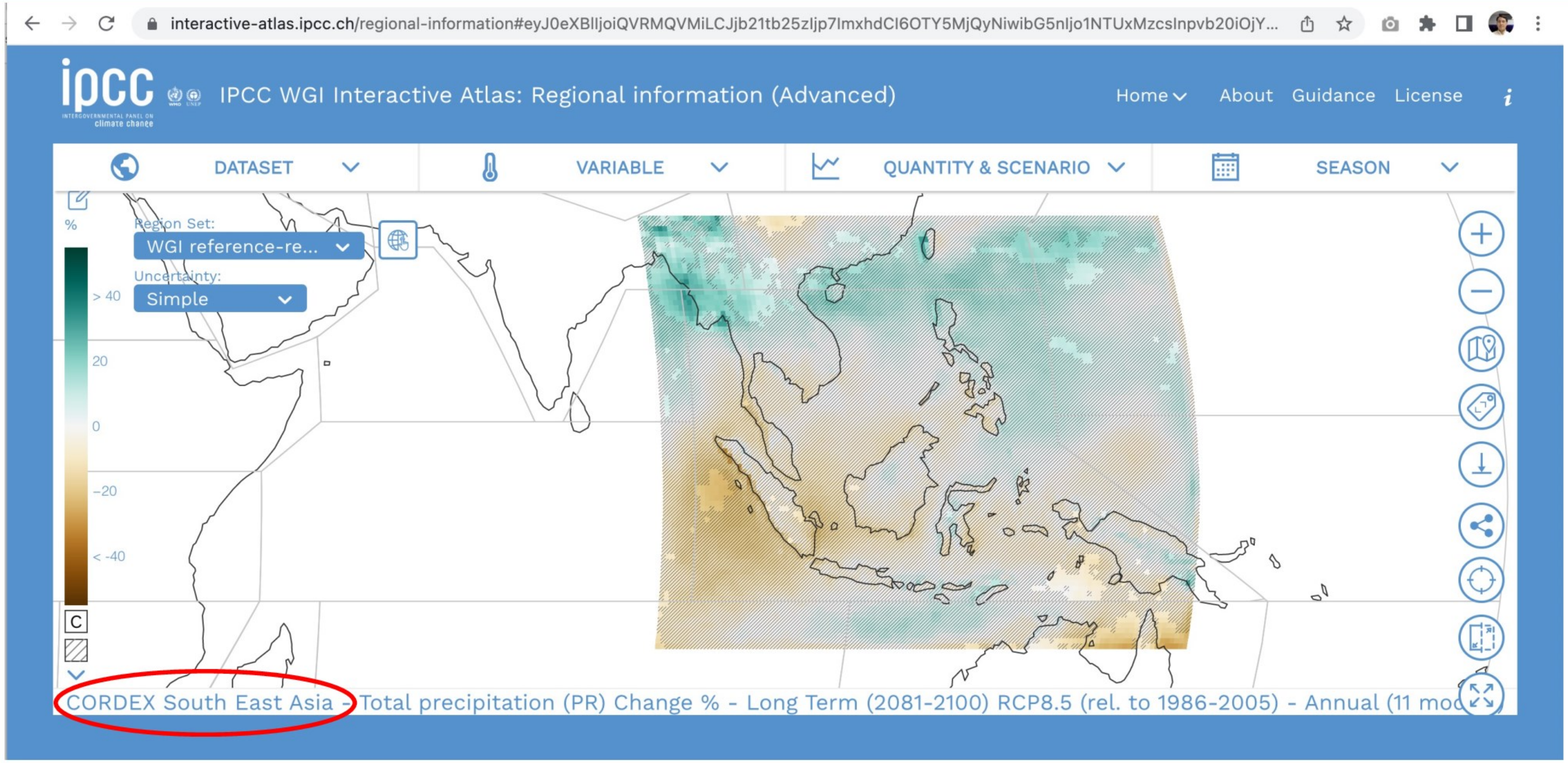


Needed for higher resolution!?

CORDEX SEA domain and model set up of SEACLID/CORDEX Southeast Asia Phase 1

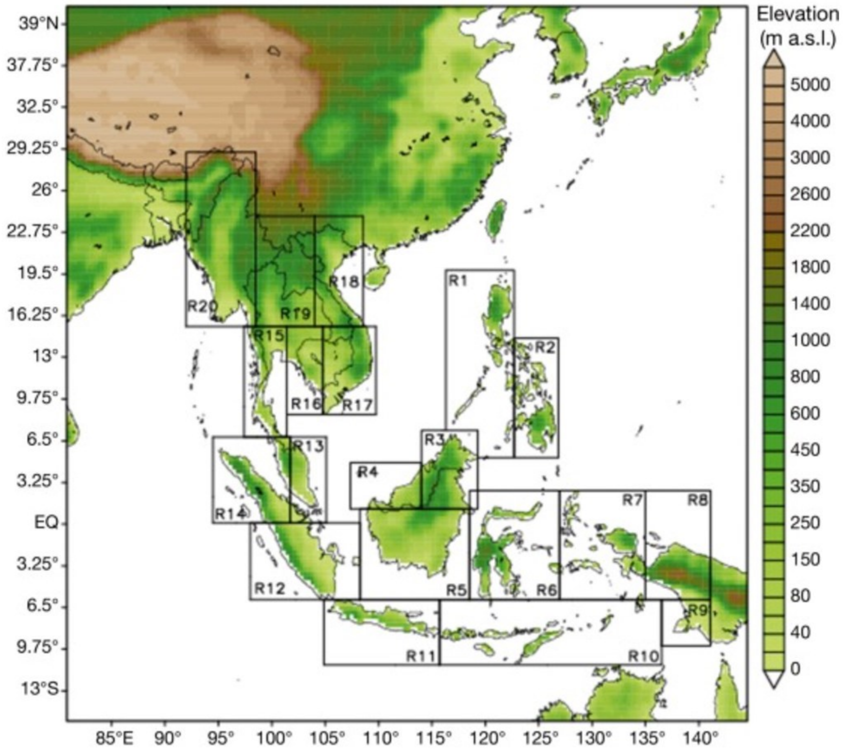
Regional Climate Model	RegCM4 v RegCM 4.3.5.7
Domain	Latiture 15.14°S – 27.26°N Longitude 89.26°E – 146.96°E
Resollution	25 km × 25 km
Domain cartographic projection	Normal Mercator
Cumulus convection Scheme	MIT Emanual
Ocean Flux scheme	Zeng Ocean model roughness formula 1
Boundary layer scheme	Holslag PBL
Moisture scheme	Explicit moisture

IPCC WGI Interactive Atlas



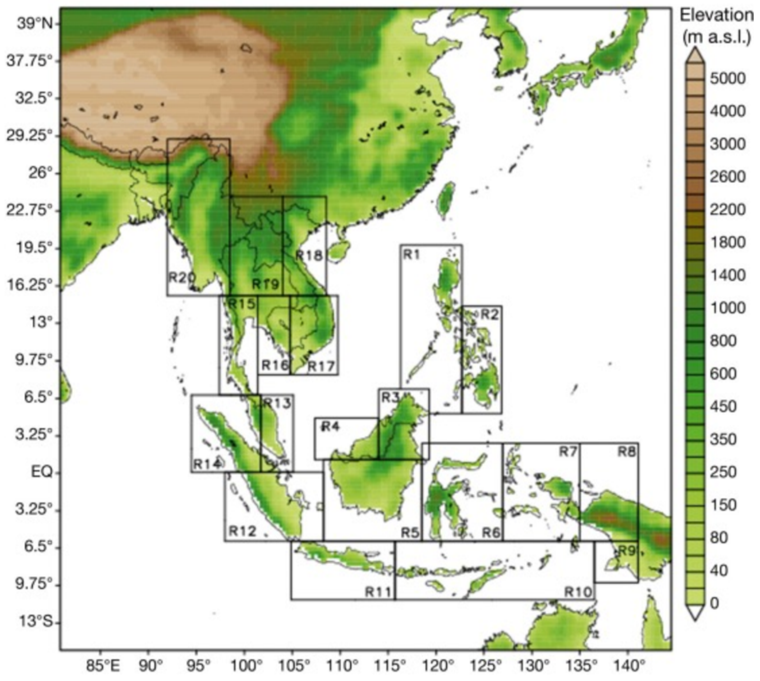
Performance of CORDEX Southeast Asia data set

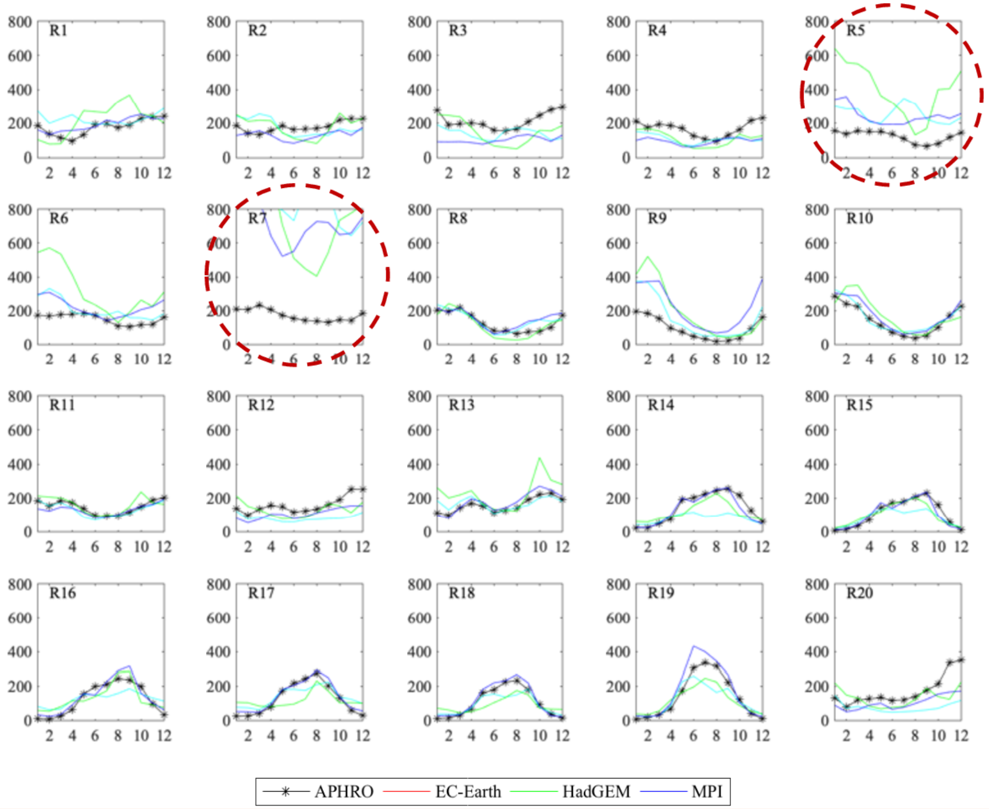
Southeast Asia Subdomains



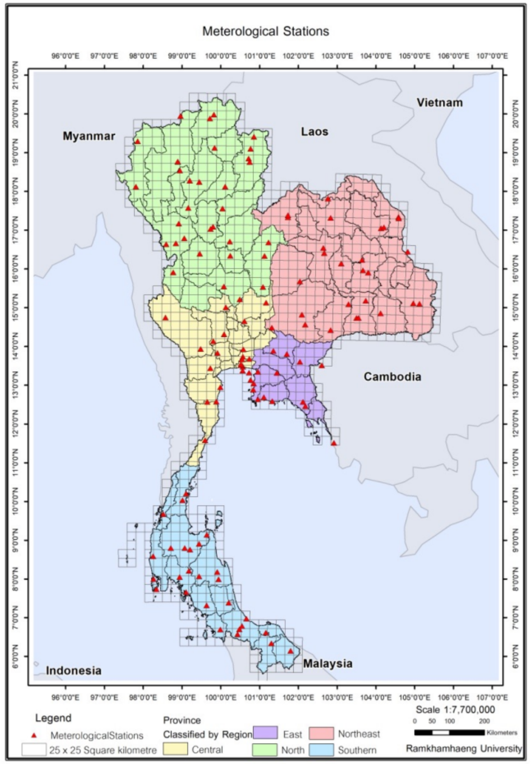
Performance of RegCM4.7 to simulate the Precipitation Seasonal Cycles over subdomains of Southeast Asia

APHRODITE VS RCMs

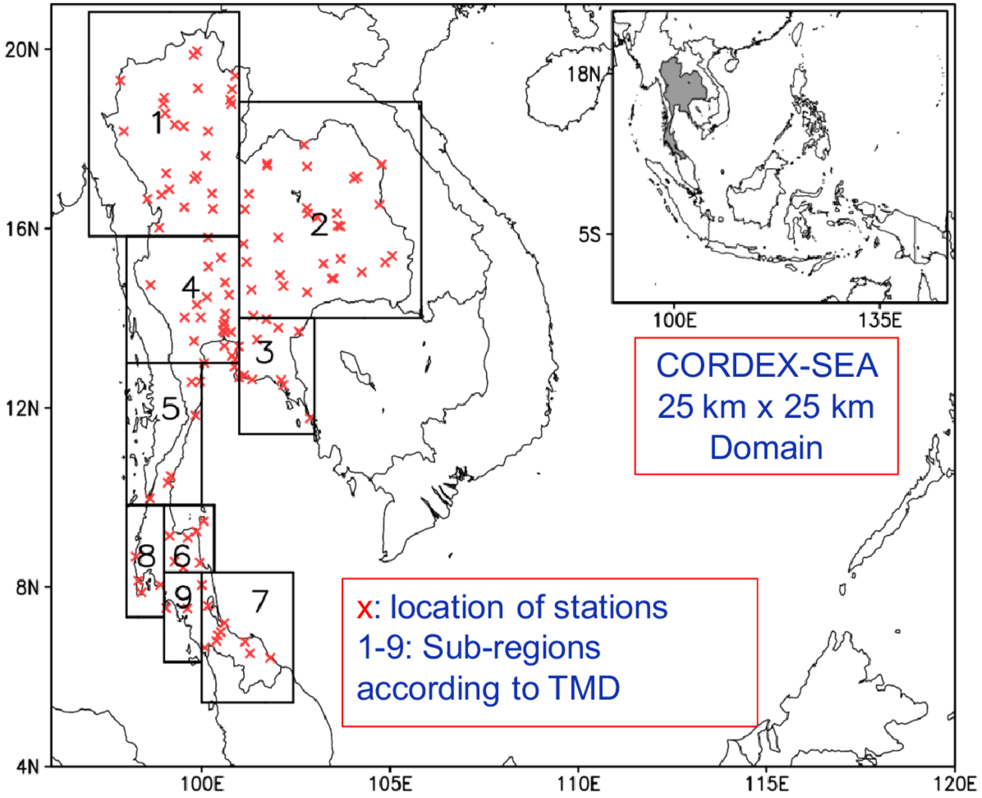




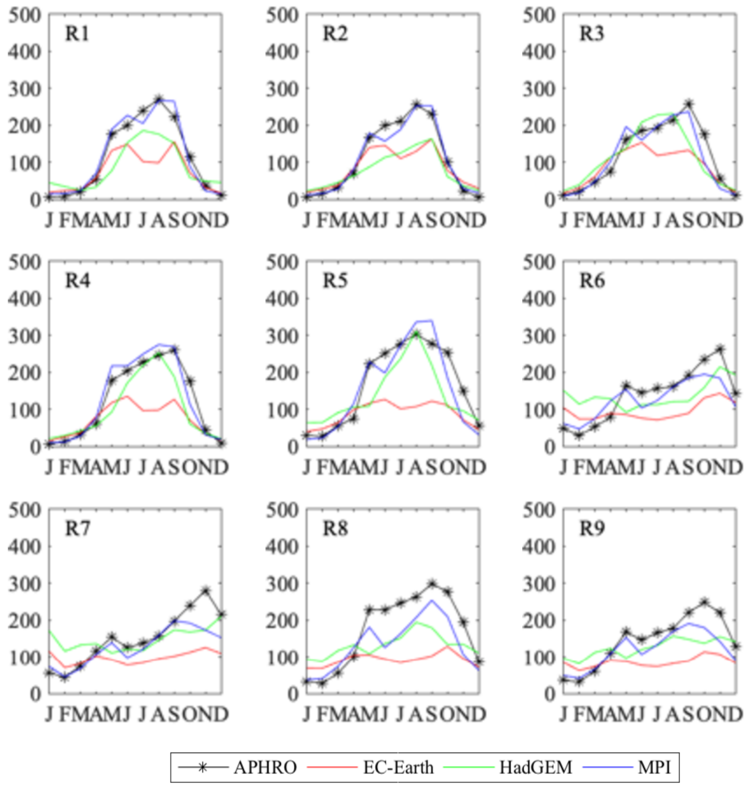
Meteorological Stations and Subregions in Thailand

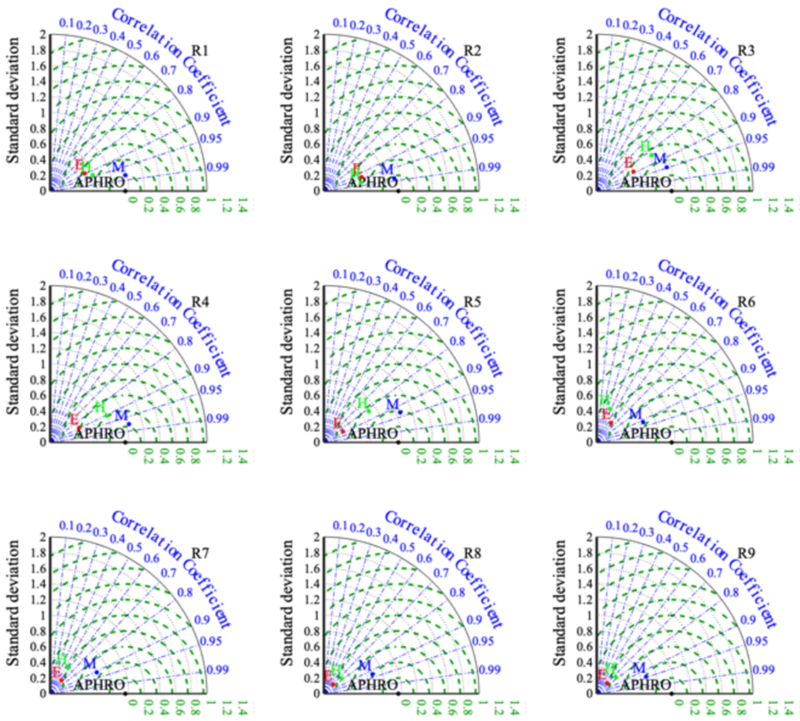


- There are 123 meteorological stations in Thailand
- Based on the definition of Thai Meteorological Department (TMD), there are 5 regions in Thailand.



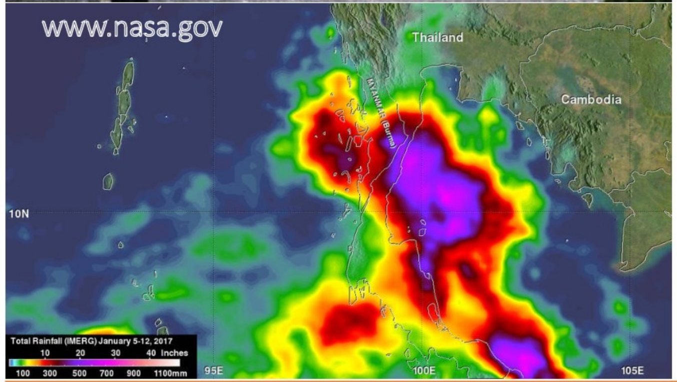
Performance of RegCM4.7 to simulate the Precipitation Seasonal Cycles over subdomains of Thailand

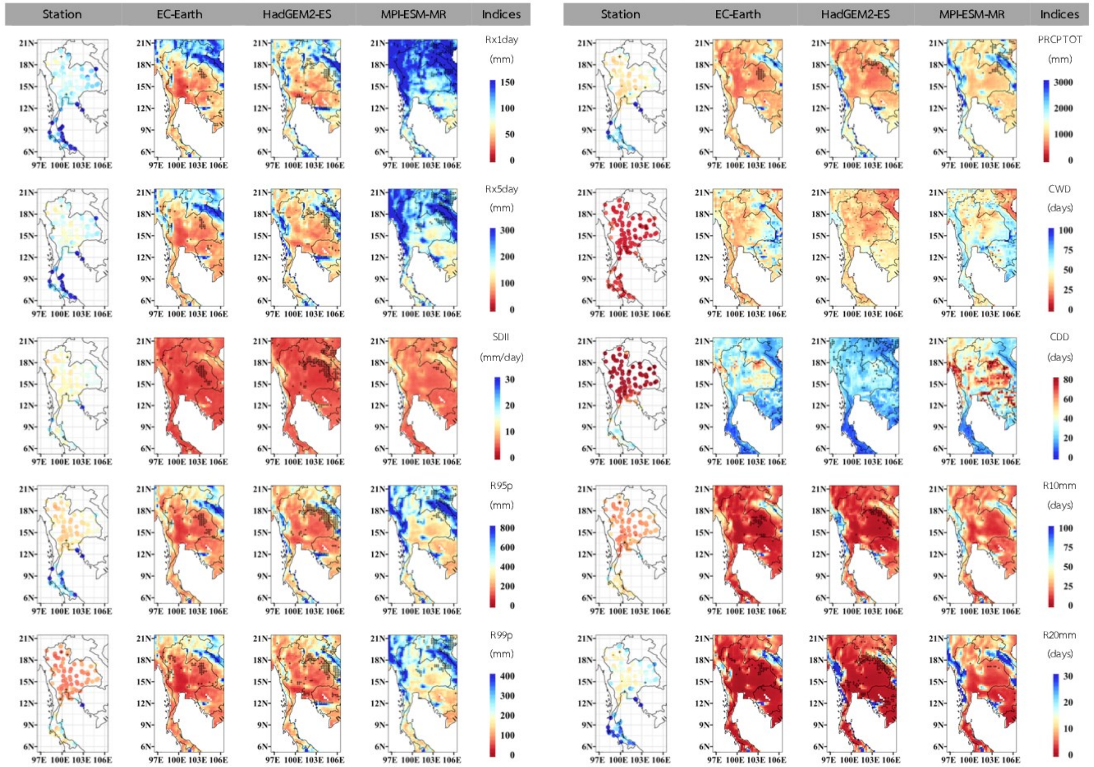




หมายเหตุ : APHRO - ชุดข้อมูลอ้างอิง E – EC-Earth H – HadGEM2-ES และ M – MPI-ESM-MR

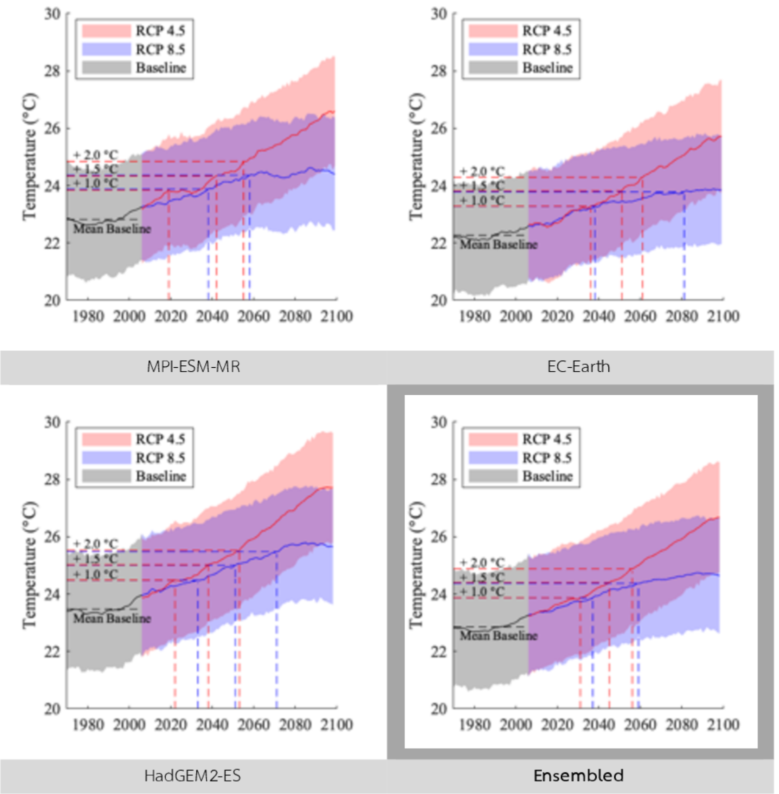
Extreme Precipitation Indices :
RCMs vs Observation : 1970 – 2005

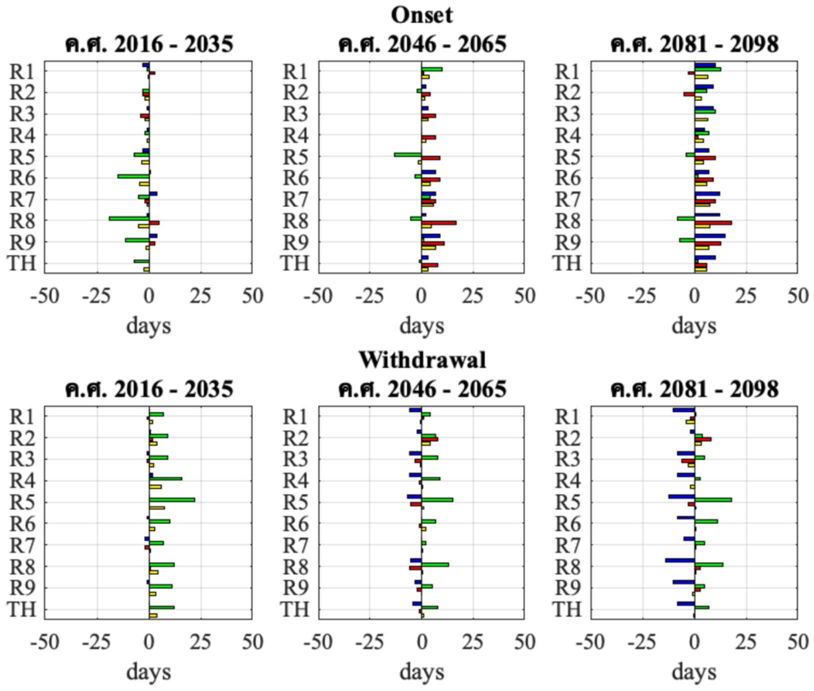




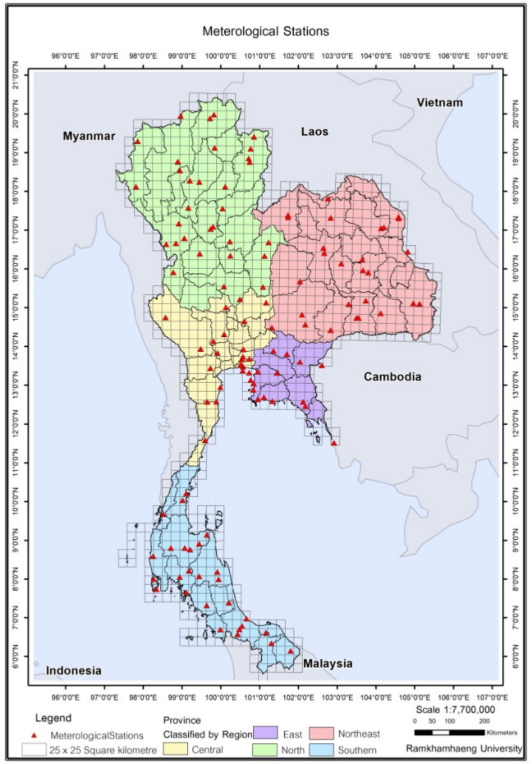
Climate Projection : CORDEX Southeast Asia

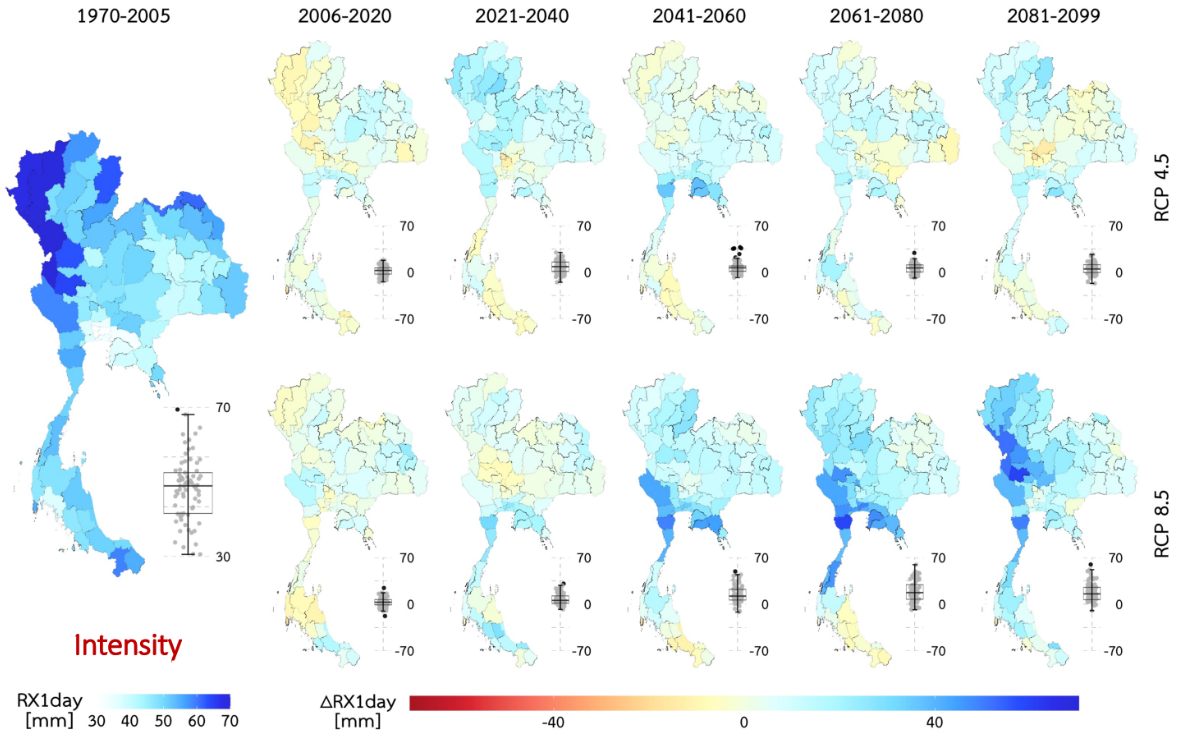
Projection of Temperature Anomaly : Thailand



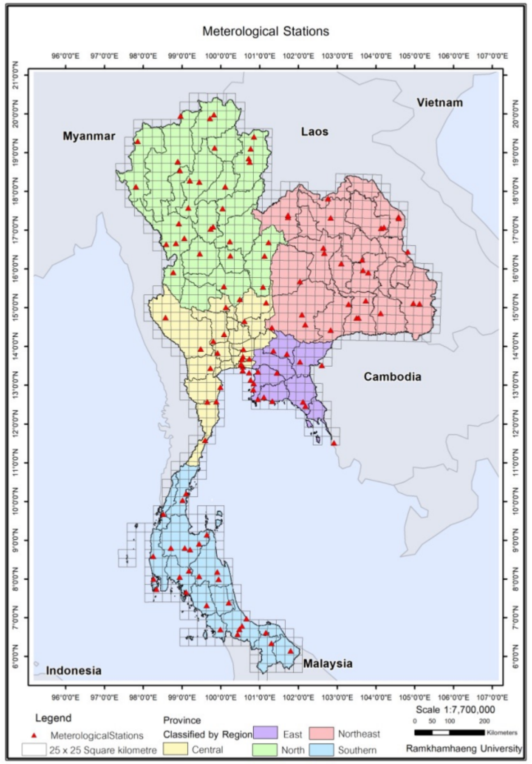


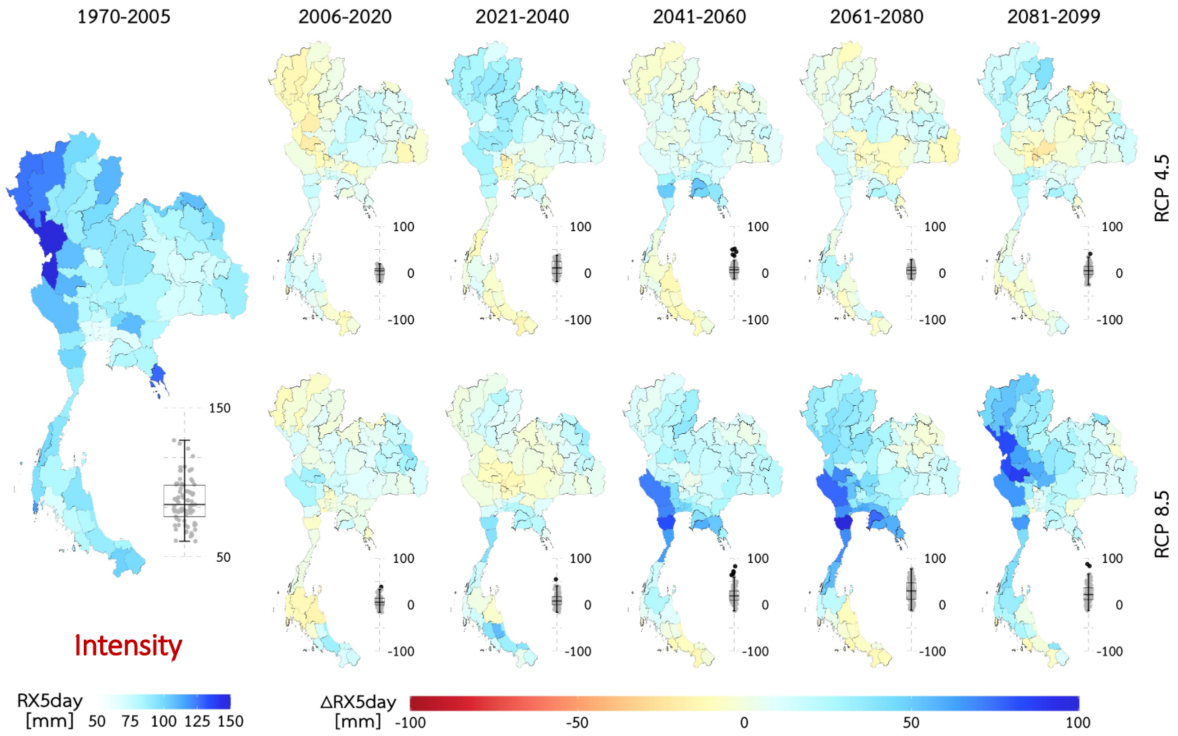
Maximum 1-day precipitation total :
Max 1-day precipitation



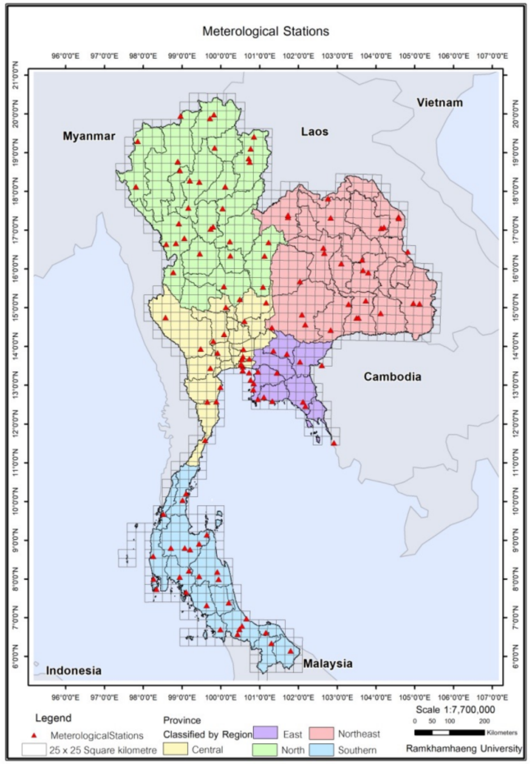


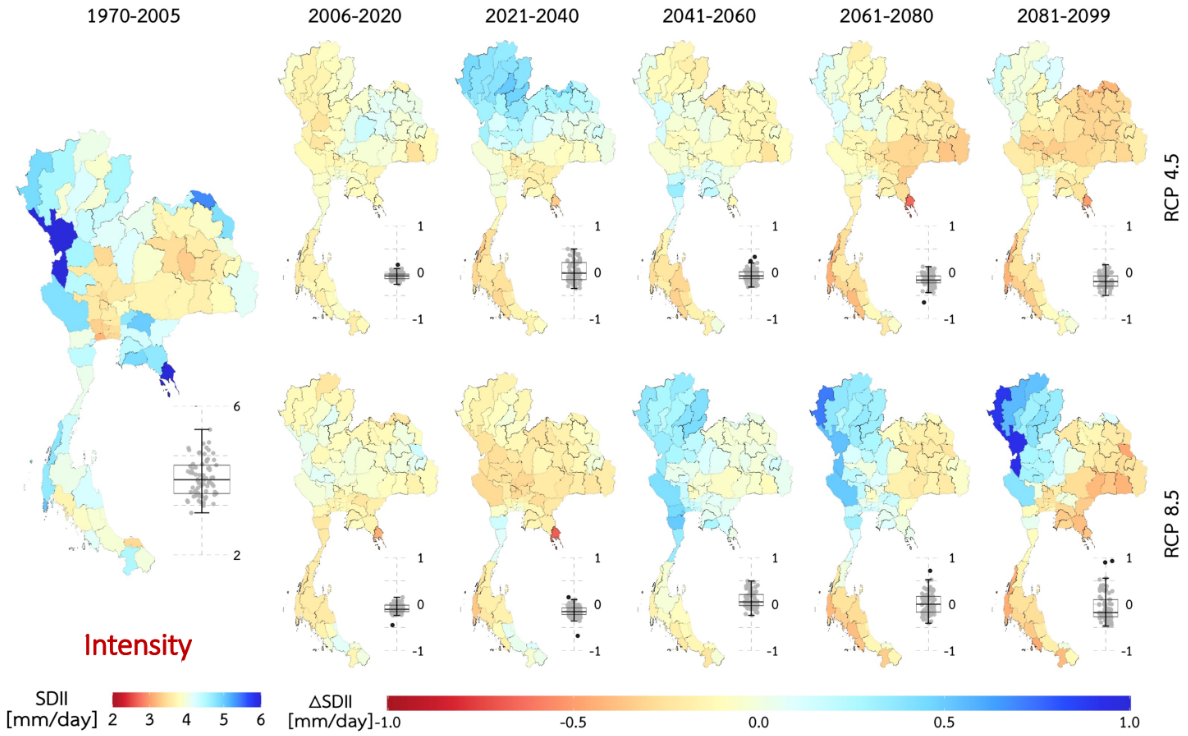
Maximum 5-day precipitation total :
Max 5-day precipitation



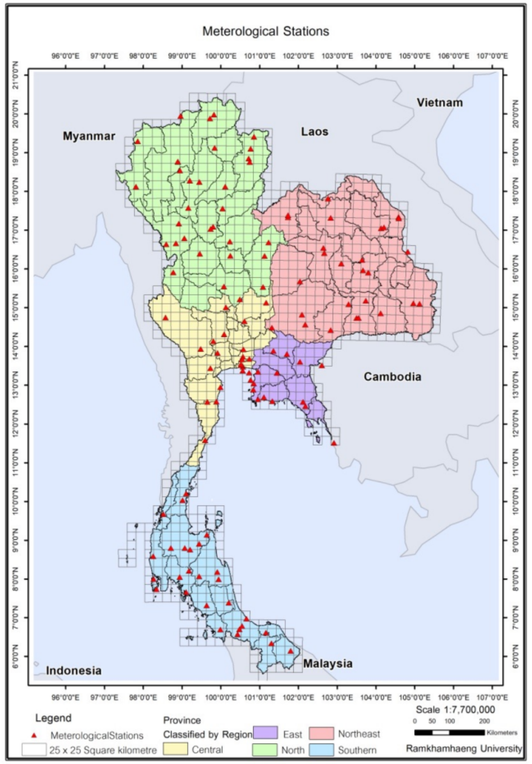


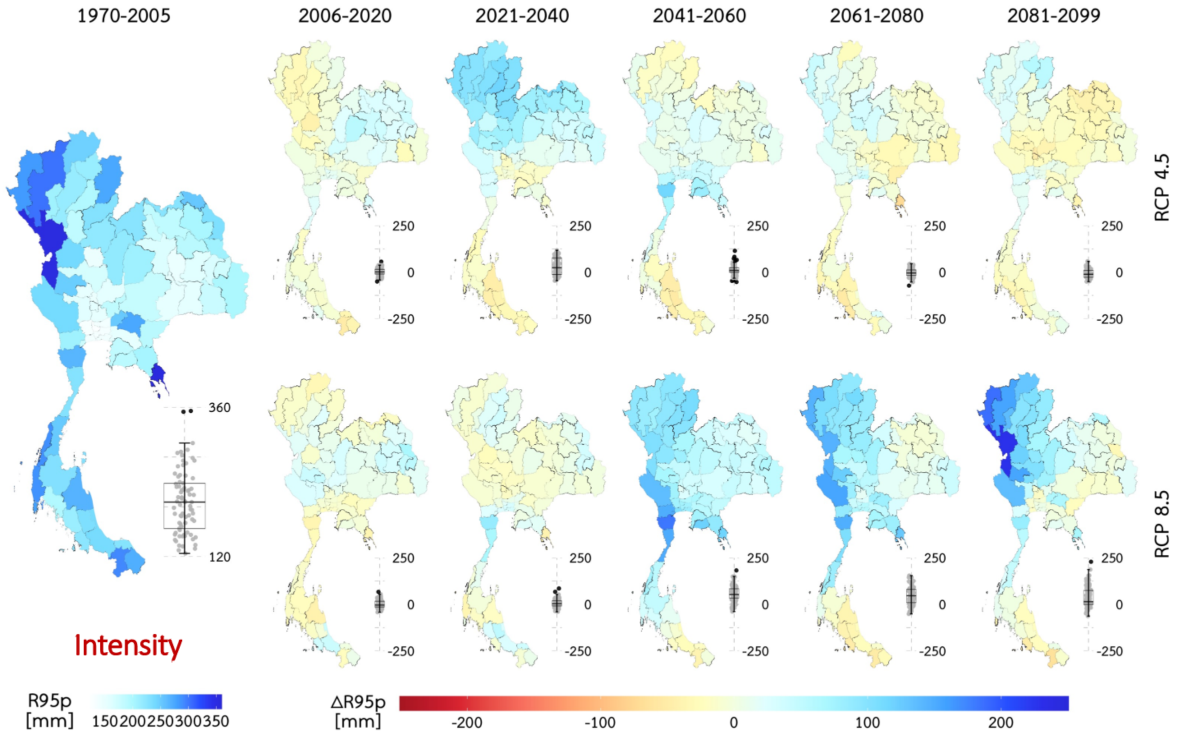
Annual total precipitation divided by the number of wet days (precipitation ≥ 1.0 mm : Cool days





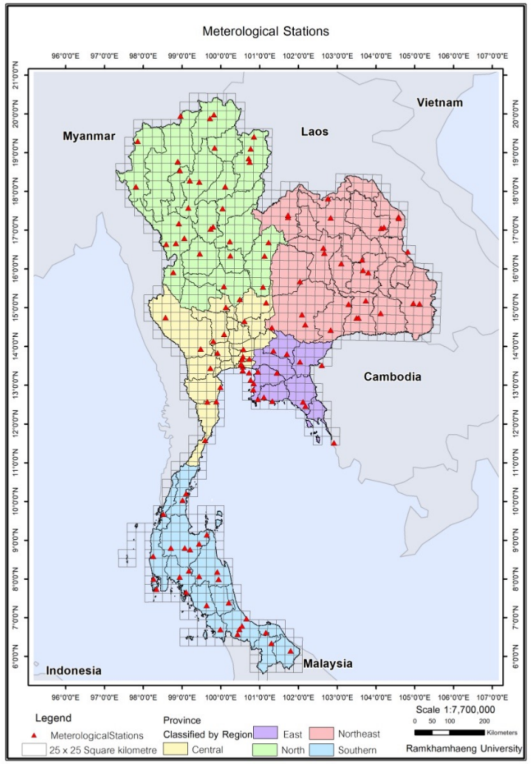
Annual sum of daily precipitation > 95th percentile : Annual contribution from very wet days

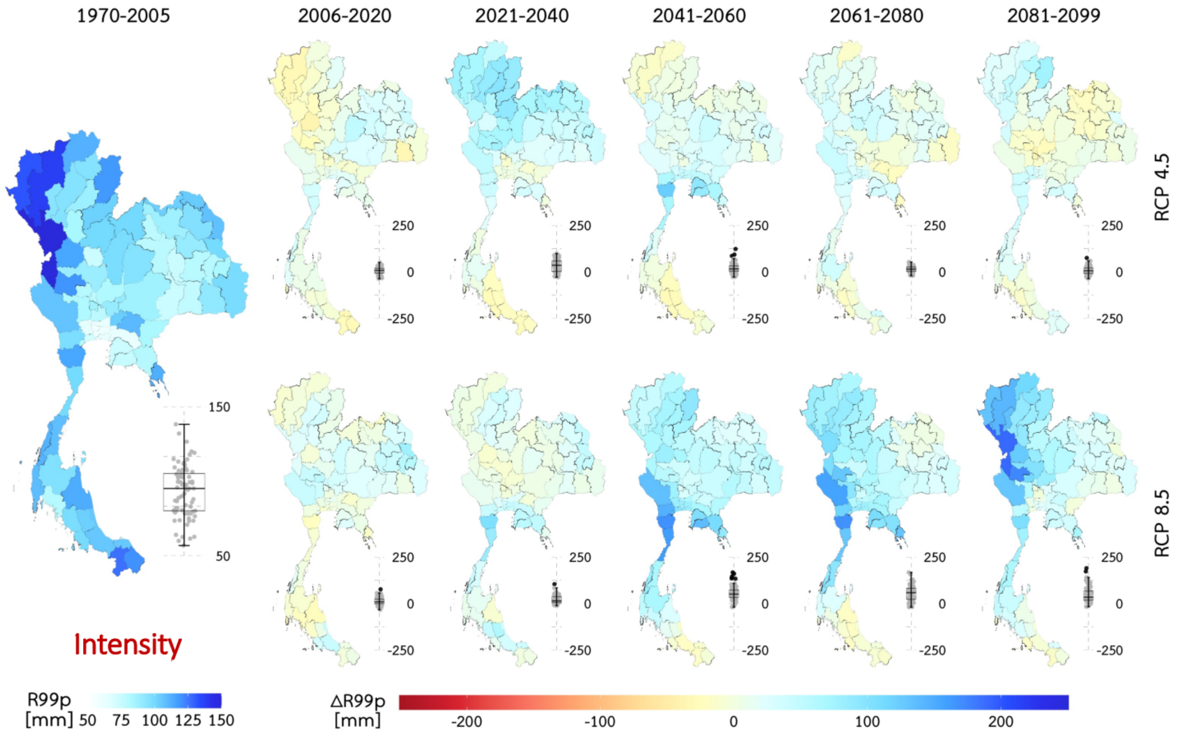




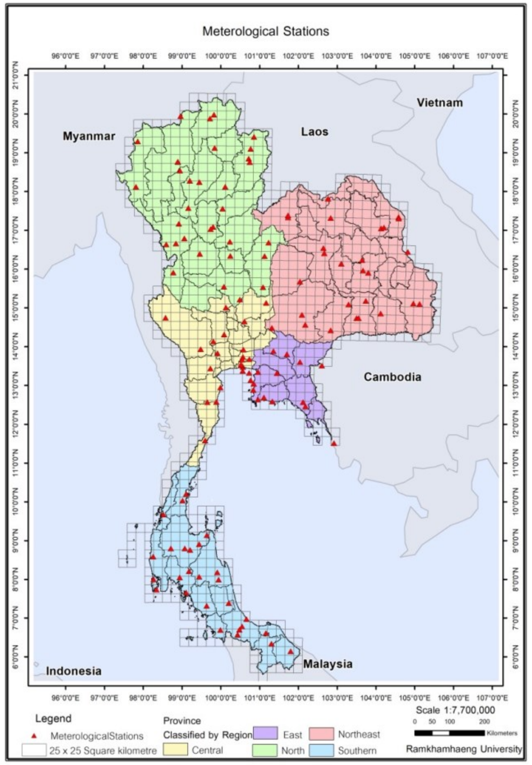
Annual sum of daily precipitation > 99th percentile :

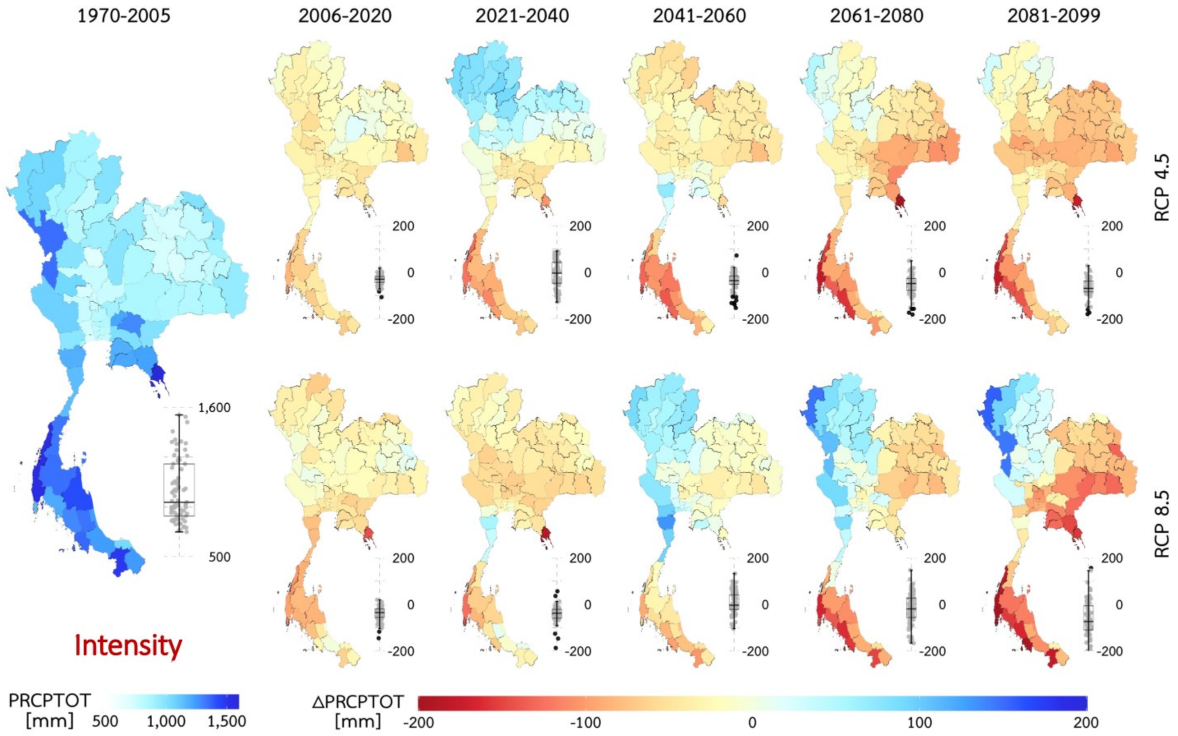
Annual contribution from extremely wet days



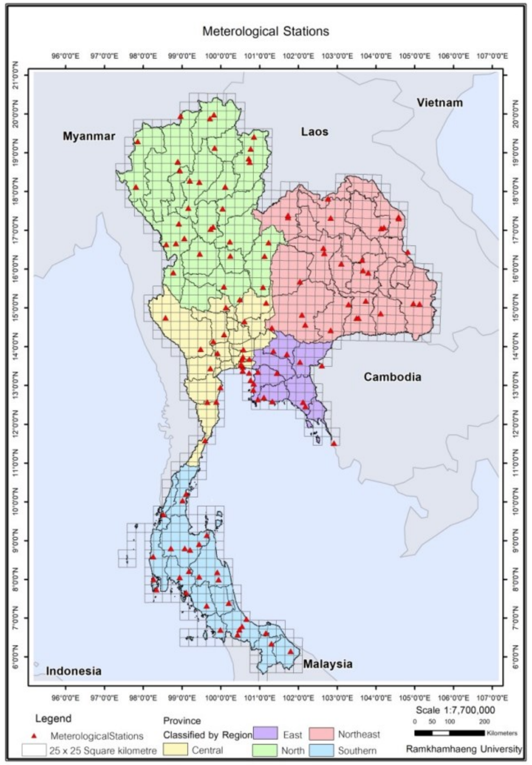


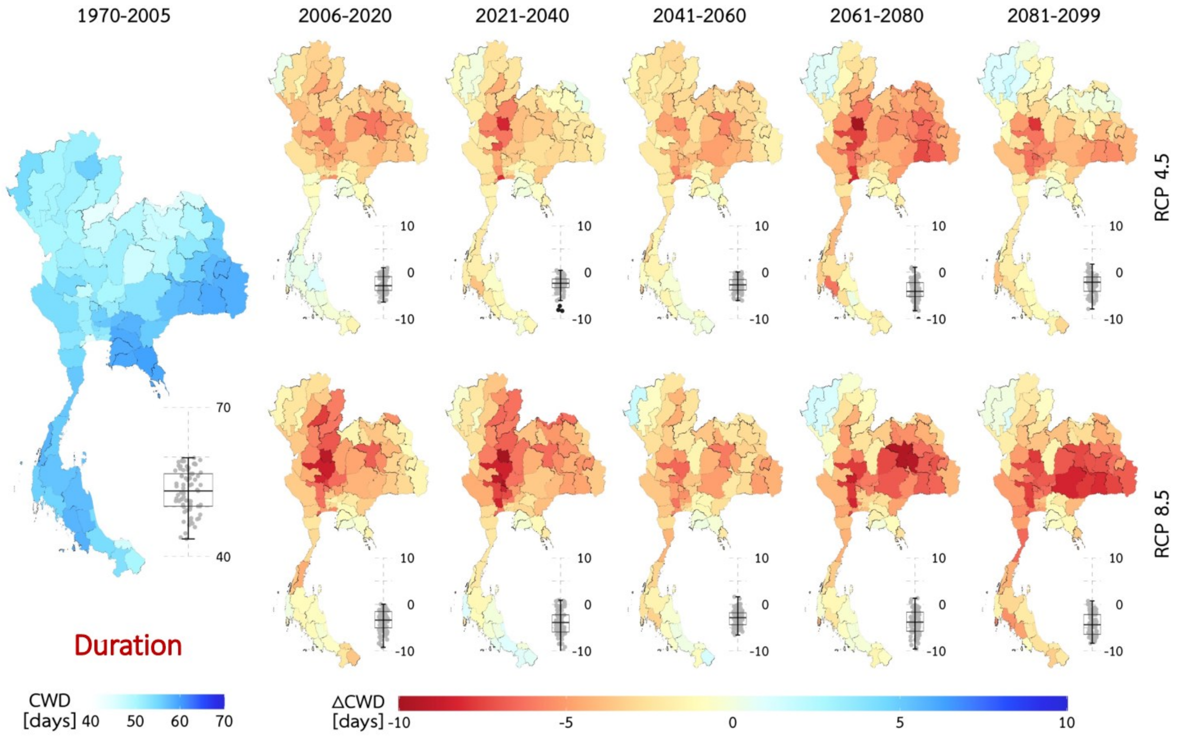
Annual total precipitation from days ≥ 1.0 mm : Annual contribution from wet days



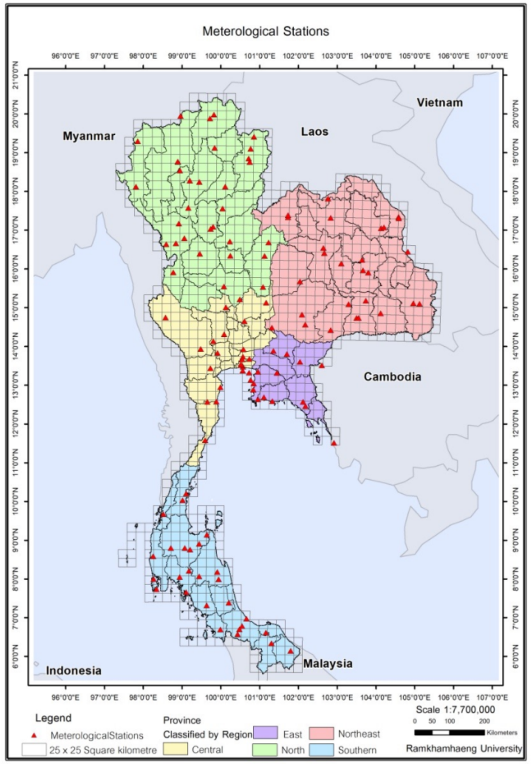


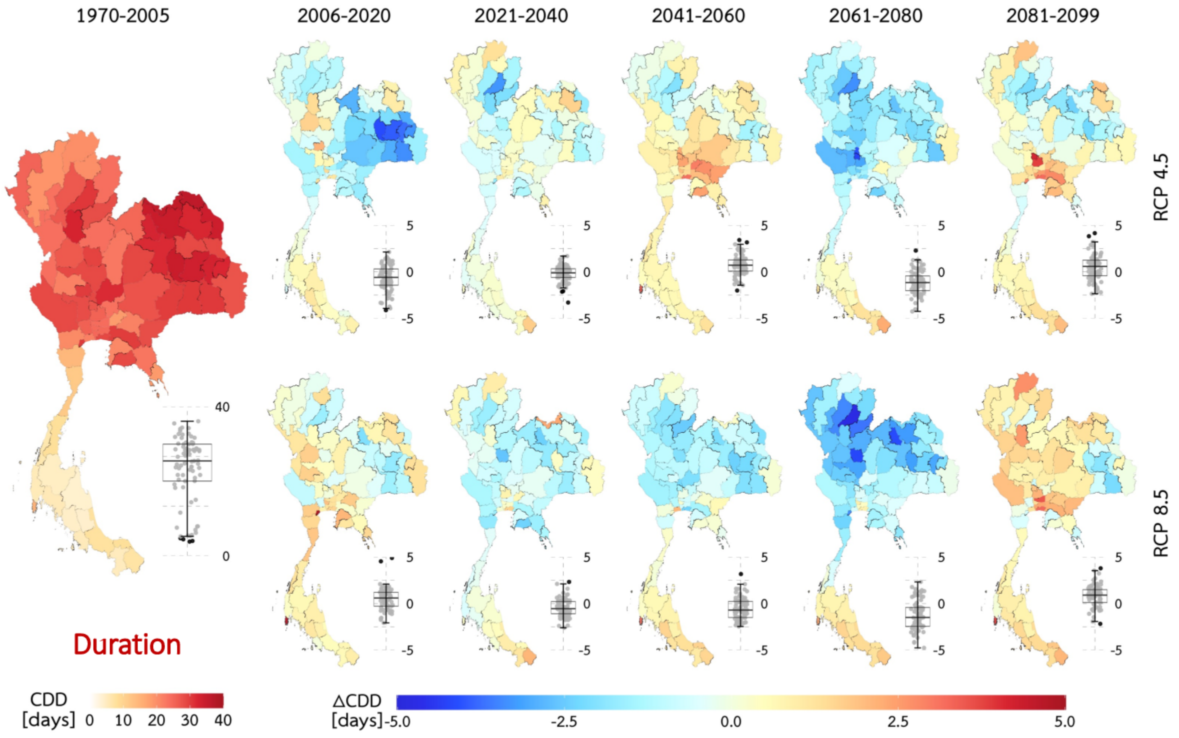
Maximum annual number of consecutive wet days : Consecutive wet days





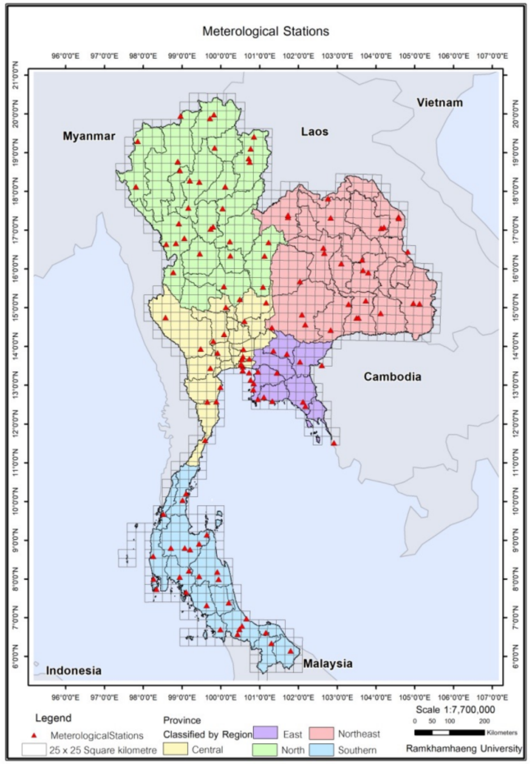
Maximum annual number of consecutive dry days : Consecutive dry days

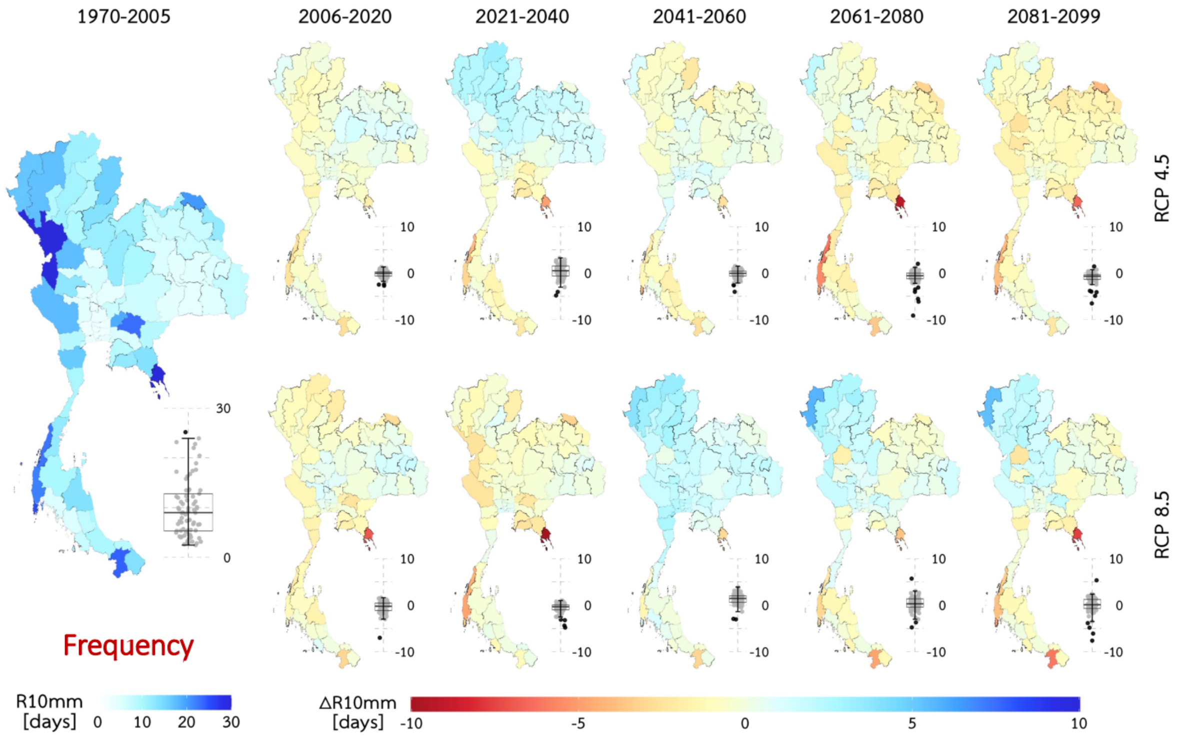




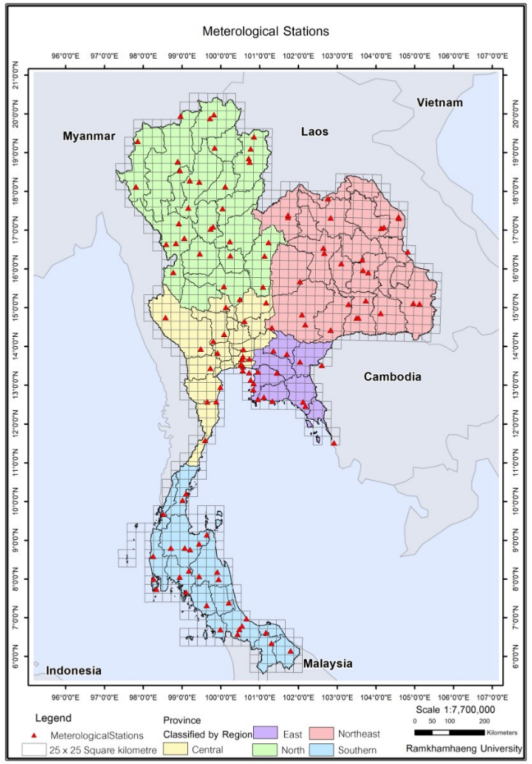
Annual number of days when precipitation ≥ 10 mm :

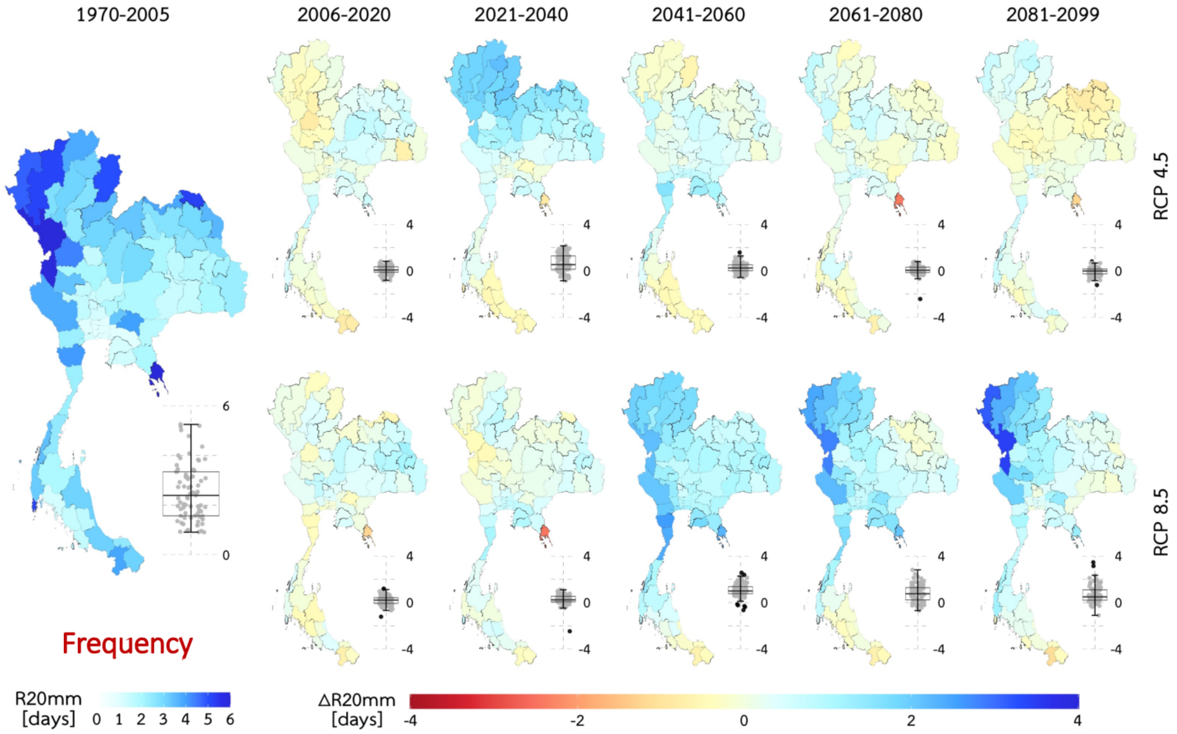
Heavy precipitation days





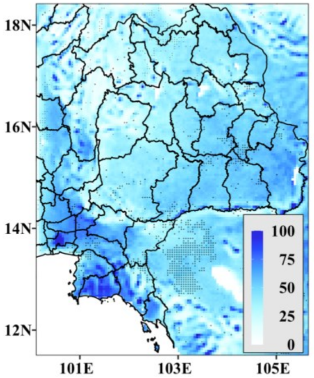
Annual number of days when precipitation ≥ 20 mm :
Very heavy precipitation days

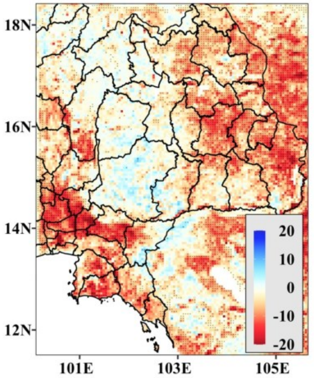


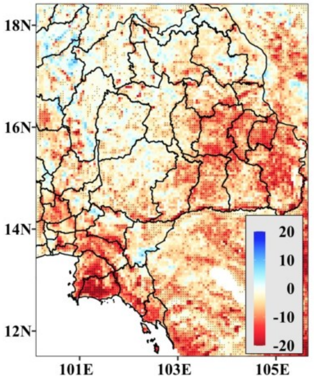


Extreme Climate Projection
over the vulnerable areas of Thailand

CWD
1970 - 2005

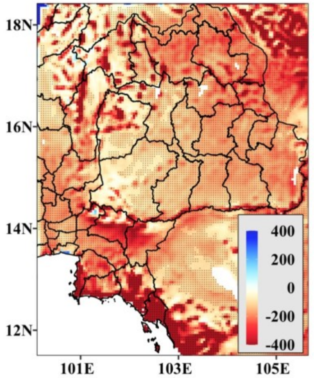


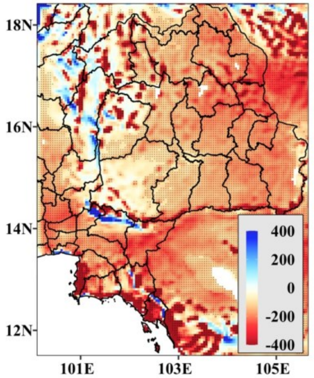




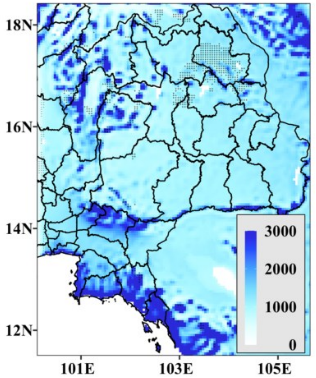
RCP4.5
2070 - 2099

RCP8.5
2070 - 2099



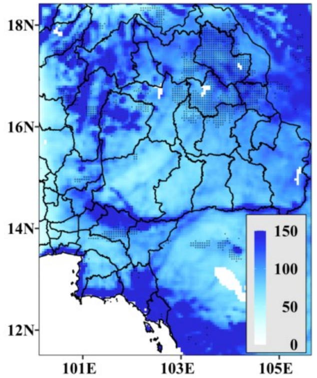


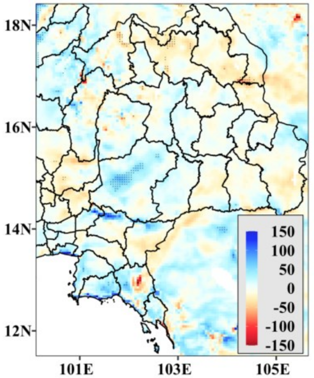
PRCPTOT
1970 - 2005

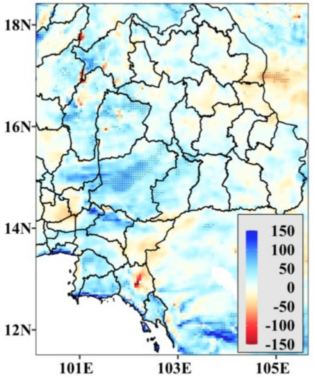


Extreme Climate Projection
over the vulnerable areas of Thailand

Rx1day
1970 – 2005

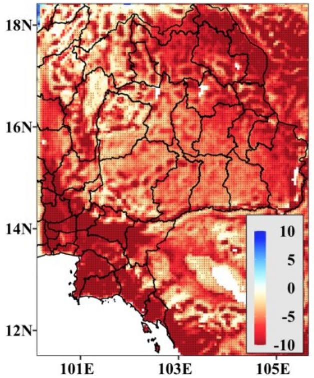


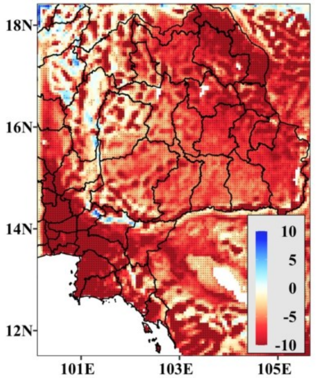




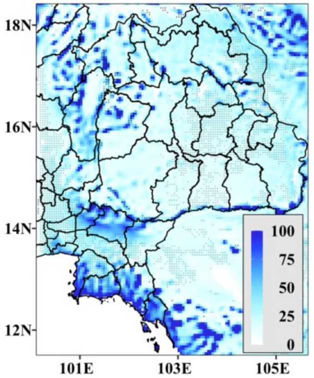
RCP4.5
2070 – 2099

RCP8.5
2070 – 2099

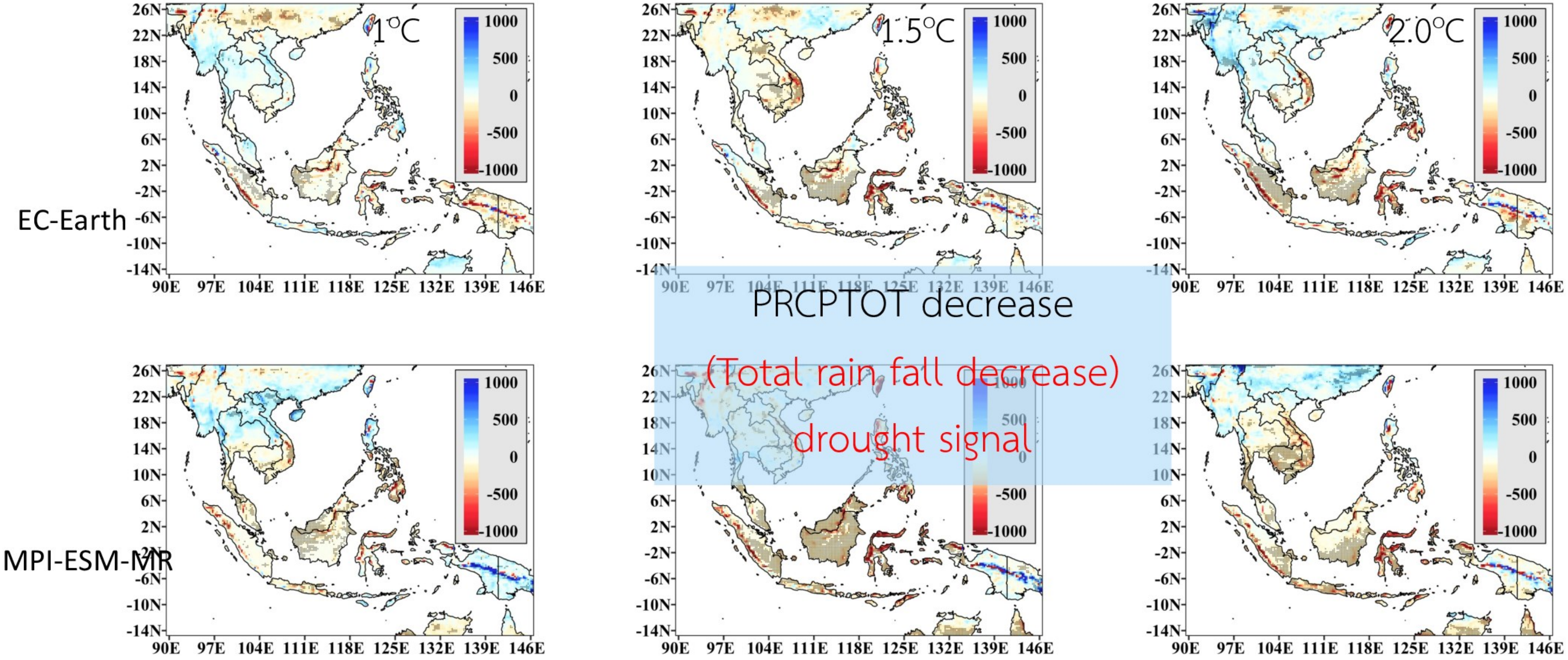




R10mm
1970 – 2005



Annual total precipitation from days ≥ 1.0 mm :
Annual contribution from wet days

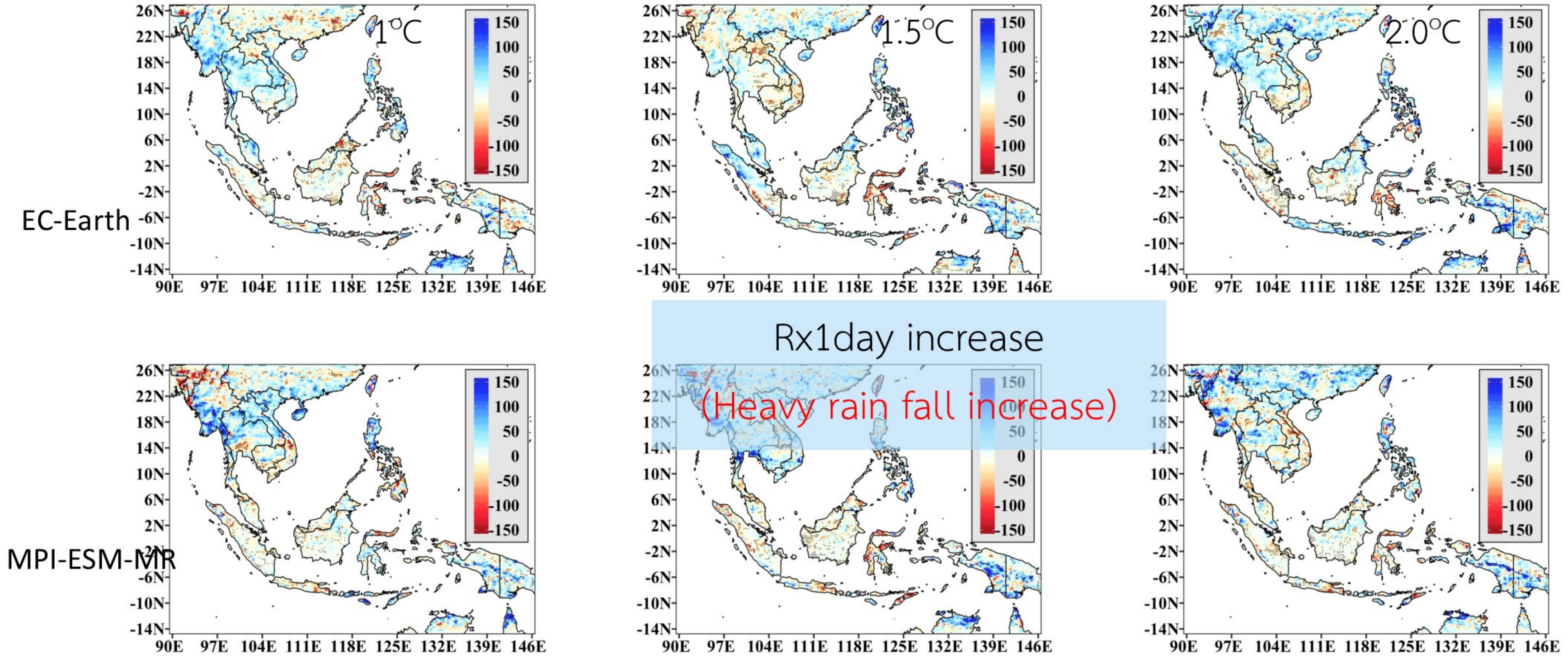


PRCPTOT decrease

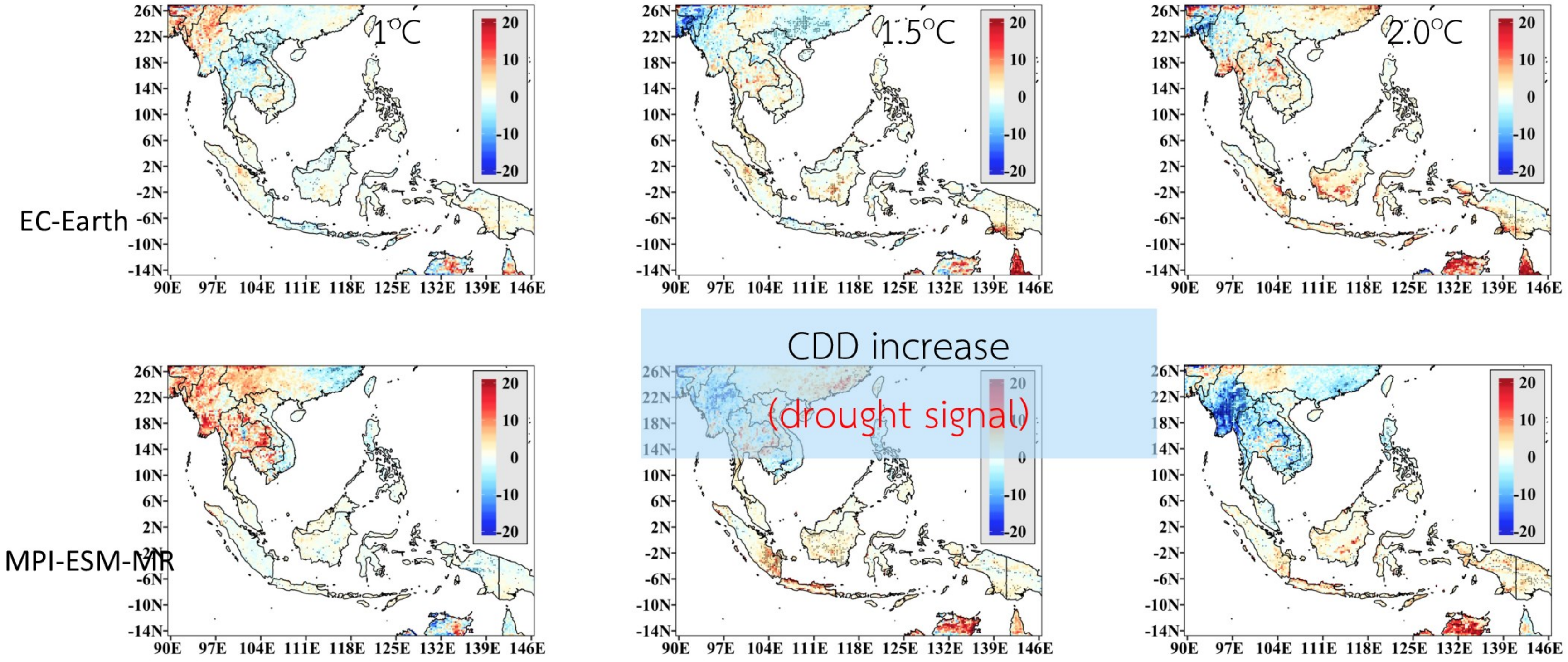
(Total rain fall decrease)

drought signal

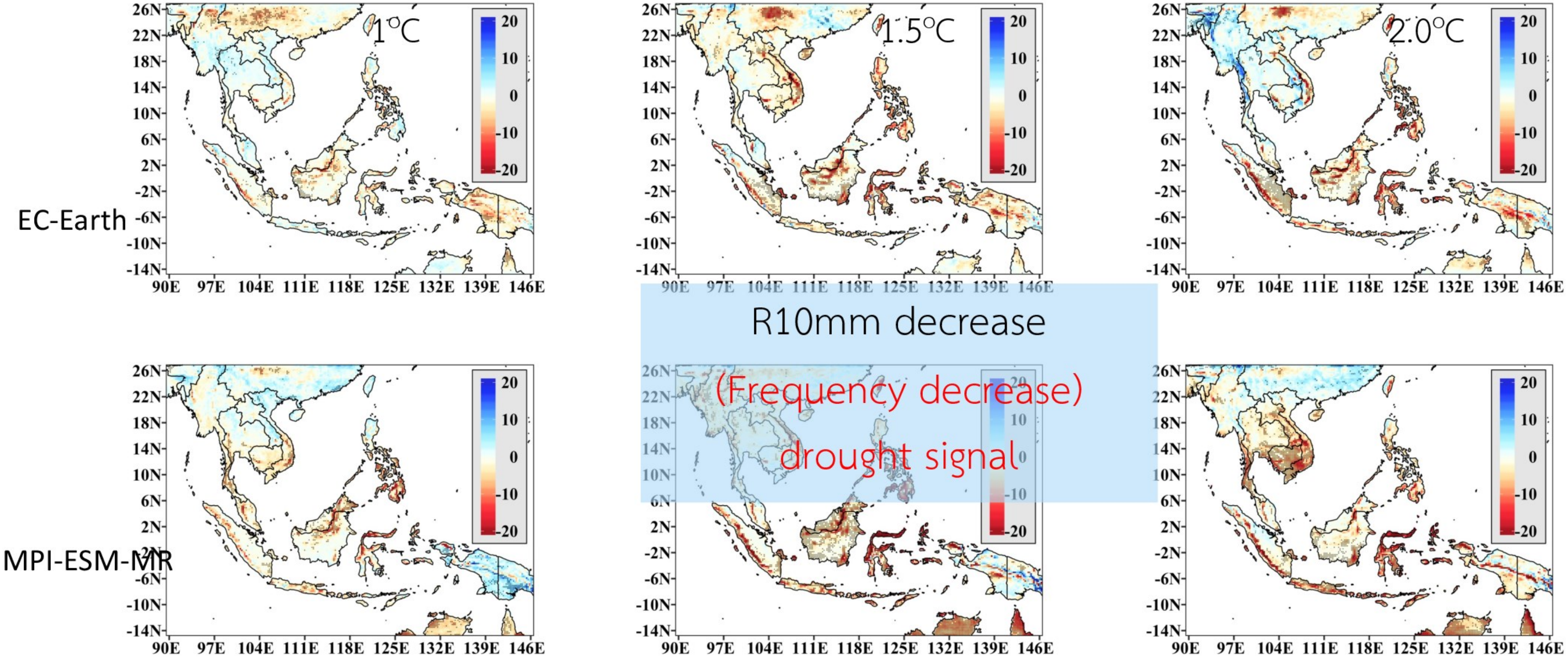
Maximum 1-day precipitation total :
Max 1-day precipitation



Maximum annual number of consecutive dry days : Consecutive dry days



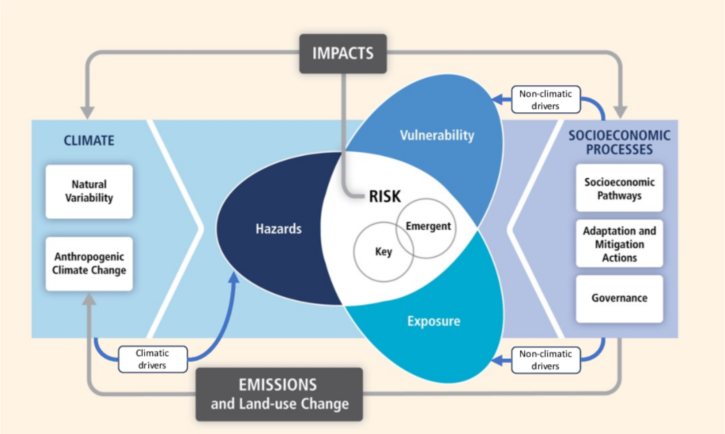
Annual number of days when precipitation ≥ 10 mm :
Heavy precipitation days



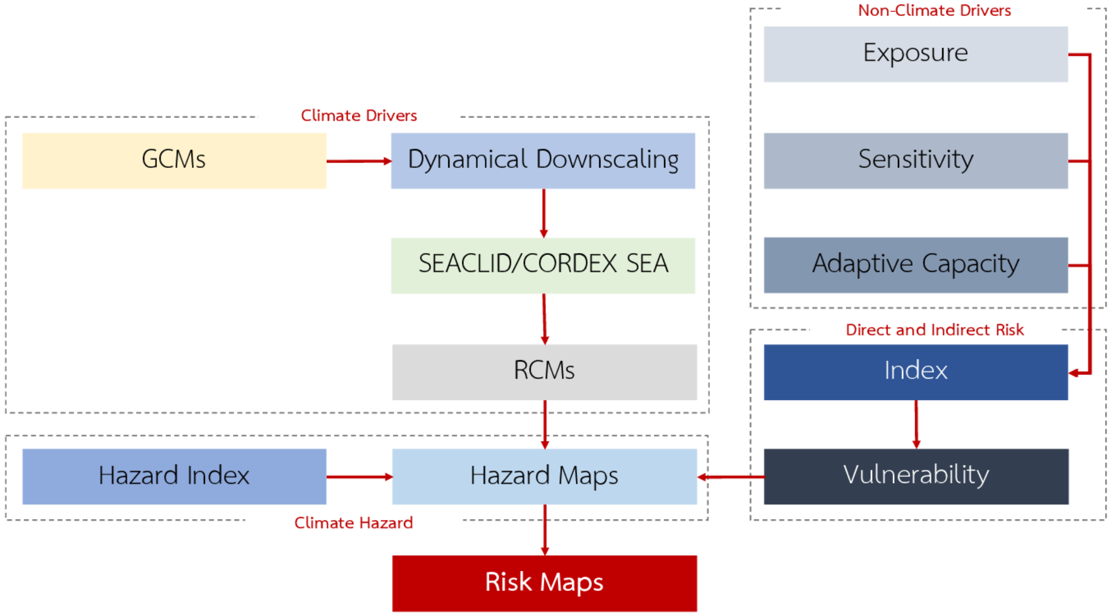
Risk Maps Database under Climate Change

Funded by the Office of Natural Resources and Environmental Policy and Planning

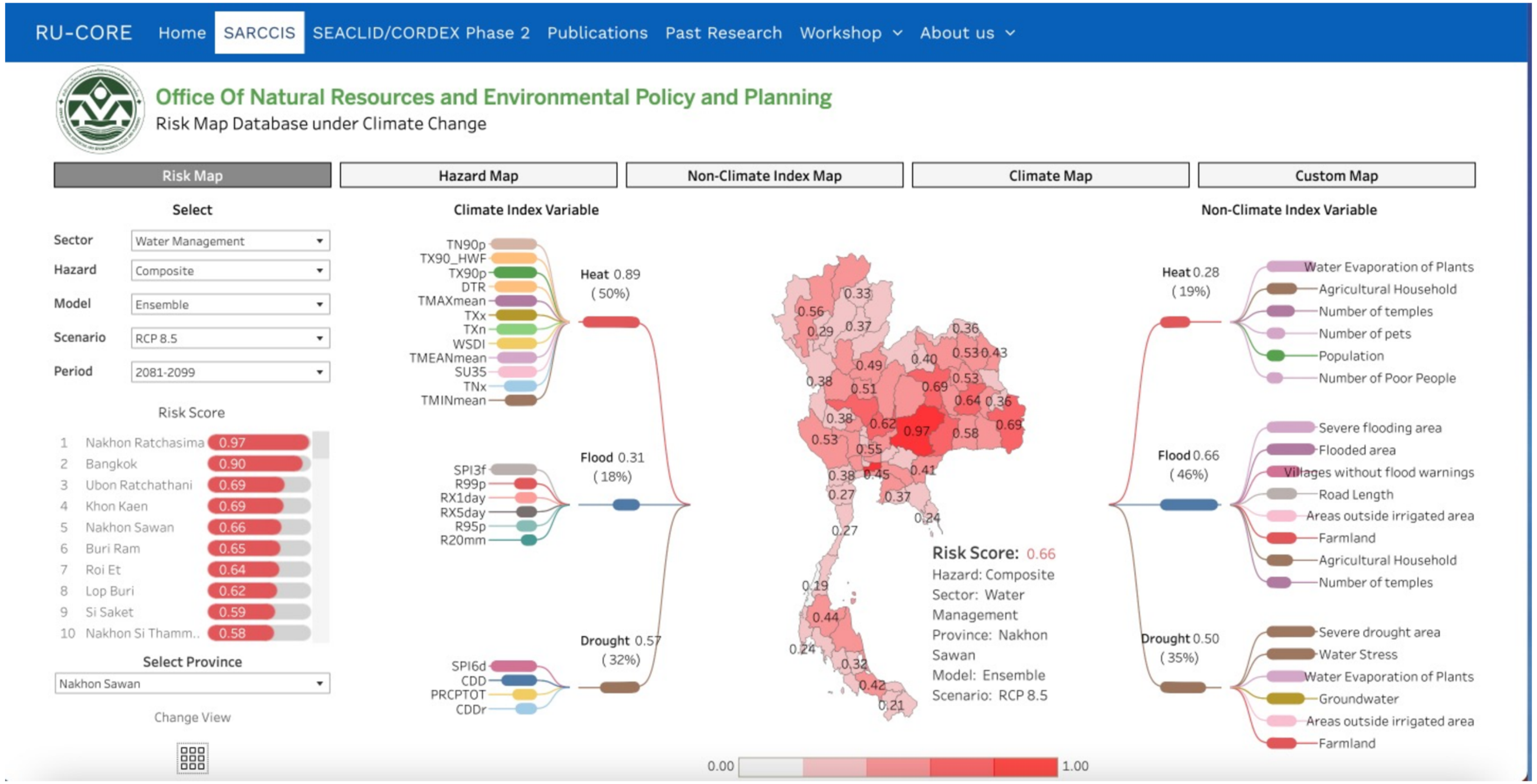
SARCCIS >> SEACLID/CORDEX SEA data set for Risk Maps



Risk Maps
Conceptual Framework



SARCCIS >> SEACLID/CORDEX SEA data set for Risk Maps



Conclusions

- With a total of three RCM members, the RCMs showed reasonable reproduction of the annual cycle of rainfall during the historical period over nine sub-regions in Thailand and 20 sub-regions in Southeast Asia.
- The RCMs also produced reasonable patterns of regional circulations associated with the summer and winter monsoons.
- During late century only the northern part of Thailand (R1) showed significant and robust increase in mean rainfall under RCP8.5.
- The northeastern, central, eastern and southern parts of Thailand are projected to be drier compared to historical period for all future periods and both RCP4.5 and RCP8.5.

THANK YOU

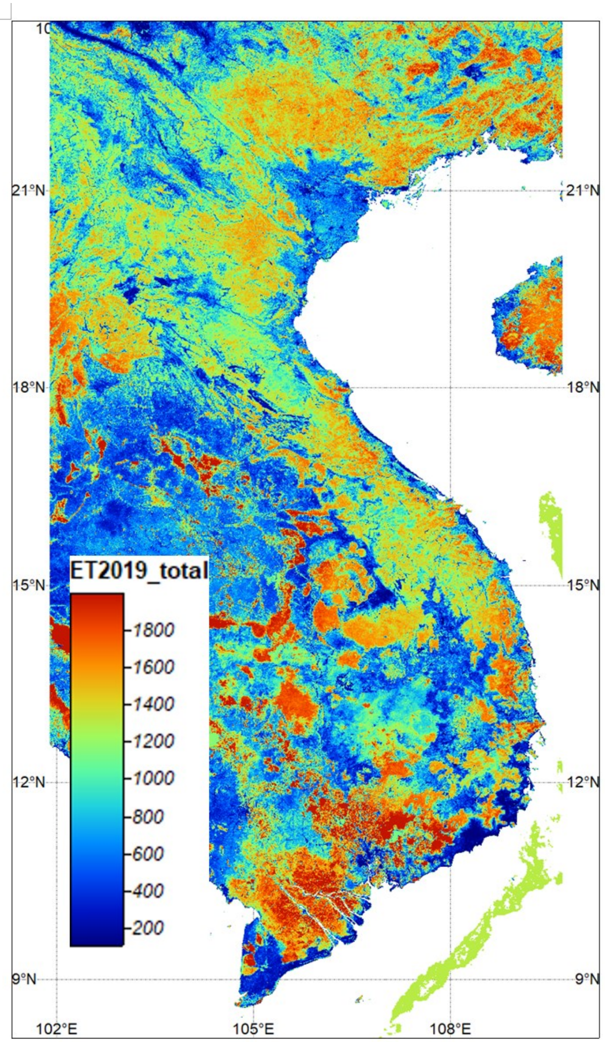
Projected impact of Climate Change and other stressors on water uses and allocations

Lan Thanh Ha
Institute of Water Resources Planning (IWRP)



Climate change context

- Vietnam is ranked 28th/49 countries in Asia with a National Water Security Index score of 59.9/100 (Asian Water Development Outlook report, ADB, 2020);
- Climate change is likely to accelerate water scarcity (FAO, Water Scarcity in AP, 2023).
- Ranked 13th/180 countries in term of climate vulnerability (Global Climate Risk Index, Germanwatch, 2019);
- Vietnam lost $10 billion in 2020 (3.2% of GDP) to climate change impacts (World Bank, 2021).

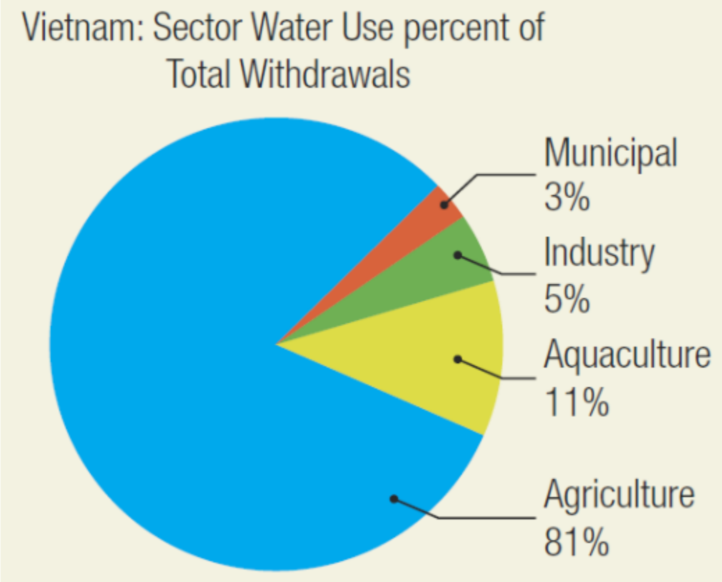


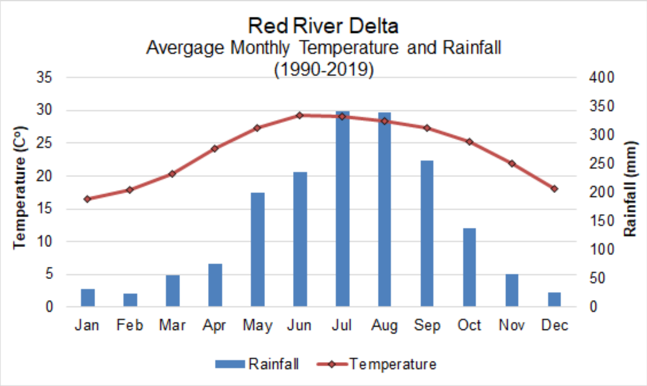
Maps of ET in 2019, one of highest year with 20-30% increase

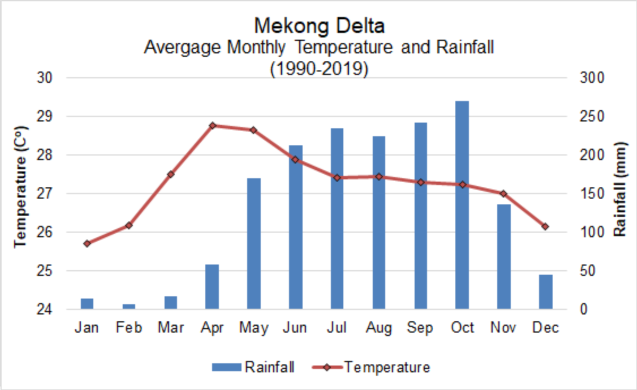
Source: FAO WS in Vietnam, 2021; map from FAO's WaPOR

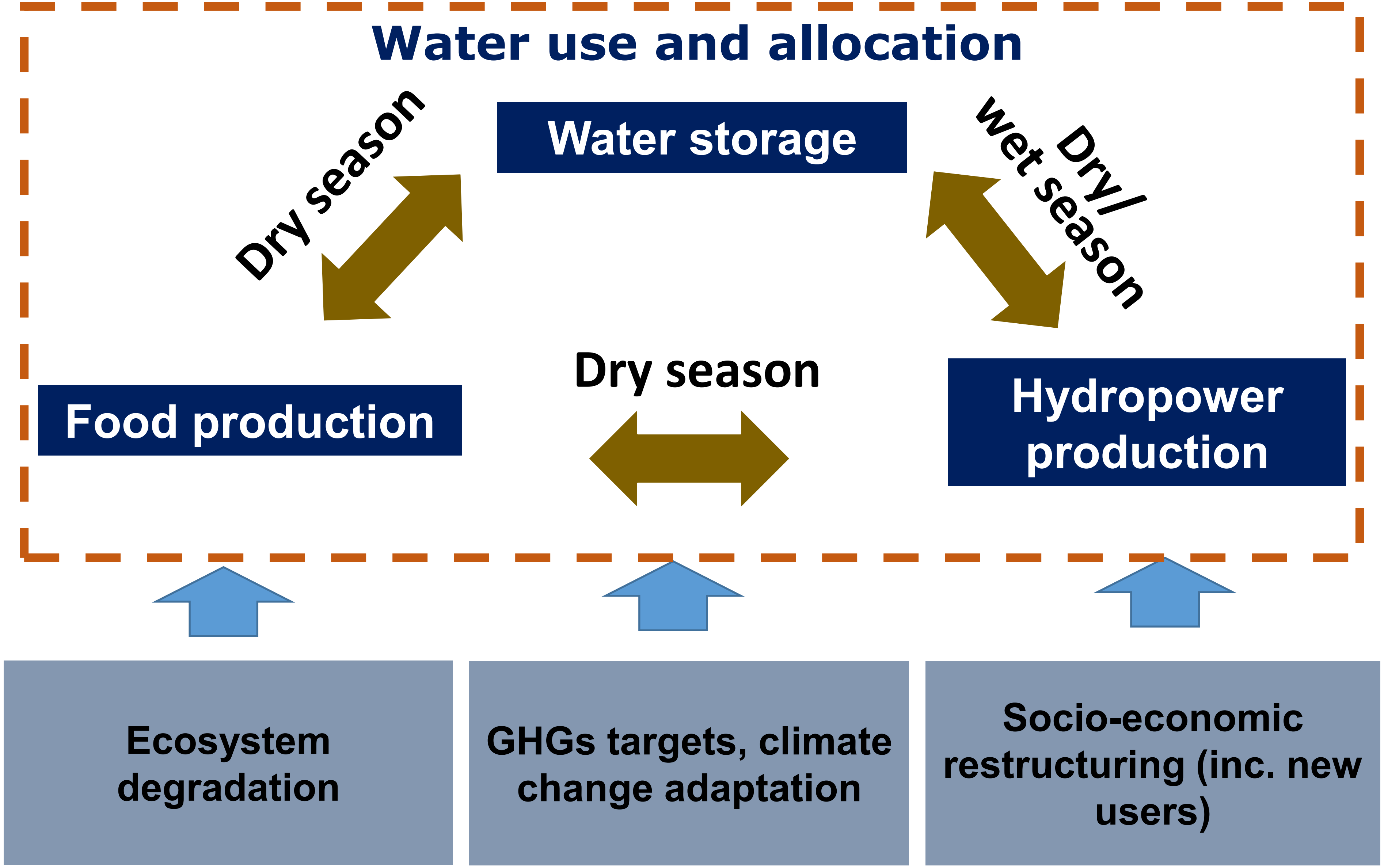
Water resources in Vietnam

- Unevenly distributed (spatial and temportal)
- Depends on transboudary water
- Increasing in water demand
- Water use efficiency, governance, climate change, disaster risks.

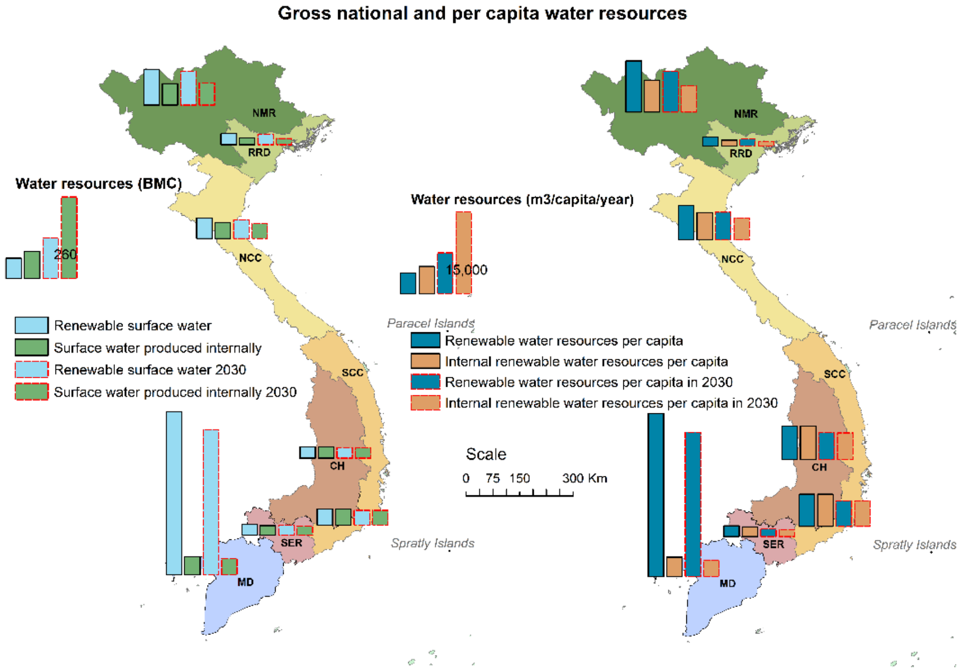


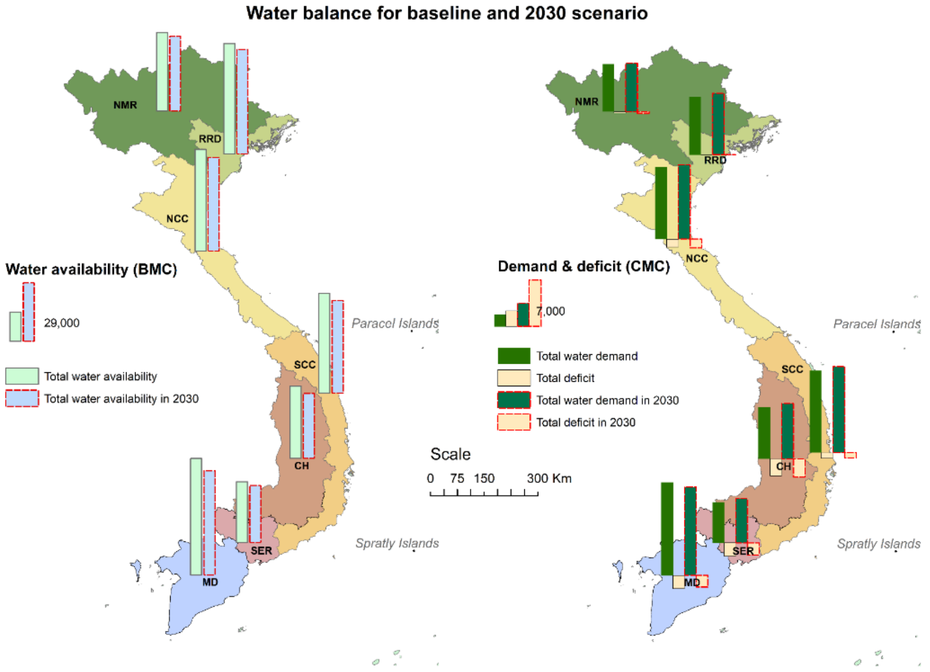





Water use and allocation
Water storage
Dry season
Dry/ wet season
Food production
Dry season
Hydropower production
Ecosystem degradation
GHGs targets, climate change adaptation
Socio-economic restructuring (inc. new users)

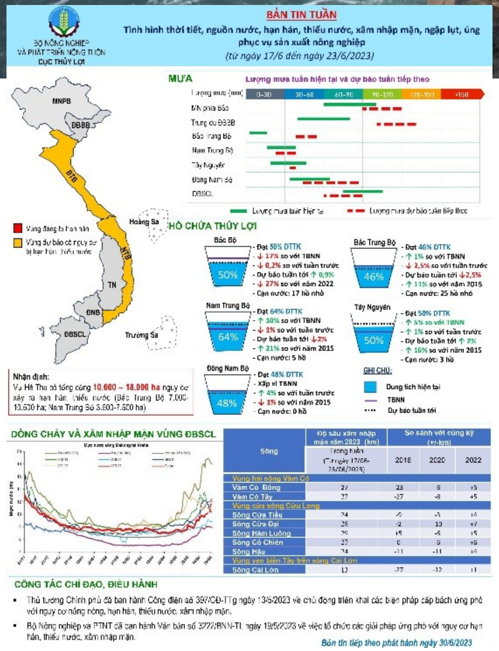
Projected climate change impact on demand & deficit





Source: MARD, National WR and disaster prevention master plan; Water security and Dam safety Programme.

Tackling water use and water allocation challenges – how it took place in Vietnam



- Focus on structural (grey) solutions
- Independent projects:
  - *Irrigation/Rural water supply*
  - *(Urban) water supply*
  - *Hydropower*
  - *Flood/drought prevention*
  - *Industrial*

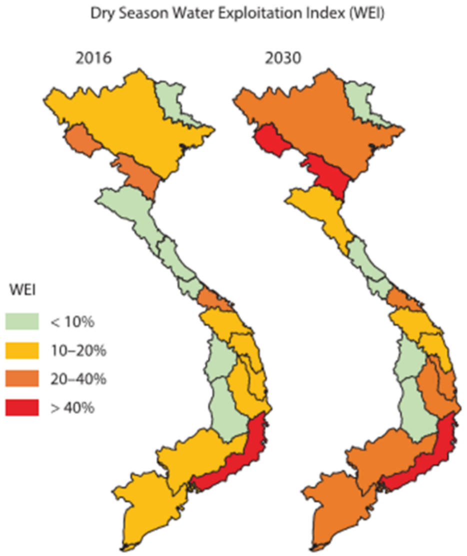
  managed by sectoral agencies lacking of coordination
- Focus on water supply, not on demand management
- Lack of attention to environmental and social aspects
- Institutional, governance, lack of operational water accounting

Water quality deterioration

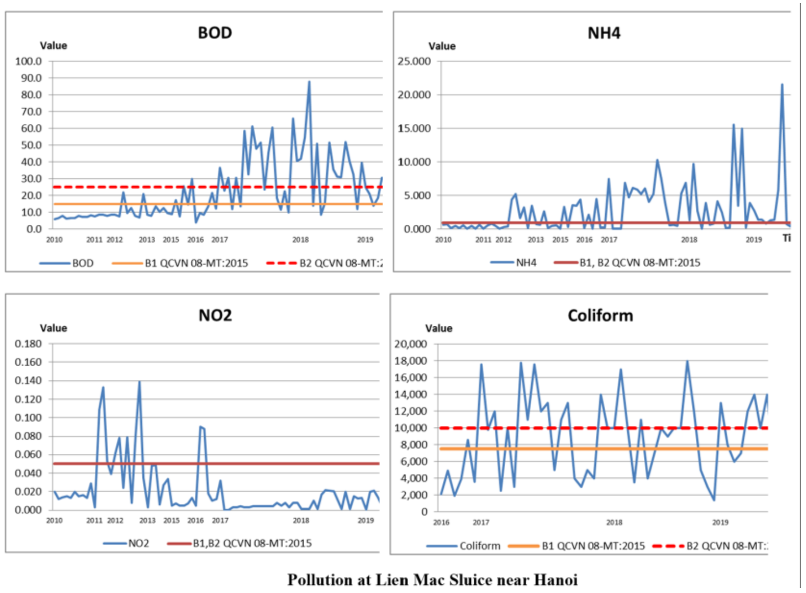
- Combination of: *domestic, industry, craft villages and agricultural use*
- Become more severe in recent years
- Hotspots include major river basins and cities: Red, Mekong, Dong Nai
- Significantly contribute to water scarcity
- Challenging to regulate, lacking of accounting framework

(FAO, Water Scarcity Report for Vietnam, 2022)

Basin	2016	2030
Bang Giang - Ky Cung	1%	2%
Red - Thai Binh	19%	27%
Ma	35%	44%
Ca	9%	12%
Gianh	2%	3%
Thach Han	5%	6%
Huong	23%	28%
Thu Bon & Vu Gia	11%	15%
Tra Khuc	13%	16%
Kone	19%	23%
Ba	19%	24%
Dong Nai	19%	28%
SERC	41%	58%
Sesan	<1%	1%
SrePok	5%	6%
Mekong	19%	22%



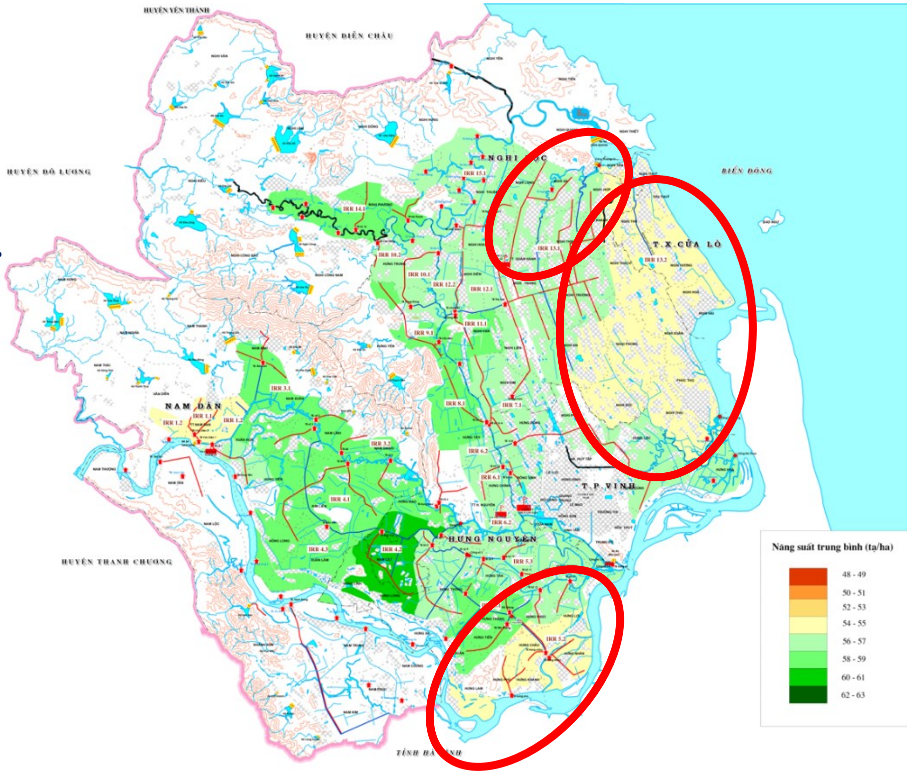
2030 Water Resources Group 2017

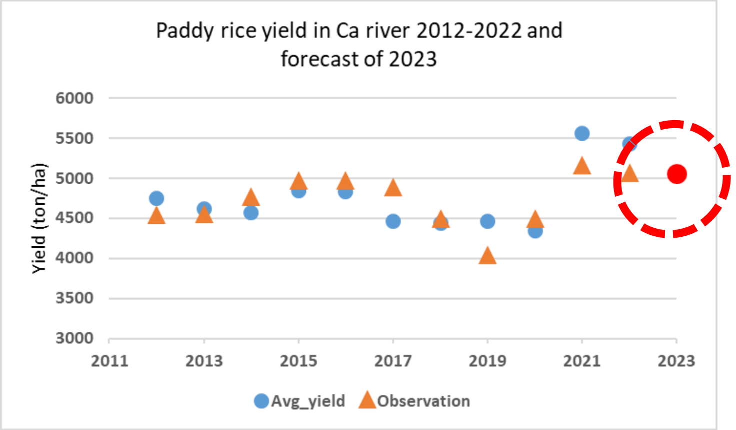


IWRP, Report on WQ in Nhue river, 2020

Increasing demand

- Agricultural being the highest consumption sector of water (70-85%)
- Change in demand pattern: domestic, industry, tourism
- Prone to climate change, water scarcity, pollution
- Needs of demand management and water reallocation

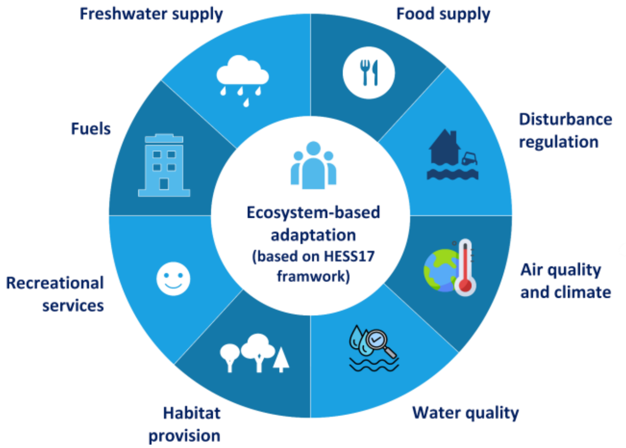




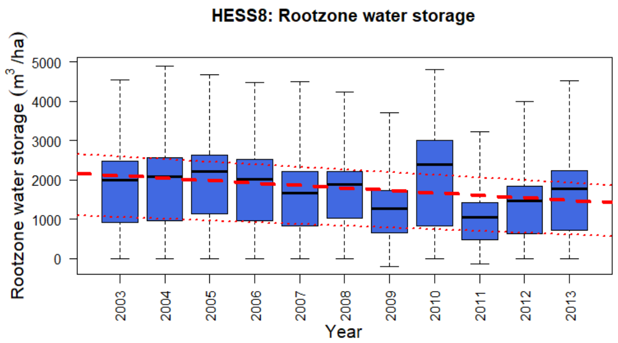
Paddy rice yield (ton/ha) in Ca river delta
Source: Nguyen Van Tuan et al., 2022; FAO's WaPOR tool

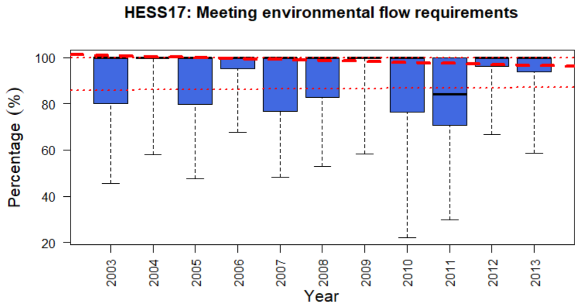
Water-related ecosystem degredation

- Lacking of accounting framework
- Intertwined with water use and allocation
- Rapidly declining, prone to climate change
- Challenging to monitor/assess



Source: Ha et al., 2023a (doi.org/10.3390/su15076182)





Ecosystem services in Red River Delta (Source: Ha et al., 2023b)

Projected stressors on water use vision until 2045

- Increased demand/abstraction
- Absence of new suitable supply infrastructure sites
- Full or over-allocation of water resources
- Economic development/diversification (new users)
- Environmental degradation/loss of ecosystem services
- Climate Change/increasing variability

Source: MARD, Water Security and Dam safety Programme (draft), 2023

Thank you for your attention!

(lanht.tl@mard.gov.vn)

Drought Situation in Thailand

"PANEL 1: Projected impact of Climate Change and other stressors on water uses and allocations"

River Basin Management Division
Office of the National Water Resources (ONWR)

4th July 2023

Outline

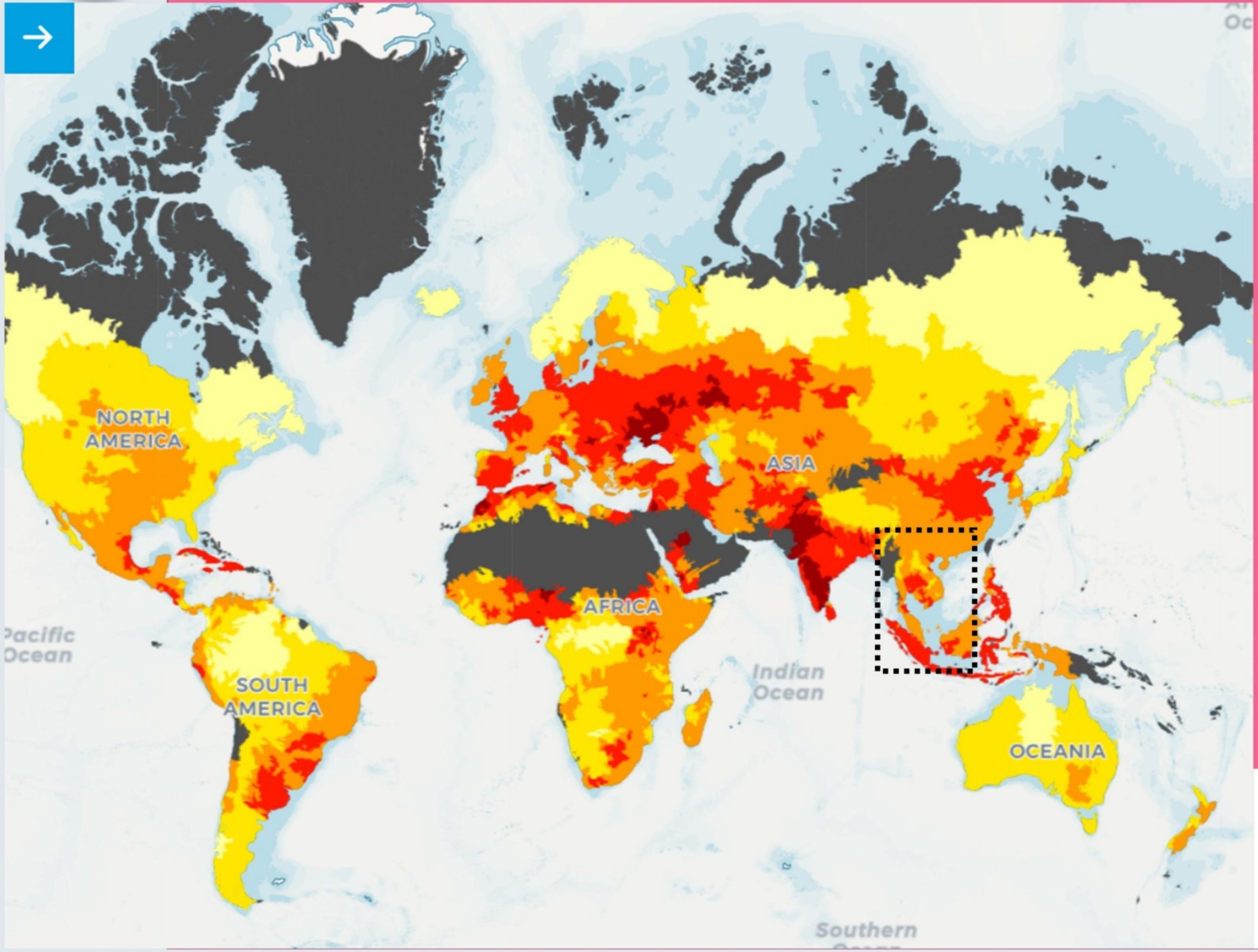
1. Water scarcity situation at the global level

2. Thailand water status

3. Seasonal Water Resources Management in Dry Season

1.

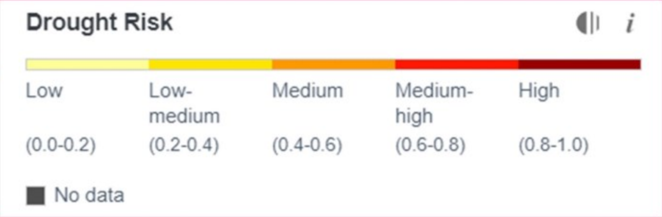
Water scarcity situation at the global level

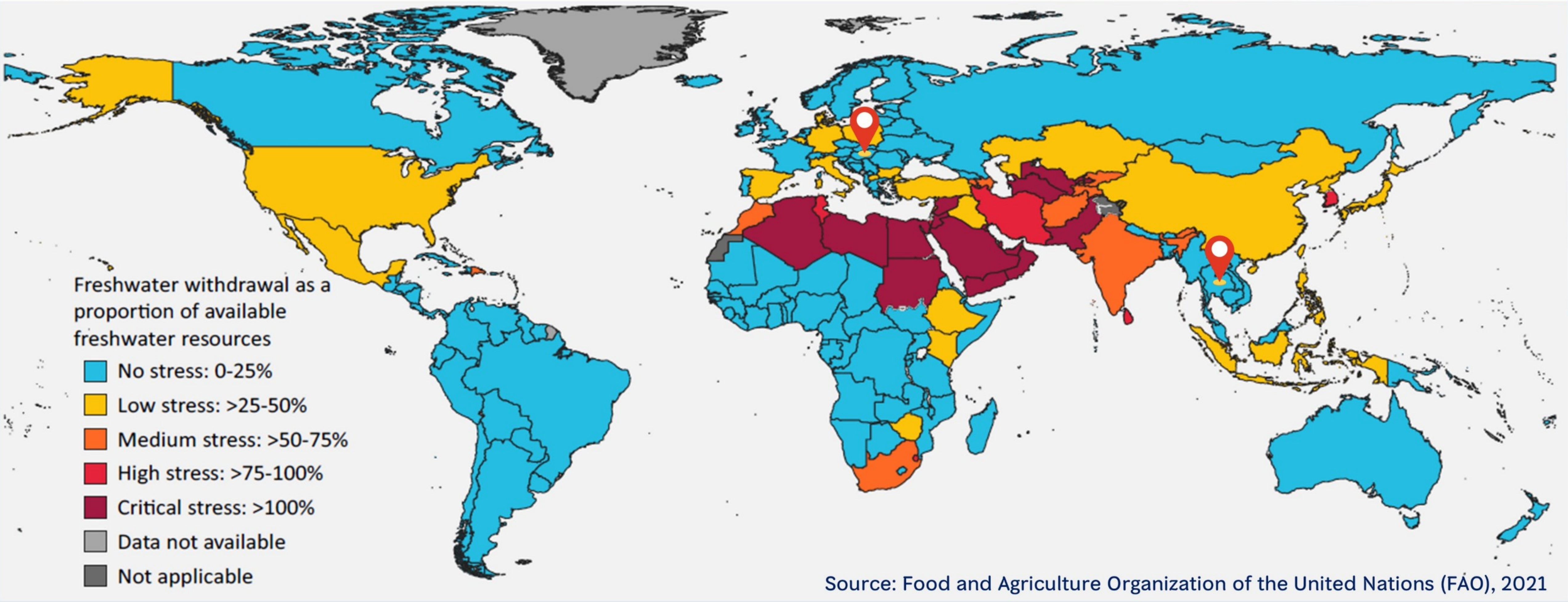


DROUGHT RISK

Description: Drought risk measures where droughts are likely to occur, the population and assets exposed, and the vulnerability of the population and assets to adverse effects. Higher values indicate higher risk of drought.

Source: WRI Aqueduct 2019





Level of water stress by countries: freshwater withdrawal as a proportion of available freshwater resources in 2018 (%).

2.

Thailand water status

"Types of water source"

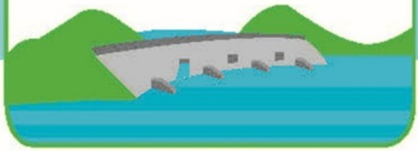
Rainfall

- ✓22 river basins
- ✓515,934 sq.km.
- ✓annual rainfall 1,500 mm.

(30 years average rainfall 1991 - 2020)

Natural flow

- ✓ annual runoff 224,024 mcm.



Ground water

- ✓ ground water 1.13 million mcm.

Water Storage

- ✓ Water storage 78,747 mcm.

"Water demand management"

The Water Resources Act, B.E. 2561 of Chapter 4 : Water Allocation and Water Usage in order of prioritization, recognizing water for

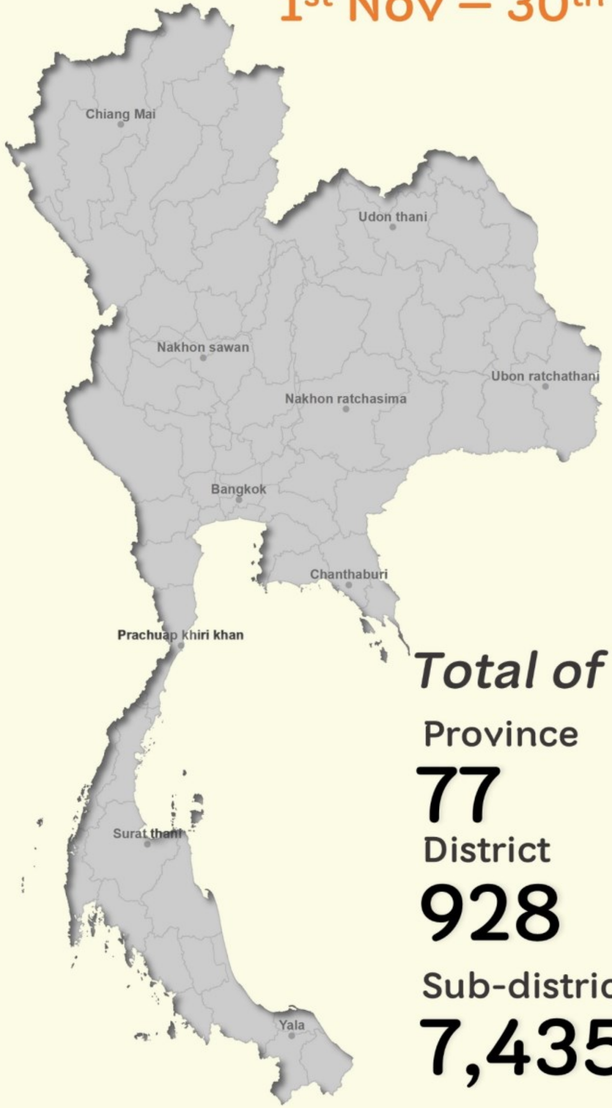
1. Consumption
2. Ecosystem conservation
3. Disaster Prevention
4. Cultural Preservation
5. Transportation
6. Agriculture
7. Industry
8. Commerce
9. Tourism

Statistics of Droughts in the past 6 years (2017-2023)

Reference: Department of Disaster Prevention and Mitigation. Ministry of Interior. Thailand

Dry Season

1st Nov – 30th Apr

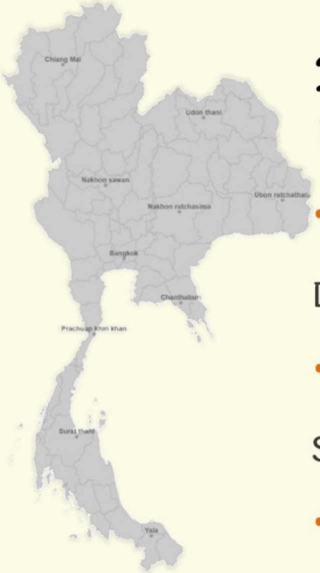


Total of

Province
77

District
928

Sub-district
7,435

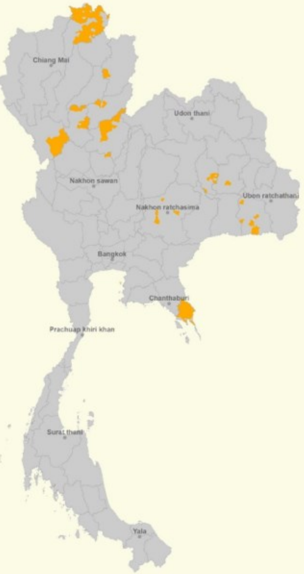


2017 /2018

Province
-

District
-

Sub-district
-

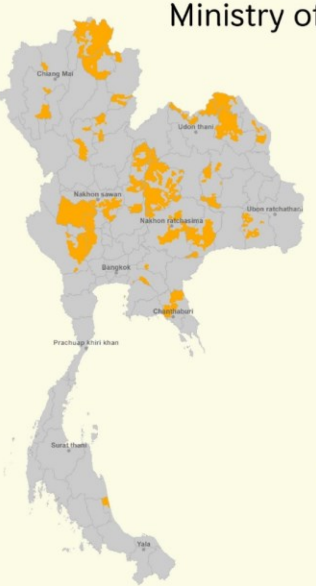


2018 /2019

Province
13

District
43

Sub-district
179

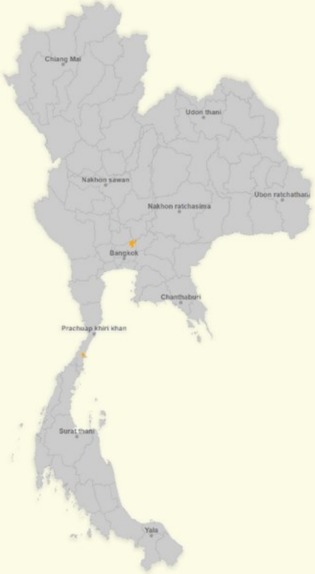


2019 /2020

Province
27

District
157

Sub-district
836



2020 /2021

Province
2

District
2

Sub-district
5

2021 /2022

Province
1

District
1

Sub-district
1

2022/2023

Province
4

District
5

Sub-district
13

3. Seasonal Water Resources Management in Dry Season

Duration of Seasonal Water Resources Managem

**Northern | Northern east | Central | Eastern
Western | West Coast of Southern**

Wet Season	Dry Season
1st May – 31st Oct	1st Nov – 30th Apr

East Coast of Southern consists of 7 provinces

(Surat Thani, Nakhon Si Thammarat, Phatthalung, Songkhla, Pattani, Yala and Narathiwat)

Wet	1st Sep – 28th Feb
Dry	1st Mar – 31st Aug

Remark : The beginning of the rainy season is based on the announcement of the Meteorological Department.
The beginning of the dry season is based on regions, including Northern, Central region and East start 1st Nov Northern East starts 1st Dec West starts 1st Jan and Southern starts 1st Mar.

Seasonal Water Resources Management Framework in Dry Season

Pre - season

Preparation and Raising Awareness

To assess the amount of water available , determine water allocation plan and Crop plan , forecast drought risk areas and propose the countermeasures to the NWRC and the Cabinet.

To raise awareness and public relations and implement the seasonal plan of WRM and the countermeasures

1st Nov

1 st Sep

During the season

Analysis, Monitoring and Evaluating the situation

Driven by the Provincial Water Resources Subcommittee, the River Basin Committee and the NWRC throughout the season.

To raise awareness and public relations the situation and ongoing assistance of related-agencies.

15th Dec

End of season

Evaluation at the End of the Season

To summarize the seasonal water resource management (After Action Review, AAR) in order to be the solution for next season and propose the NWRC and the Cabinet for acknowledgement

30th Apr

15th May

15th Apr

Seasonal WRM Framework in Dry Season

Revised on 14th March 2022
(approved by National Water Resources Committee , NWRC)

by River Basin Management Division (ONWR)

Guideline for the seasonal WRM planning

to propose the 9 countermeasures Dry Season in 2021/2022

The amount of water available

on 1st November 2021 **72,596** MCM

Irrigation area 37,857 MCM

Rainfed area 34,739 MCM

Water allocation plan

4 Sectors **31,732** MCM

Irrigation area 22,280 MCM

Rainfed area 9,452 MCM

(4 sectors in terms of consumption, agriculture industry and ecological conservation)

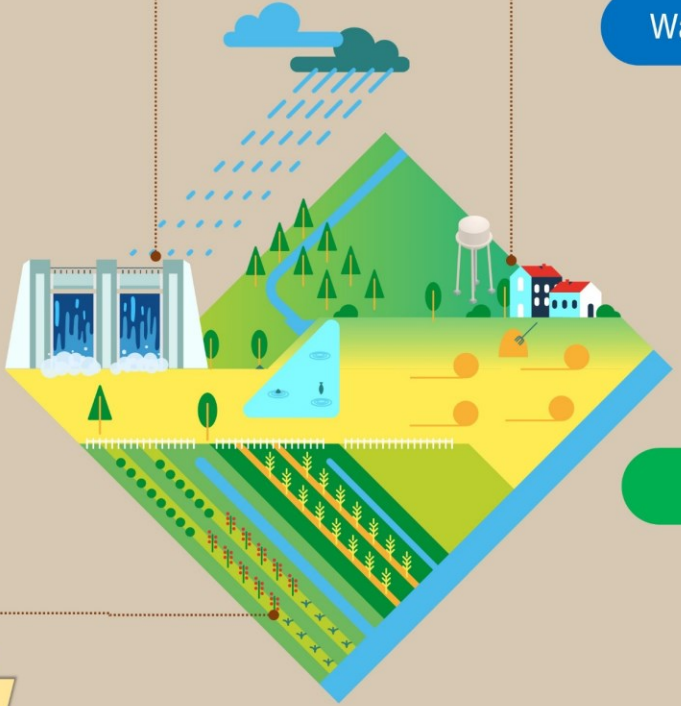
Crop Plan

11.65 million rai — Paddy field 9.02, Field crop 2.63

Irrigation area **6.95** million rai — Paddy field 6.41, Field crop 0.54

Rainfed area **4.70** million rai — Paddy field 2.61, Field crop 2.09

(1 rai = 1,600 square meters)



Forecasting the drought risk areas

Water consumption

- PWA Service area (assess on 20th Oct 2021)
  33 branches 24 provinces
- Outside PWA Service Area
  ONWR in collaboration with Department of Local Administration to survey and evaluate the risk areas
  25 sub-districts
  in 9 districts 5 provinces

Agriculture

- Areas of Paddy field
  Department of Water Resources analyzed the water balances in the sub-districts and forecasted the risk areas
  64 sub-districts
  28 districts 11 provinces
- Perennial plant
  The risk areas are based on total rainfall in wet season that is less than 20 percent of average rainfall (30 years)
  23 sub-districts
  10 districts 4 provinces

Water Quality (salinity)

- 4 main rivers (Chao Phraya river, Tha Chin River, Mae Klong River Bang Pakong River)
- MWA Bangkok (East side) and Samut Prakan
  PWA 5 branches 3 provinces

by River Basin Management Division (ONWR)

OFFICE OF THE NATIONAL WATER RESOURCES

9 Countermeasures Dry Season in 2021/2022

SUPPLY

1 Accelerating to store water

2 Providing Water reserves in the risk areas

explore, investigate the potential areas which can be developed as a water reserve

* To promote water management each community in the rainfed areas utilize water and rainwater

3 Filling the water

to water sources in agricultural and risk areas

DEMAND

4 Defining water allocation in dry season

Follow up and supervise according to plan in order not to affect water shortage and set up the water user registration

5 Planning crops in dry season

To promote and support cultivation in the flood -affected areas as first priority

6 Preparing the water reserves for the lowland areas

to be planted in the coming wet season

7 Monitoring the water quality

in the main river and sub river and prepare the plan in case of crisis

MANAGEMENT

8 Monitoring and Evaluating

To supervise in accordance with the plan

9 Raising awareness and public relations

To encourage all sectors to cooperate in saving water use and also follow to the plan of dry season

Approved by the Cabinet on 11th January 2022

by River Basin Management Division (ONWR)

Results of Implementation 9 countermeasures Dry Season in 2021/2022

1 Accelerating to store water

on 1st Nov 2021

61,849 MCM

(Large/Medium/Small reservoirs and Natural water resources)

4 Defining Water allocation in dry season

(1st Nov 2021 – 30th Apr 2022)

Total water allocation (irrigation area)

17,972 MCM (108 % of plan)

(seasonal plan 16,677 MCM)

7 Monitoring Water Quality (salinity)

4 main rivers

(1st Nov 2021 – 30th Apr 2022)

- Chao Phraya river
- Tha Chin River
- Mae Klong River
- Bang Pakong River

normal criteria

(Except Chao Phraya River on 24th Dec 2021 Salinity was 0.28 g/l)

- MWA (2 provinces)
  Bangkok (East side) and Samut Prakan
  Salinity at Samlae intake pumping station is normal criteria
  ** The operation by MWA in collaboration with RID released raw water to push seawater intrusion simultaneously which were 7 times during the season.
- PWA 5 branches 3 provinces
  There were 3 branches in Chachoengsao that salinity of water was higher than normal criteria sometimes.

2 Providing Water reserves in the risk areas

Chao Phraya River Basin and Bangkok

444 areas **181** MCM

PWA provide the water reserves for PWA risk areas

82.12 MCM

5 Planning crops in dry season

Total cultivated area (1st Nov 2021 – 30th Apr 2022)

13.34 Million rai (seasonal plan 11.65 Million rai)

Paddy field (2nd round)

11.23 Million rai

(plan 9.02 Million rai)

*Paddy field (3rd round) 0.06 Million rai

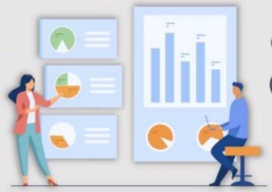
Field crop

2.05 Million rai

(plan 2.63 Million rai)

The number of registration who cultivate the paddy field (2nd round) **342,209** households **5,509,691** rai

8 Monitoring and Evaluating



All agencies collaborated to monitor and evaluate weekly and monthly

(1st Nov 2021 – 30th Apr 2022)

**** There is no drought area during this season. ****

3 Filled the water

(1st Nov 2021 – 30th Apr 2022)

Department of Royal Rainmaking and Agricultural Aviation

operated **11** bases (26 aircrafts)

The result is 411 flights

1. Preventing and Coping with drought areas about 54.5 Million rai
2. Filling the water in the reservoirs 12.5 MCM

6 Preparing the water reserves for the lowland areas

Royal Irrigation Department reserves the water for cultivation is **11** lowland areas **1.22** Million rai

The amount of water reserves **1,388** MCM

9 Raising awareness and public relations

To encourage all sectors to cooperate in saving water use before and throughout the dry season

total **1,529** times

All agencies within The National Water Administration Center (NWAC)

Result of Seminar (AAR)

Water Resources Management in Dry Season 2021/2022

on 31st May 2022 at Office of the National Water Resources via video conference

There are around 230 participants including , related-agencies 7 ministries and 30 departments, Representatives of the River Basin Committees and Thai Water User Organizations, Experts, Academics and the Private Sectors.

Main issues of the season

1 Exceed cultivation plan every year

To enhance the measure for reducing water demand and increasing income using policies of promoting other crops which are more water productivity

2 Empowering the communities in water resources management

Local Government Organization (LGO) is important to mobilize the measures but there is lack of potential at local level especially rainfed areas. Therefore, the potential agencies will be mentor to support LGO.

3 Providing the water reserves from surface water and groundwater

To enhance Local Government Organization in collaboration related-agencies to survey the water resources in order to coping water shortage at local level

4 Monitoring Water Quality

In addition, monitoring salinity that would also monitor other criteria for water quality. Moreover, the solution of seawater intrusion recently wastes a lot of fresh water for repelling. Hence, the solution would research the large-scale project concretely.

15 Related-agencies present the implementations problems and obstacles

by River Basin Management Division (ONWR)

10 COUNTERMEASURES Dry Season in 2022/2023

OFFICE OF THE NATIONAL WATER RESOURCES

Approved by the Cabinet on 1st November 2022

SUPPLY

1 Accelerating to store water

2 Monitoring, Providing water reserves and Planning of machinery and equipment in the risk areas

3 Filling the water to water sources, agricultural areas and risk areas

DEMAND

4 Defining water allocation and Planning crops in dry season

5 Enhancing agricultural water productivity

6 Preparing the water reserves for the lowland areas to be planted in the coming wet season

7 Monitoring the water quality in the main river and sub river, prepare the plan in case of crisis and warn the risk area

MANAGEMENT

10 Monitoring and Evaluating to supervise in accordance with the plan and report on drought assistance

9 Raising awareness and public relations the situation and plan of dry season

8 Empowering the communities in water resources management to adequate water for consumption and agriculture throughout the season

Note: 1. No. 4 is combine from No. 4 and 5 of the countermeasures of dry season in 2021/2022
2. No. 5 and 8 are added from ARR of Water Resources Management in Dry Season 2021/2022

by River Basin Management Division (ONWR)

Thank You

"as water is the national security"

OFFICE OF THE NATIONAL WATER RESOURCES

@ONWRNEWS www.onwr.go.th

Session 1: Water security in the GMS in a changing climate

Break-out group discussion

- How does scarcity manifest in your country?
- What is the impact on the food, energy and environment sectors?
- What are supply side options and what are their consequences?
- What are the water allocation challenges?
- What is being done?

ADB

Greater Mekong Subregion Sustainable Agriculture & Food Security Program

Food and Agriculture Organization of the United Nations

Session 2: Water accounting to lay foundation for managing water security

ADB

Greater Mekong Subregion Sustainable Agriculture & Food Security Program

Food and Agriculture Organization of the United Nations

Australian Aid

THE AUSTRALIAN WATER PARTNERSHIP

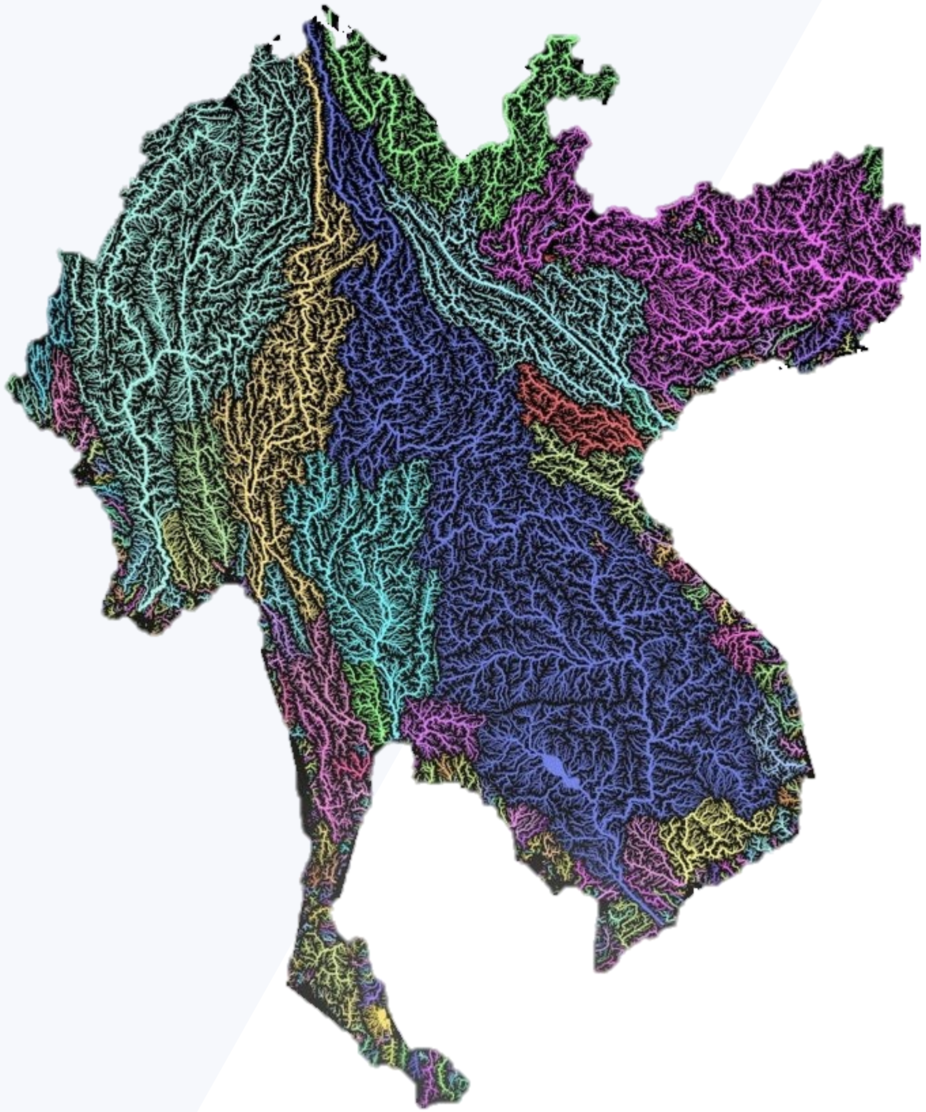
Water accounting

A brief policy focused rationale

Hugh Turral

hugh.turral@gmail,com

4-5 July 2023, Bangkok



The need for water accounting

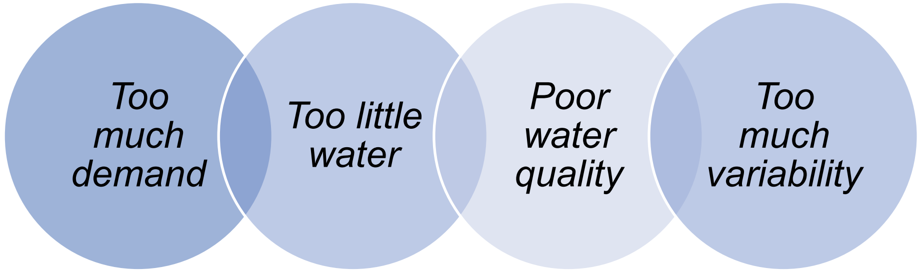
Rising water scarcity in Vietnam, Thailand & China; seasonal water scarcity in Laos, Cambodia and Myanmar.

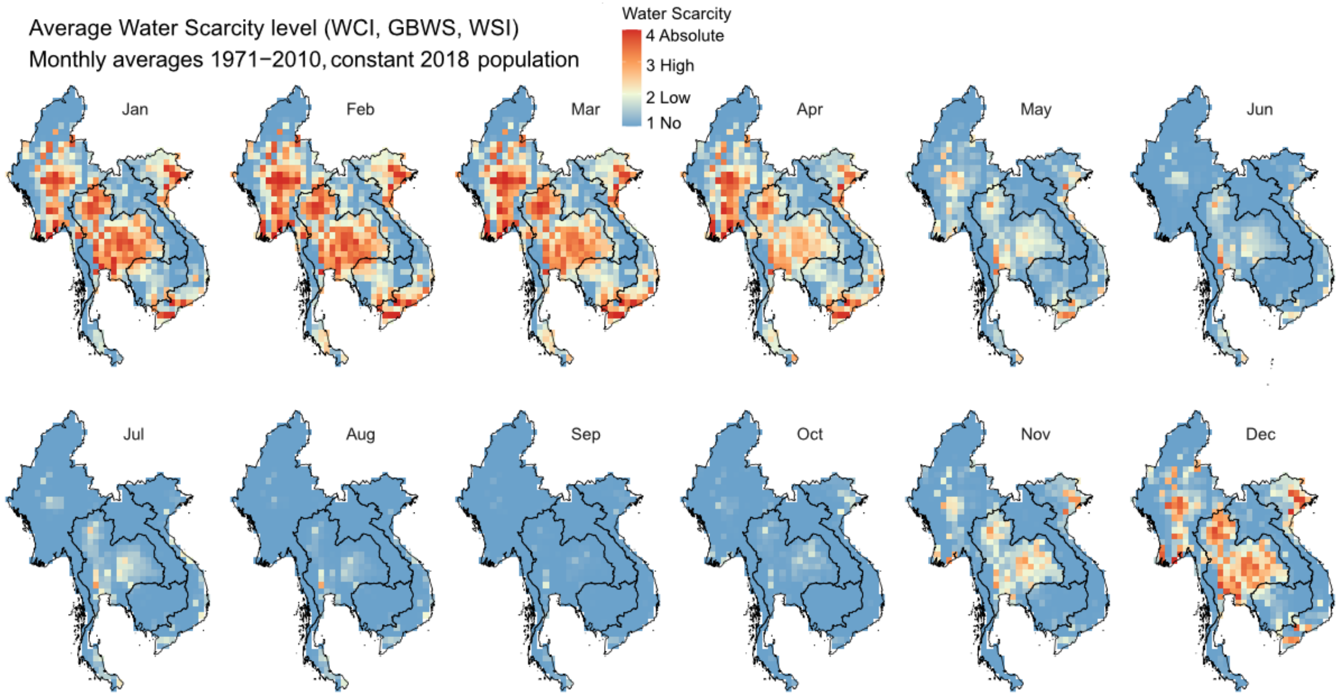
- Intersectoral competition
    - Agriculture the dominant consumer
- Environmental degradation (rivers, wetlands, coastal zones)
- Widespread decline in surface and some groundwater quality

CLIMATE CHANGE IMPACTS

NEXUS

Consider the consequences of un-sustainable water use in your sector: *farming, fish, energy, WASH, aquifers, ecosystems*

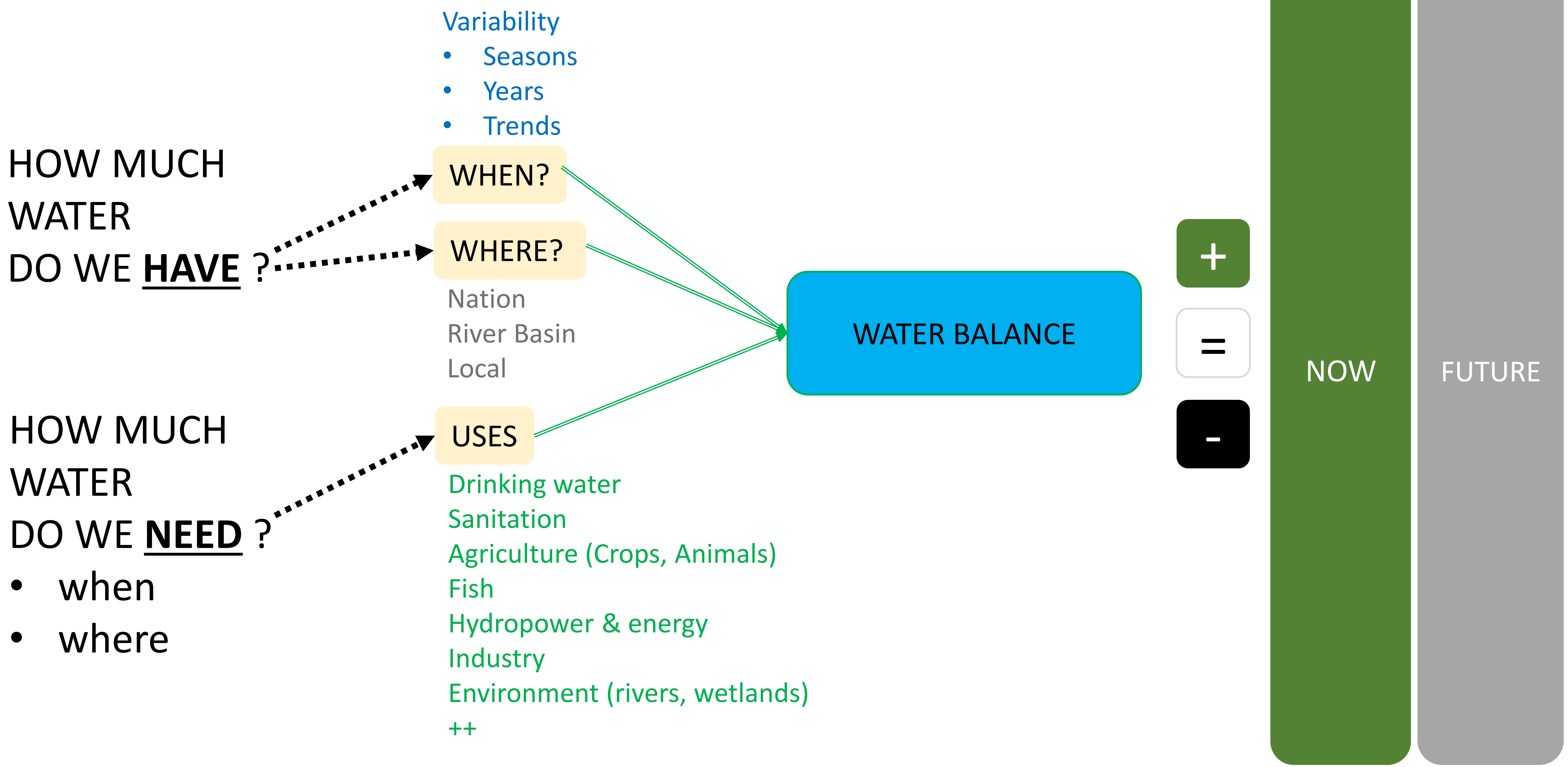




Source: Kallio Aalto University for FAO WSP

What information do you need for policy development, water resources planning and management?

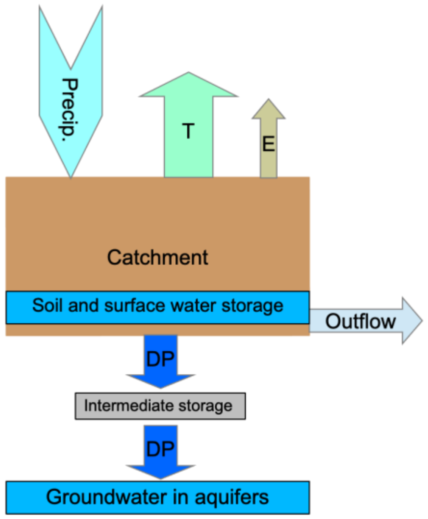
Water Accounting - what does it involve?

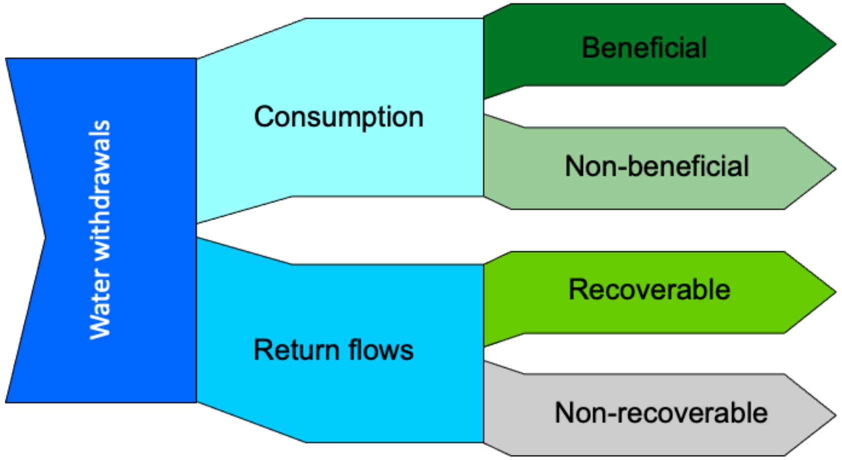


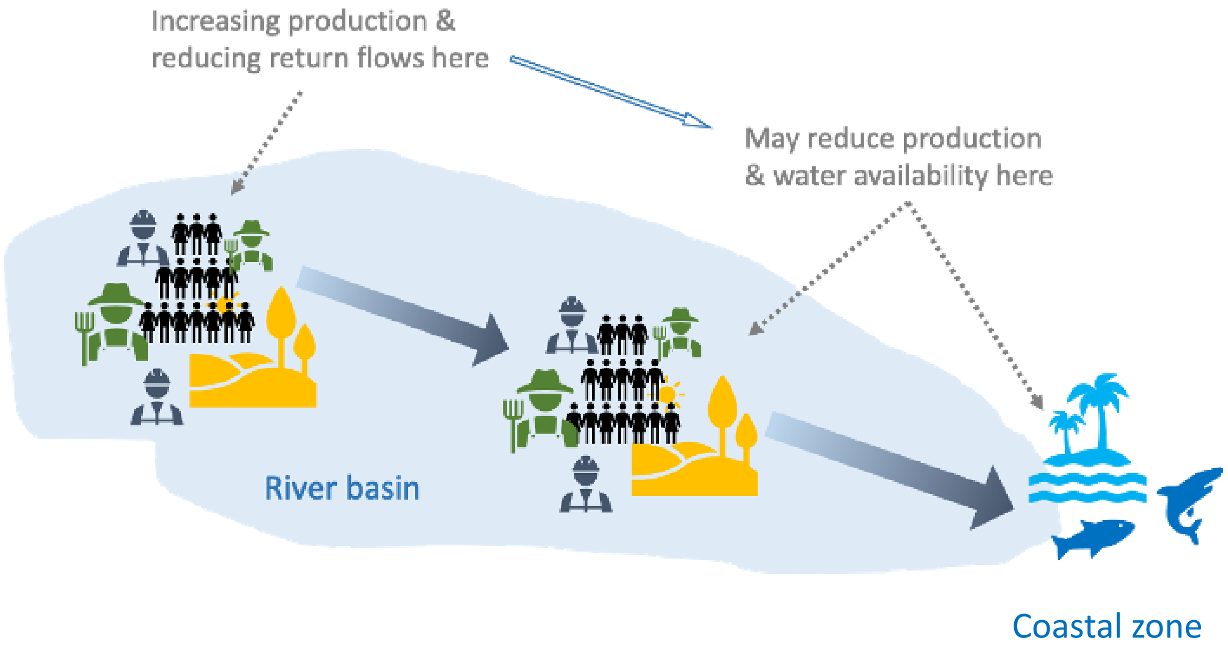
We are primarily concerned with the water we can manage – stream flows and groundwater

Water Accounting

- Needs continuity, detail and reliable data
- Data is often patchy, messy and of varying quality
- **START SIMPLE & IMPROVE!**
- There are multiple uses & **USERS** of water – irrigated agriculture typically accounts for 80% + of water use in Asia, and most of it is **consumed** as evaporation and transpiration by crops, trees & vegetation
- **Understanding consumption, particularly in agriculture, is important because of what happens to return flows**
- **The options to save water for other uses at basin scale depend on understanding consumption and return flow and the connections between different users**







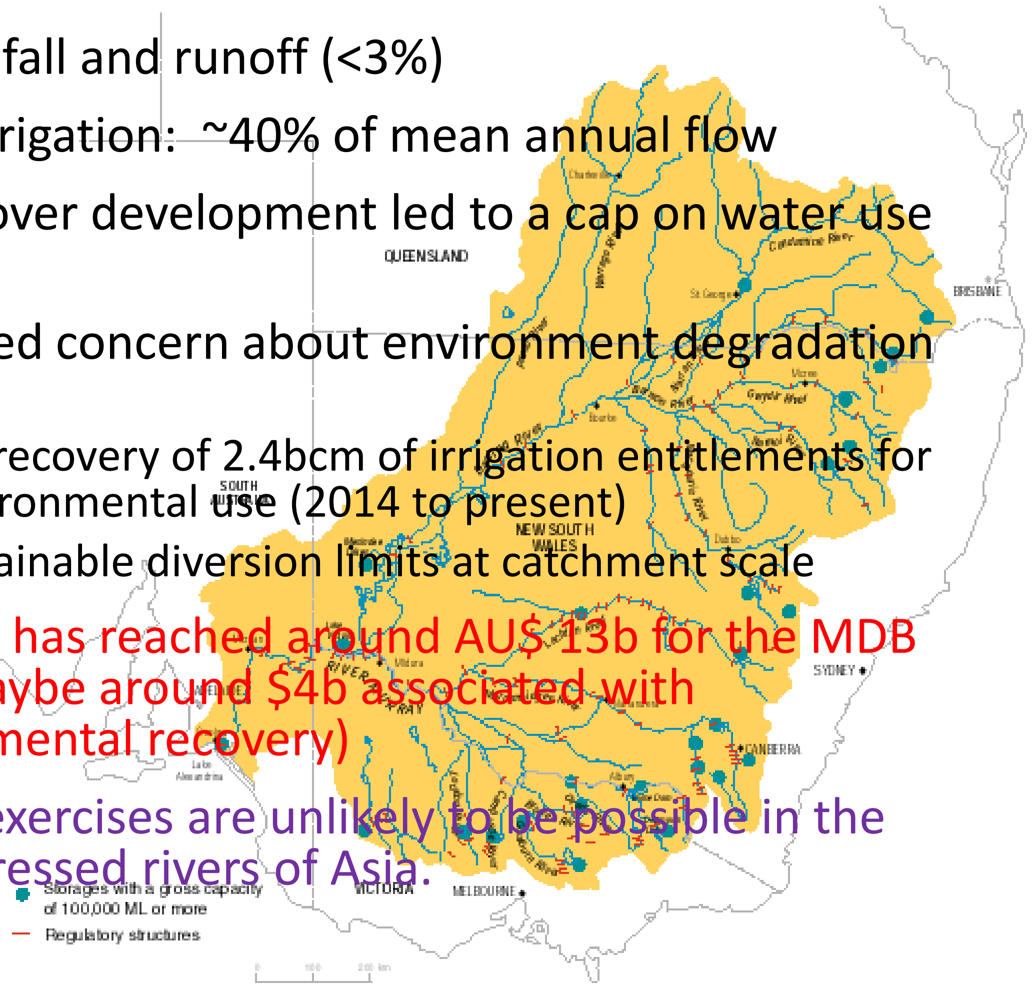
Policy implications lie in local versus basin-level social, economic and environmental benefits, and equity

Environmental Water Use

- Environmental water needs to maintain *rivers, wetlands, estuaries, coastal zones, + riparian vegetation* are typically ignored in Asia, especially where large amounts of water are extracted for irrigation.
- Where environmental flows (EFs) are specified,
  - they are usually expressed as minimum flows – typically at around 10% of minimum annual flow.
  - It is rarer still that these are monitored and managed.
- Habitat is dynamic and has evolved in response to historical patterns of flow,
  - EFs to maintain healthy condition should mimic the natural pattern in terms of amount, timing, duration – and are more complex than minimum flows

The Murray Darling Basin – Australia: a cautionary tale

Figure 1 Rivers, regulatory structures and major storages in the MDB



- MDB covers 1m km^2
- Low rainfall and runoff (<3%)
- 2m ha irrigation: ~40% of mean annual flow
- Fear of over development led to a cap on water use in 1994
- Continued concern about environment degradation led to
  - the recovery of 2.4bcm of irrigation entitlements for environmental use (2014 to present)
  - sustainable diversion limits at catchment scale
- The cost has reached around AU$ 13b for the MDB Plan (maybe around $4b associated with environmental recovery)
- Similar exercises are unlikely to be possible in the many stressed rivers of Asia.

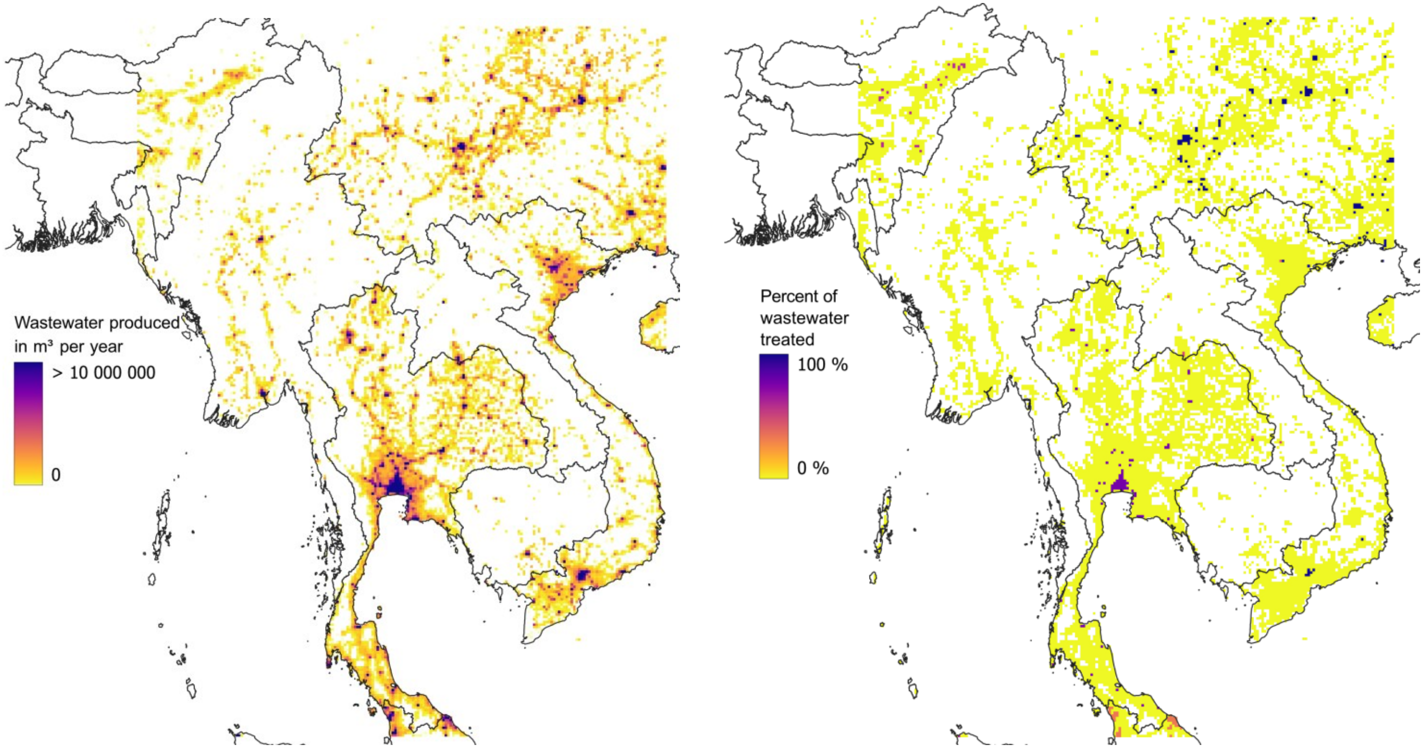
Policy implications:

water accounting should include and quantify current environmental water use and improve the assessment of e-flow requirements to sustain healthy rivers and avoid future costs in re-allocating stressed water systems to restore aquatic environments

Water Quality

- Widespread degradation of water quality in the region – in-stream, aquifers, lakes and wetlands (*multiple evidence in GMS*).
- Multiple sources and jurisdictions
  - Non-point source from cropping, point source from industry, human settlements, animal production, aquaculture
- Further reduces water availability or and increases cost of water use (treatment, public health costs, lower productivity)
- Cost of remediation is high. Reuse of urban wastewater in agriculture has benefits and costs, but only accounts for a small part of the water balance
  - Small fraction of a small fraction of total water use in most countries.

Wastewater produced & treated (2019)



Source: Kallio Aalto University for FAO WSP

Policy implications:

water accounting should include water quality assessment, mapping and monitoring in relation to flows & water use

Who is water accounting for?

ALSO

- Local government
- Catchment managers and catchment management authorities
- River managers
- Managers of water supply, sanitation and hydropower utilities
- Energy planners
- Agricultural planners
- Private sector agribusiness
- Livestock enterprises, businesses and pastoralists
- Independent policy analysts and thinkers
- WATER USERS (COMMUNITIES)

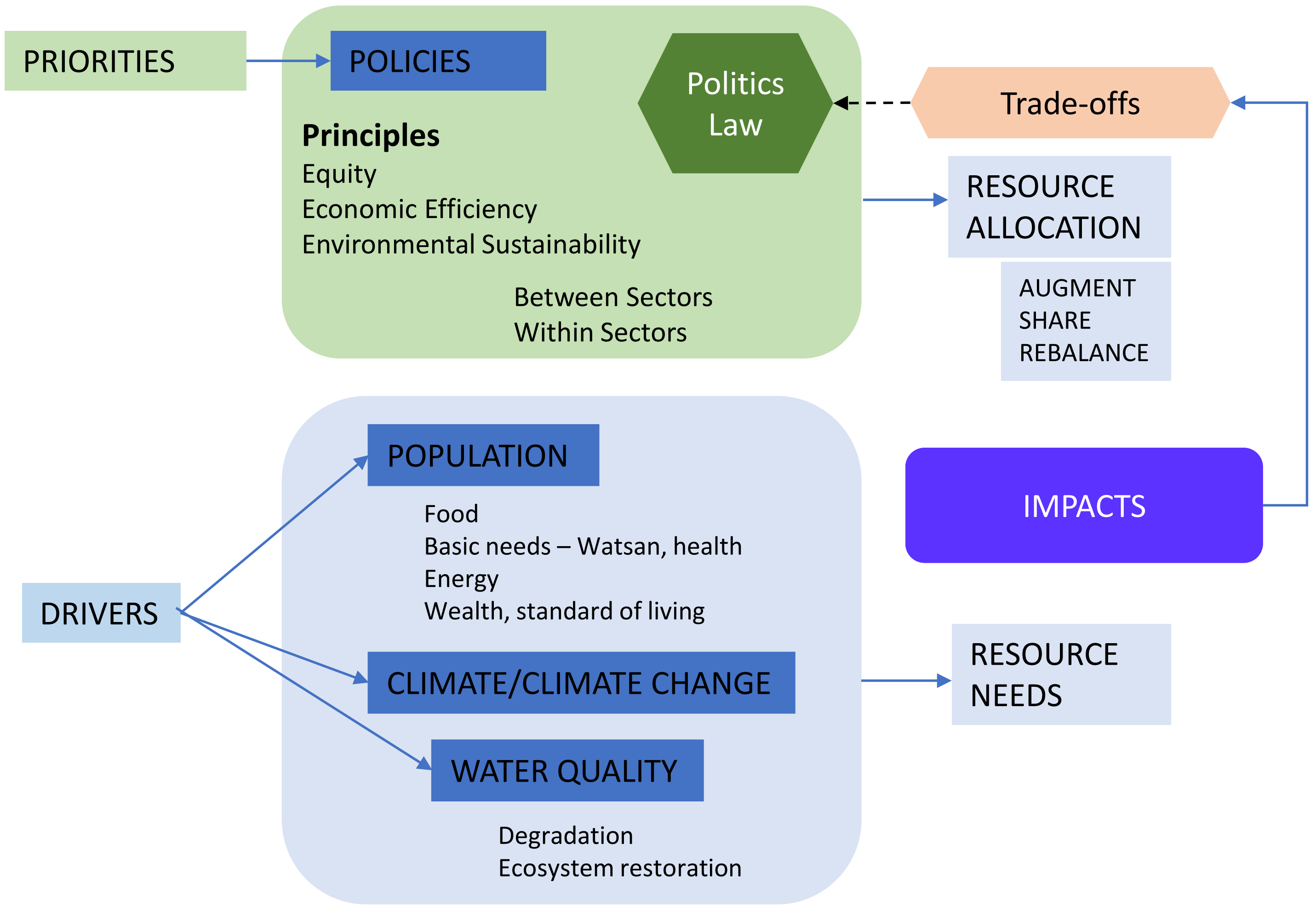
Uses of Water Accounting

Broad range of applications

- Resources assessment, planning and management of water supply systems (WASH, Irrigation) to river basins
- Performance assessment of WASH, industrial, energy and irrigation systems
- Assessment of environmental flows
- Groundwater monitoring, regulation and compliance
- Pollution management, monitoring and control
- Understanding economic and social benefits of water use

The main strategic application is the development, support and monitoring of effective, transparent and fair **WATER ALLOCATION**

- political priority setting on who gets how much water, (where and when)
- the rules designed to achieve those priorities
- the operations that implement the rules, between and within sectors.



A Water Accounting System

Building Blocks

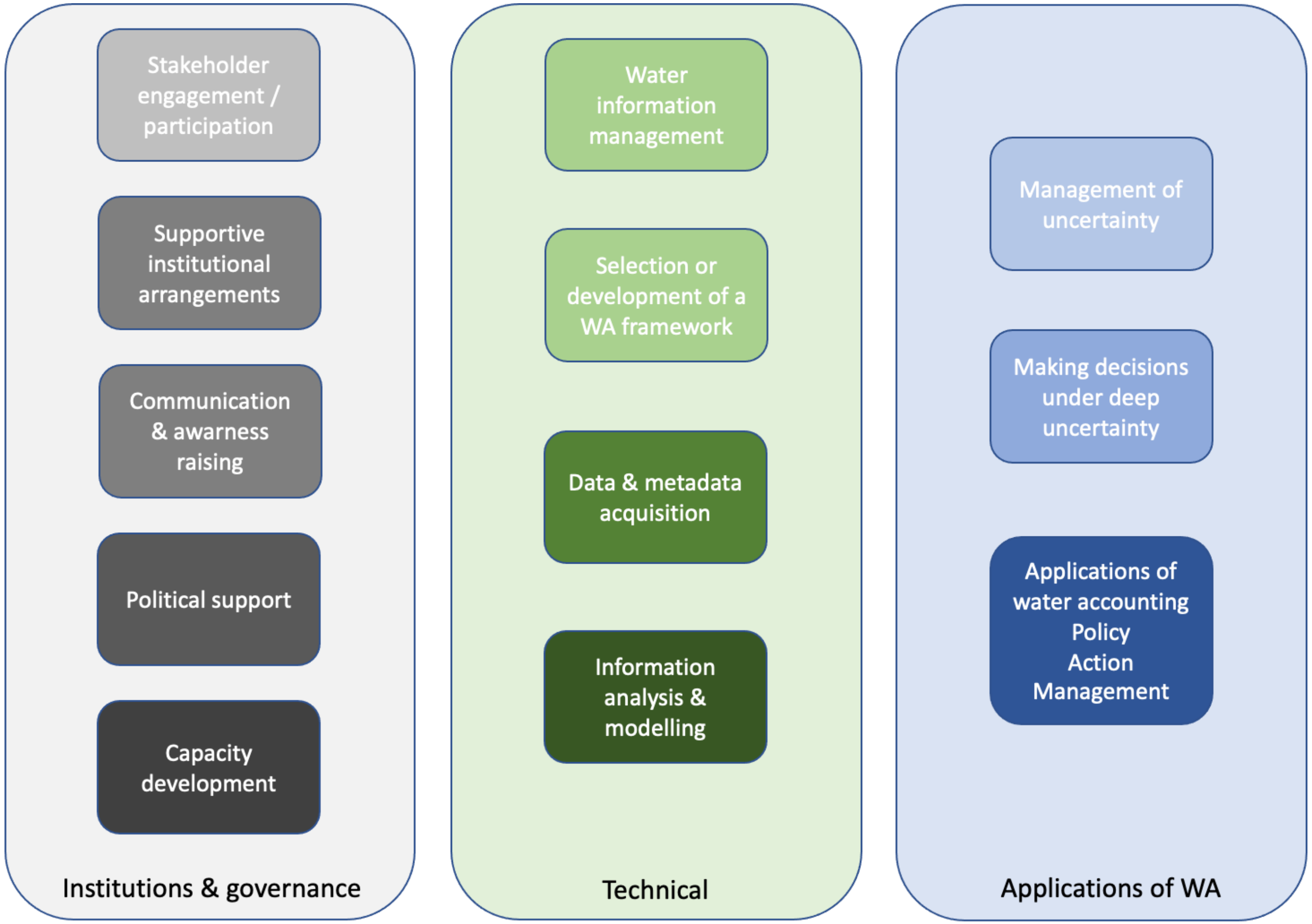
- Institutions and Governance
- Technical (water balance)
- Applications

Step by step cycle of developing and improving water accounts:

- Rapid water accounting (RIDA framework)
- Improved data, data substitution through modelling and remote sensing

Capacity building

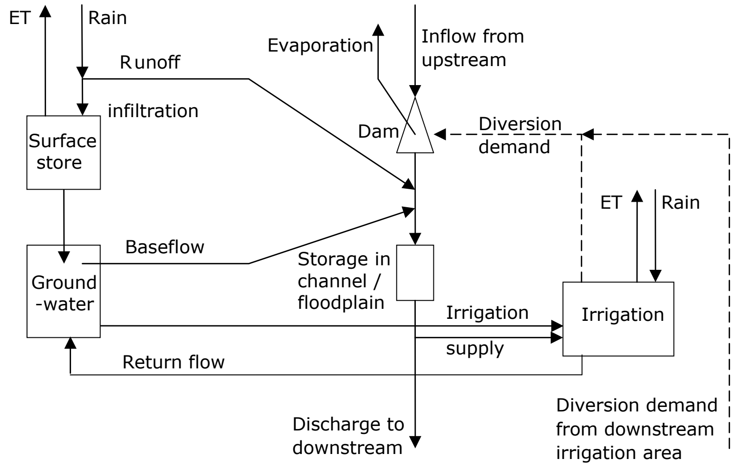
- Training
- Learning by doing
- Exchange

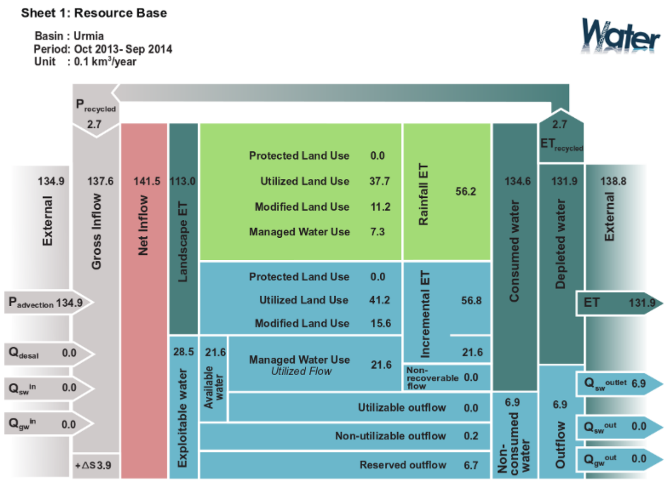


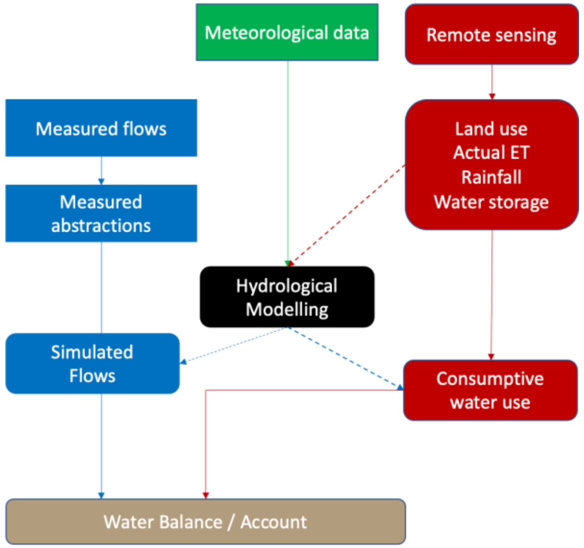
Approaches to creating water accounts

- Flow based water balance of managed surface and groundwater
  - Starting with spreadsheets and inventories of use and users
- Remote sensing-based approaches
  - Rainfall
  - Actual evapotranspiration
- Hybrid approaches
  - Using remote sensing to improve flow based and hydrologic modelling

- System of Economic and Environmental Accounting for Water (**SEEAW**)
  - Values (S, E, Env) applied to water accounting information derived from elsewhere (above)

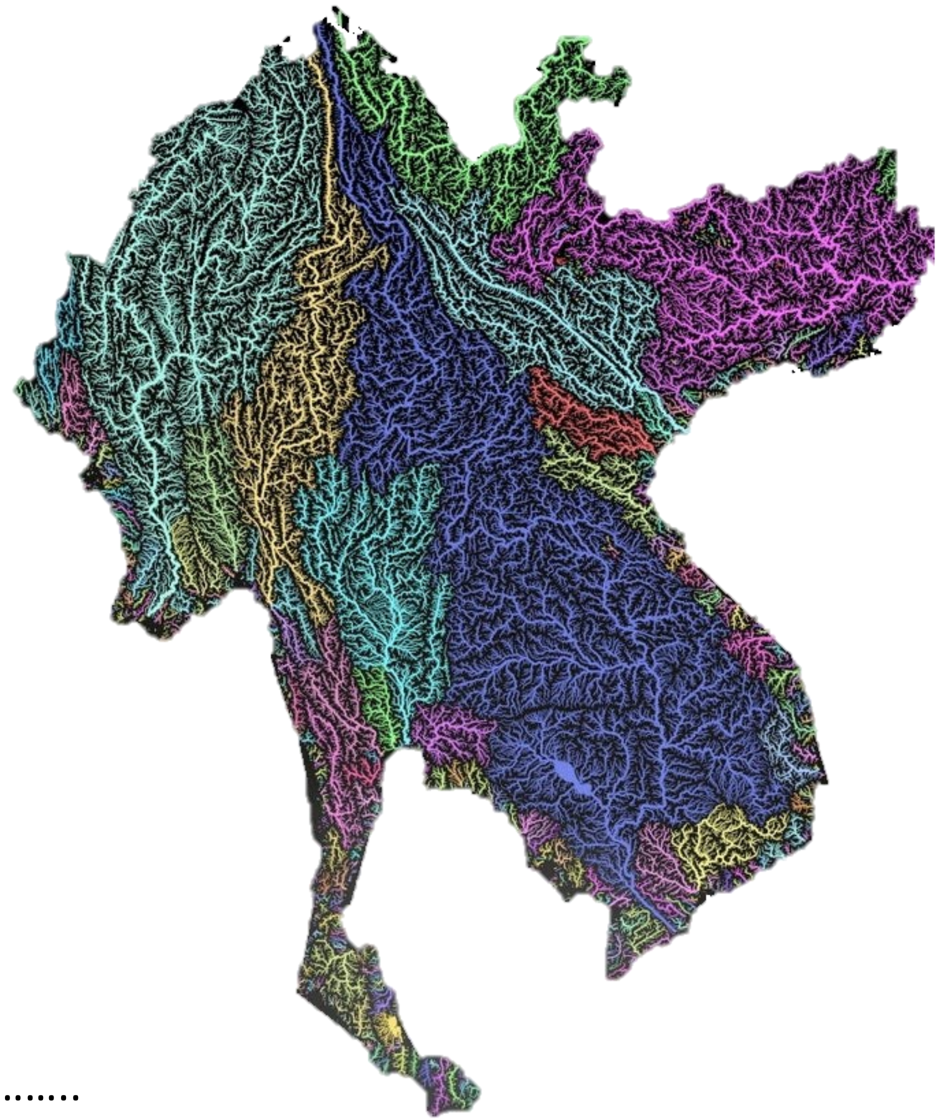






Water accounting is probably rather boring

But its very important



Later sessions delve into more details……..

Recent trends in water scarcity – by country to 2010

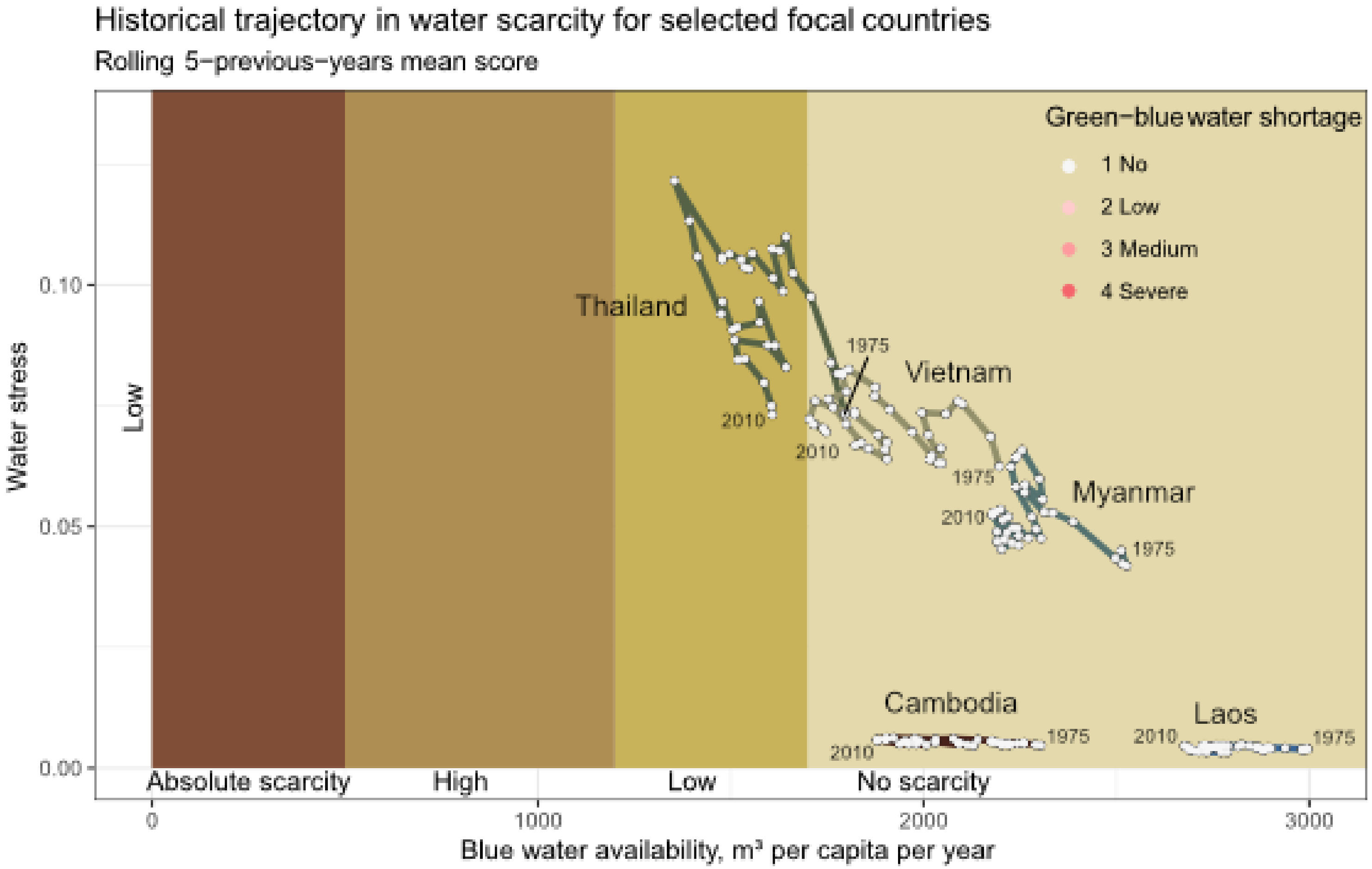
- Clear patterns of increasing scarcity (reduced per capita water availability)
- Increasing water stress (use/available renewable water resources)

DRIVERS

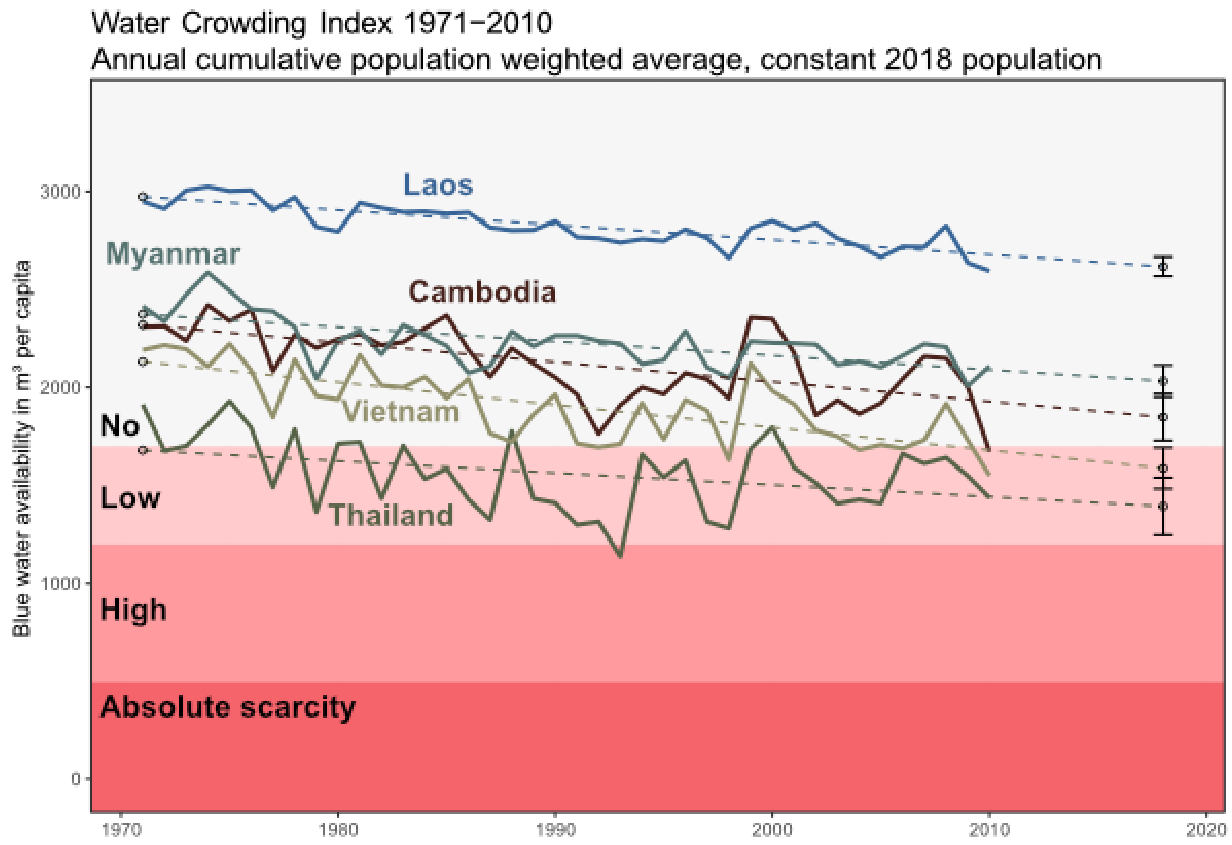
Population growth

Economic development (energy demand, industry, rising food needs and changing preferences)

Climate change



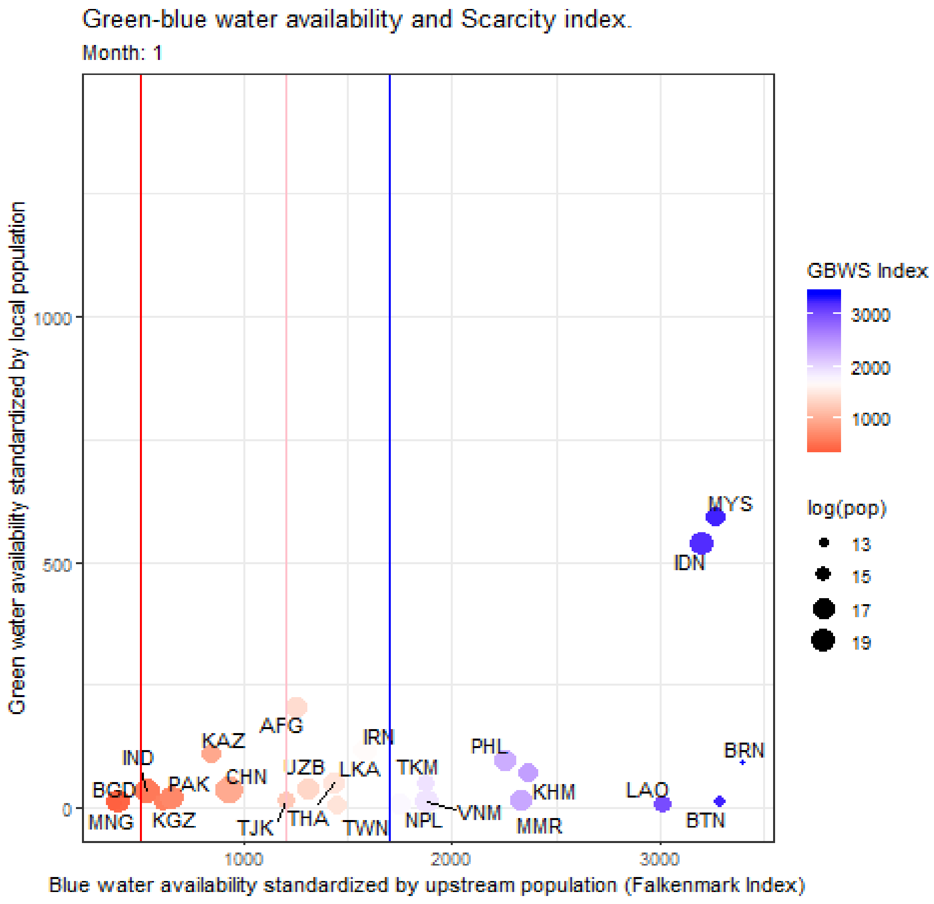
Timeseries of Water Crowding Index



Animated plot, national values,

Y= GBWS normalized by local population

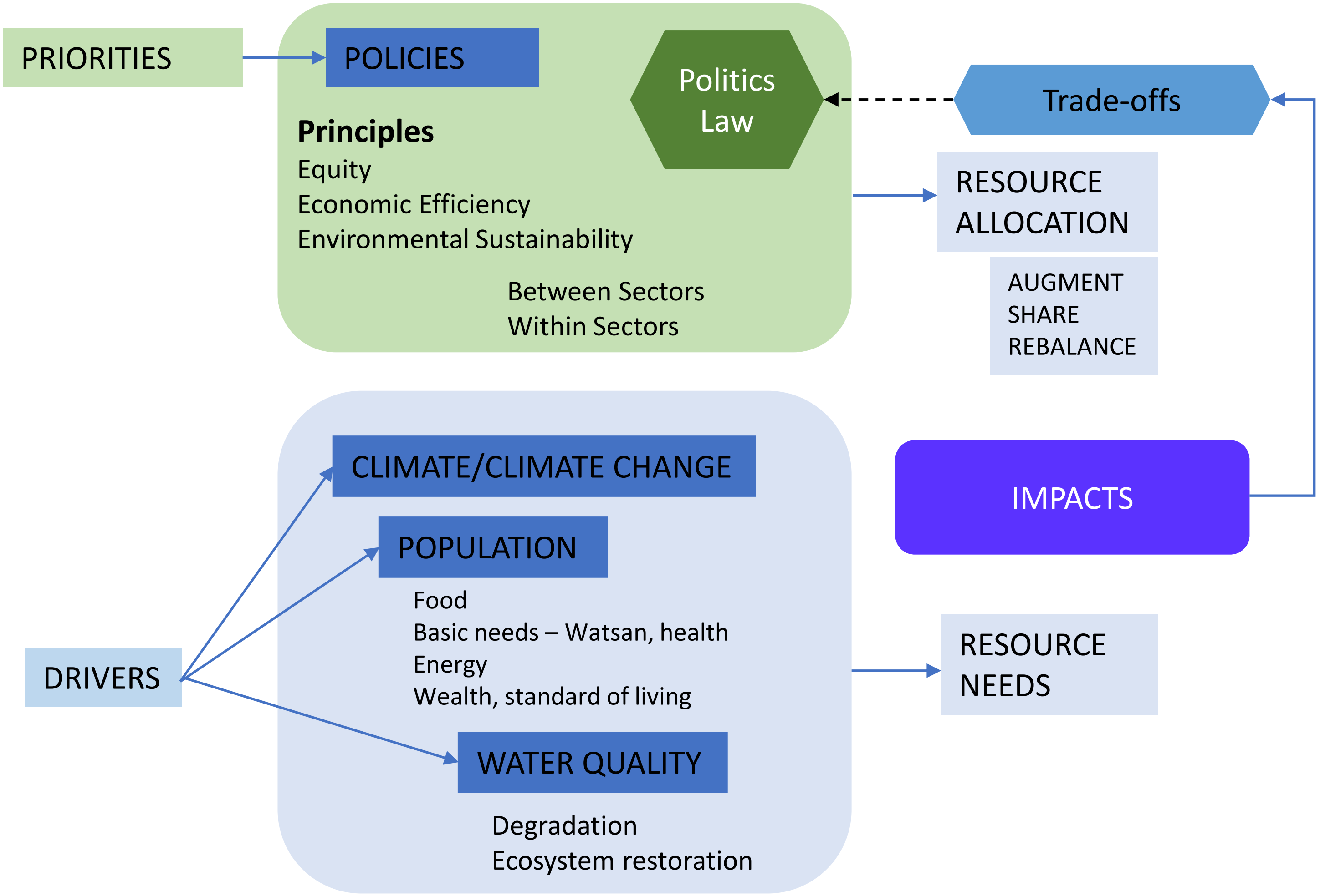
X = water availability normalized by upstream population



Take-home messages from regional analysis

- GBWS (sufficient water for agriculture for domestic consumption) not an issue in Mekong Countries
- Water scarcity in Thailand occurs particularly central plains, uplands and floodplains.
- Water scarcity is highly seasonal and there is a high variation year-to-year scarcity conditions
- Delta and floodplains are slowly getting into high scarcity category
- Uplands are particularly water stressed with high variability
- Coastal zone profile is different and less alarming than the plains, uplands and floodplains

Water allocation – what is it



Frameworks for water allocation and assessment socio-economic impacts of E-flows

Water accounting in the GMS - Policy implications for water, food and energy security in a changing climate

Mukand S. Babel
Water Engineering and Management (WEM)
Centre for Water and Climate Adaptation (CWCA)
Asian Institute of Technology (AIT), Thailand

Outlines

- Water allocation
- Integrated water allocation tool
- Socio-economic implications of E-flows
- Way forward

Water Allocation: Definition

In simple term, water allocation implies sharing of water among users

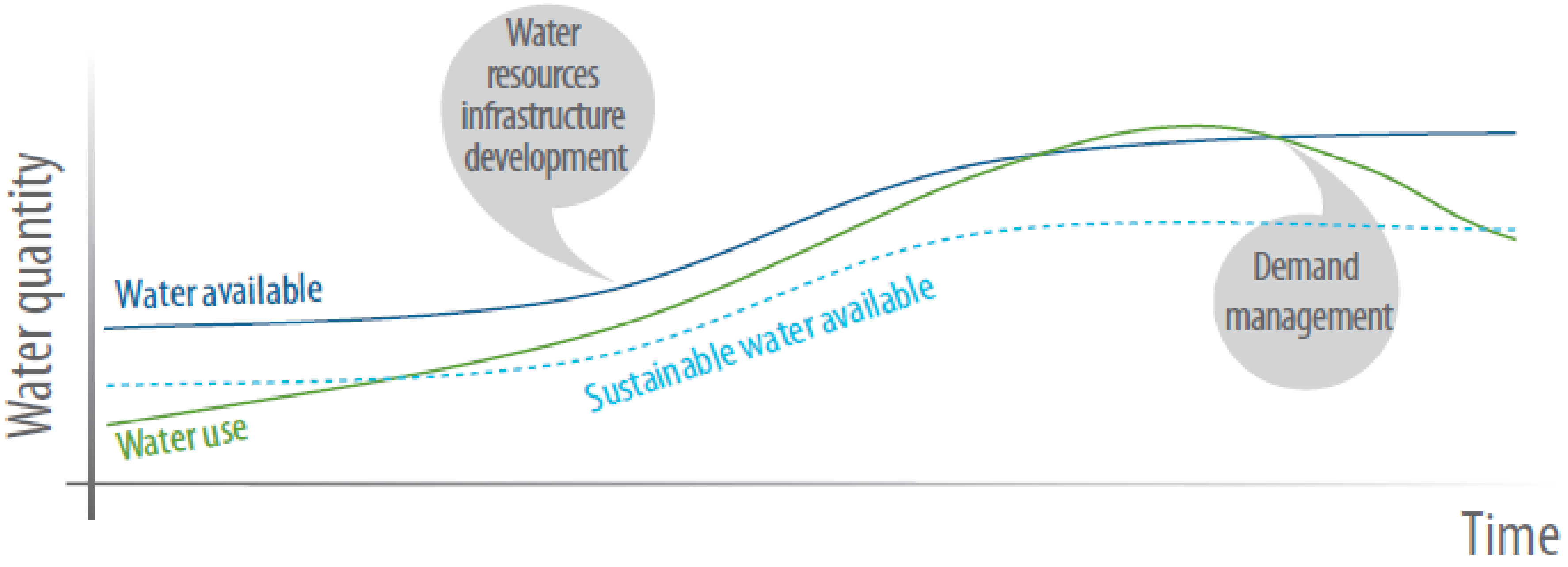
Why water allocation?

- Growth in water abstractions
- **Basin 'closure' and lack of availability of more sites for water infrastructure**
- Growth of change in economy leading to wider variety of water users with different water demands
- **Decline of freshwater ecosystems and loss of river system functions**
- Climate change

Water Allocation: Approach

Basin allocation planning should focus on

- **optimizing the use of existing supplies** through significant economic, social and environmental analyses and
- the assessment of **tradeoffs** between competing users



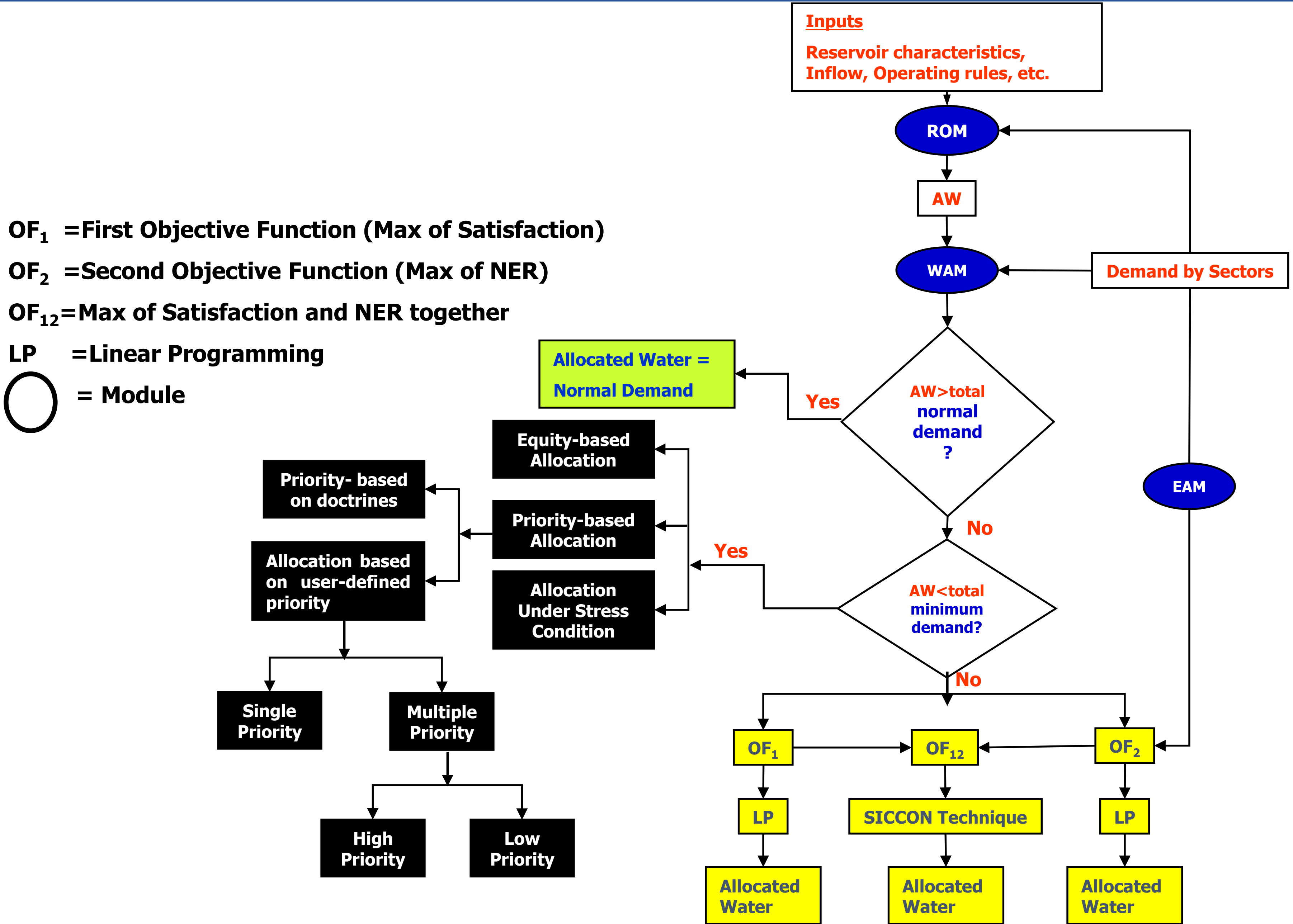
Objectives of Water Allocation

Objective	Character	Outcome
Social objectives	Equitable	Provides for essential social needs Clean drinking water Water for sanitation Food security
Economic objectives	Efficient	Maximize economic value of production Agricultural and industrial development Power generation Regional development Local economies
Environmental objectives	Sustainable	Maintain environmental quality Maintain water quality **Support in-stream habitat and life** Aesthetic and natural values

Objectives conflict with one another !!!

Integrated Water Allocation Model

Conceptual framework



Tool features

- Three modules
  - ROM (Reservoir Operation Module)
  - EAM (Economic Analysis Module)
  - WAM (Water Allocation Module)
- Two single objective functions and a multi-objective function
  - Maximization of satisfaction
  - Maximization of net economic return (NER)
  - Combination of the above two
- Linear programming and multi-objective optimization
- Six conflicting sectors: agriculture, domestic, industry, hydropower, recreation and environment

Single objectives

(i) To maximize the satisfaction of various water Sectors:

Maximize $OF_1 = \frac{1}{n}\sum_{i=1}^{n}\frac{S_{a_i}}{D_{n_i}}$ **Value: 0-1**

(ii) To maximize the net economic return:

Maximize $OF_2 = \left[\frac{\sum_{i=1}^{n} S_{a_i} * NER_i}{AW * NER_{\max}}\right]$ **Value: 0-1**

Where,

Sa_i = Water allocated to sector *i*

Dn_i = Normal or calculated water demand of sector *i*

n = Number of water demand sectors

NER_i = Net economic return per unit volume of water (US$/$m^3$)

AW = Available water

NER_{max} = Maximum net economic return among the concerning sector

Multi-objective

(iii) To maximize the Satisfaction and Net Economic Return (NER) together

$$\text{Maximize } OF_{12} = w_1{*}OF_1 + w_2{*}OF_2 - [\sigma^-_{12} + \sigma^+_{12}]$$

Value: 0-1

Where,

W_1 and W_2 = Weight given to OF_1 And OF_2 respectively

σ^+_{12} = Positive deviation from the "supposed to be zero value" of the compromise constraint developed between objectives OF_1 and OF_2

σ^-_{12} = Negative deviation from the "supposed to be zero value" of the compromise constraint developed between objectives OF_1 and OF_2

Constraints

(i) Availability constraint:

$$\sum_{i=1}^{n} S_{a_i} \le AW$$

(ii) Demand constraints:

$$D_{n_i} \ge S_{a_i} \ge D_{m_i}$$

(iii) Supply constraints:

$$\sum_{i=1}^{n} S_{a_i} \le \sum_{i=1}^{n} D_{n_i}$$

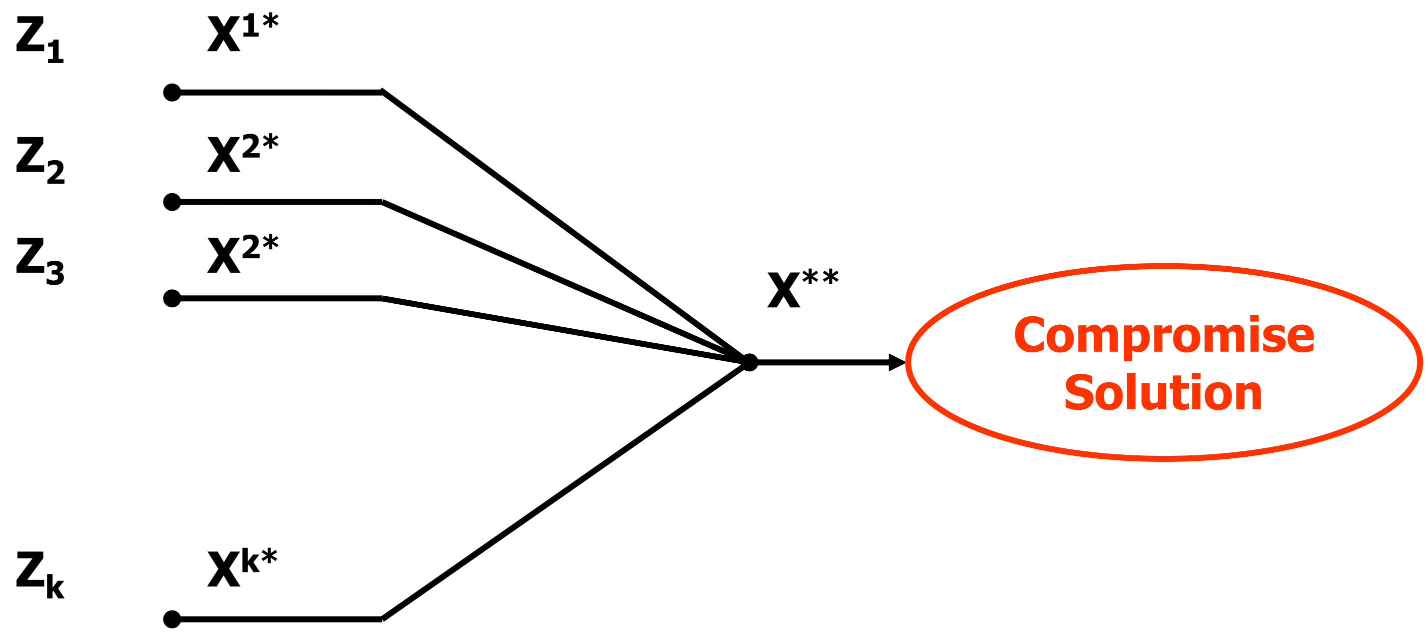
(iv) Non-negativity constraints:

$$S_{a_i} \ge 0, D_{n_i} \ge 0, D_{m_i} \ge 0$$

(V) Compromise constraint:

$$w_1 * \left[\frac{1}{n} \sum_{i=1}^{6} \frac{S_{a_i}}{D_{n_i}} - OF_1 \right] - w_2 * \left[\frac{\sum_{i=1}^{6} S_{a_i} * NER_i}{AW * NER_{\max}} - OF_2 \right] + (\sigma_{12}^{-} - \sigma_{12}^{+}) = 0$$

Operation of SICCON technique



SICCON = Simultaneous Compromise Constraint

Assessment of model suitability

- Varying Minimum Water Requirement by Each Sector
- Varying Weights Given to Two Objectives
- When Equal Preference is Given to All Sectors
- Priority or Preference is Given to a Single Sector
- Equal and First Preference is Given to Multiple Sectors

Data requirements

ROM

- Monthly inflow to the reservoir
- Reservoir characteristics including operating rules
- Rainfall, evaporation and percolation
- Installed capacity, tail water level
- Monthly demand by demand sectors

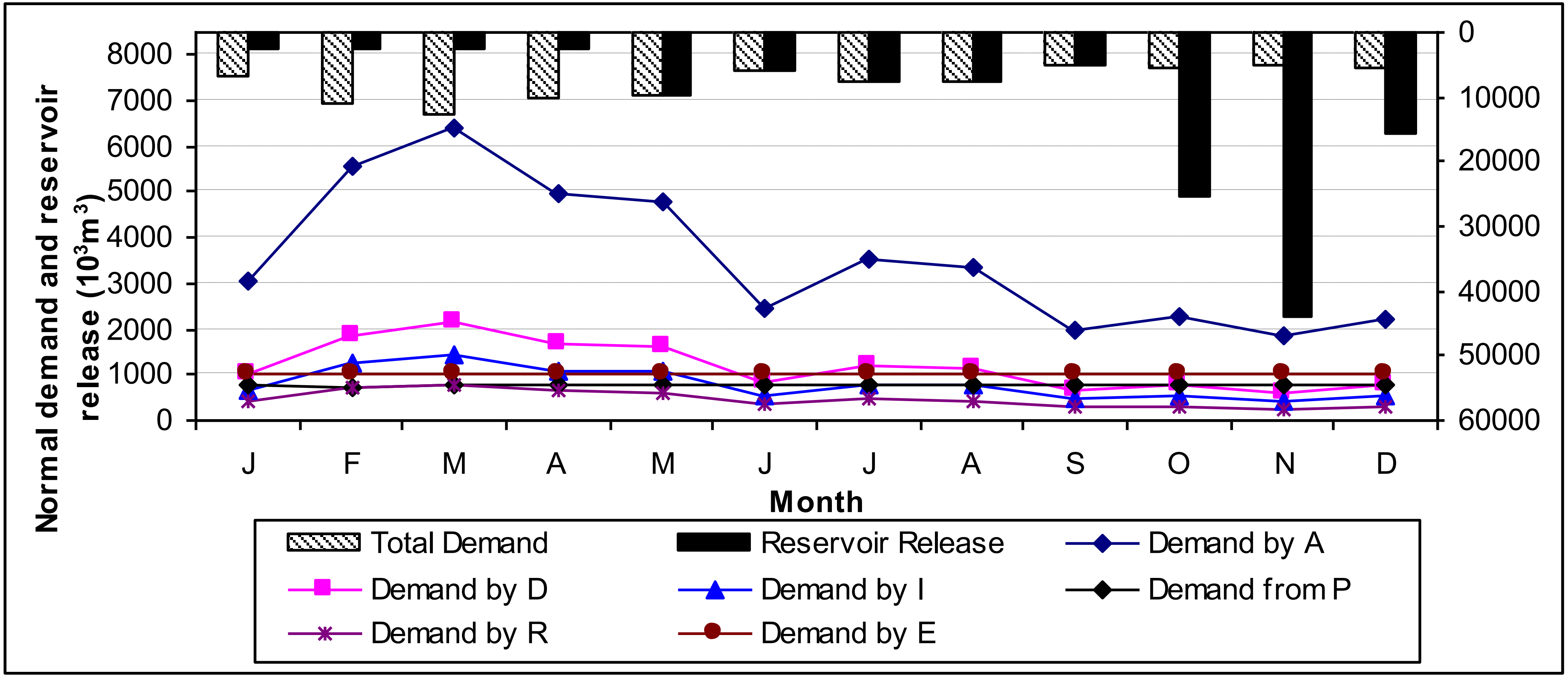
EAM

- Data related to the estimation of NER

WAM

- Normal and minimum water demand by sectors
- Available water (AW)
- Specified priority of allocation
- NER (if OF_2 or OF_{12} is considered)
- weights to be given to OF_1 and OF_2 (if OF_{12}) is considered

Monthly demand and release



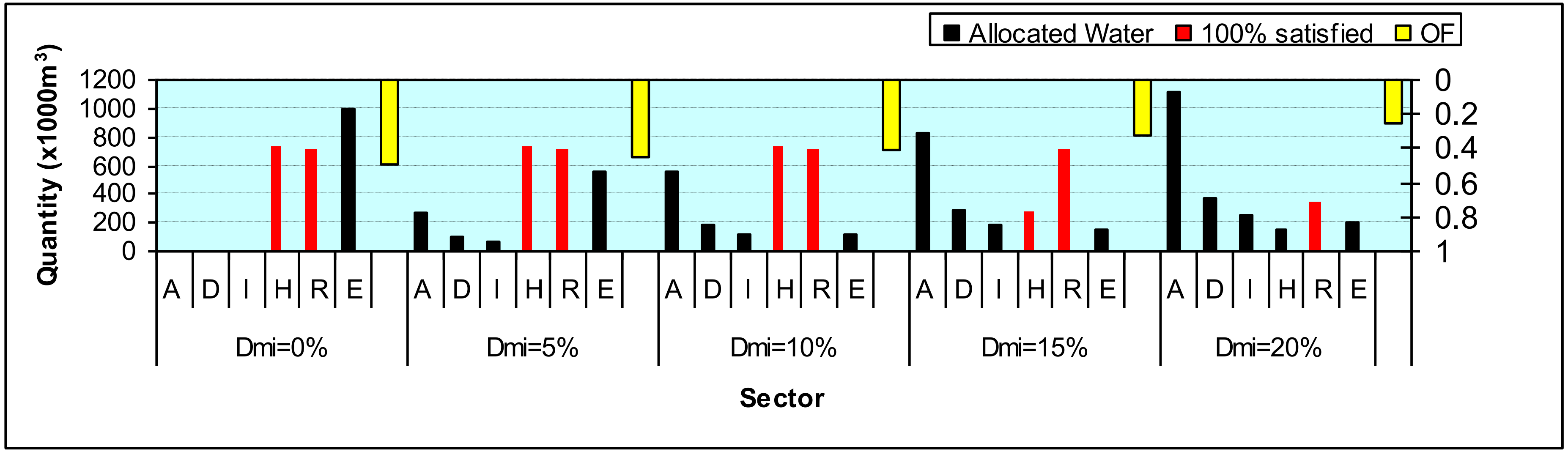
Environmental demand d/s of the reservoir = constant flow rate of 0.386 m^3/s

Results

Minimum demand (Dm_i) by the sectors varying from 0 to 20% of the normal demand (Dn_i)

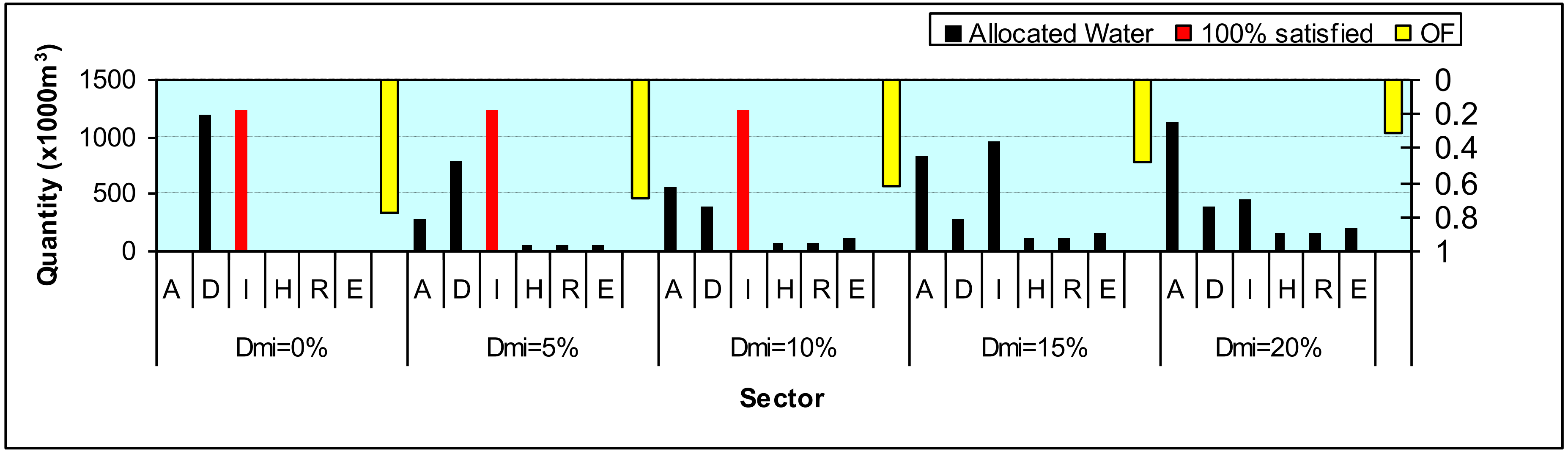
Allocation to sectors OF=OF1 (Feb)

Sector	Dn_i (1000 m³)	AW (1000 m³)	NER (US$/1000m³)	Allocated water with minimum demand of				
				0%	5%	10%	15%	20%
A	5563	2419	12	0	278	556	834	1113
D	1866		2324	0	93	187	280	373
I	1233		4361	0	62	123	185	247
H	726		917	**726**	**726**	**726**	268	145
R	702		54	**702**	**702**	**702**	**702**	342
E	1000		1423	991	558	125	150	200
OF_1				0.499	0.451	0.404	0.328	0.248



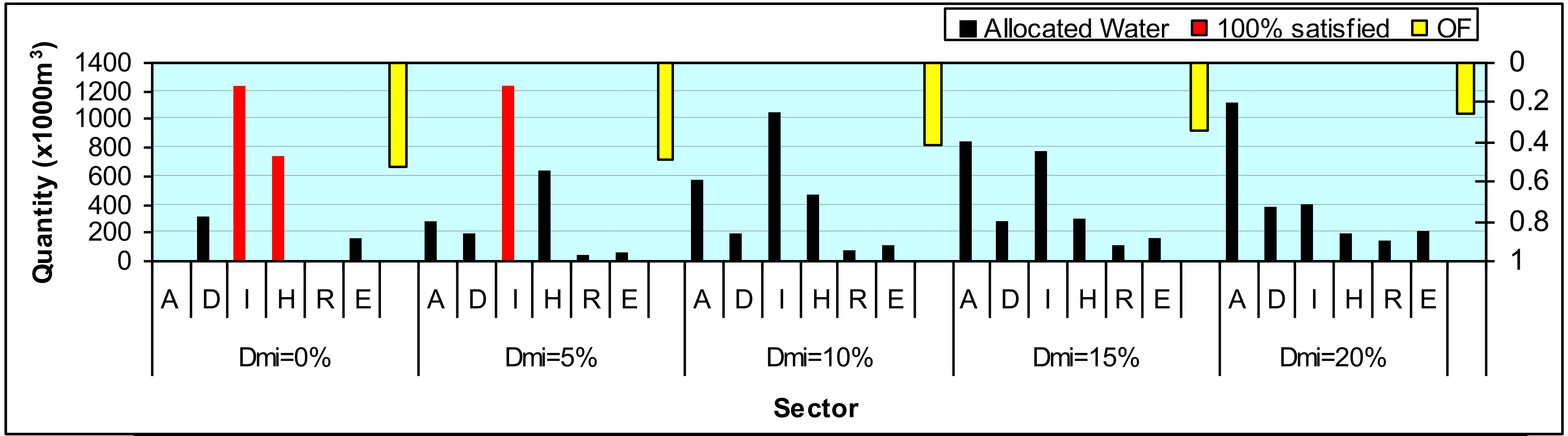
Allocation to sectors OF=OF2 (Feb)

Sector	Dn_i (1000 m^3)	AW (1000 m^3)	NER (US$/1000m^3)	Allocated water with minimum demand of				
				0%	5%	10%	15%	20%
A	5563	2419	12	0	278	556	834	1113
D	1866		2324	1186	787	387	280	373
I	1233		4361	**1233**	**1233**	**1233**	941	448
H	726		917	0	36	73	109	145
R	702		54	0	35	70	105	140
E	1000		1423	0	50	100	150	200
OF_2				0.770	0.693	0.615	0.481	0.308



Allocation to sectors OF=OF12 (Feb)

Sector	D_{ni} (1000 m^3)	AW (1000 m^3)	NER (US$/1000$m^3$)	Allocated water with minimum demand of				
				0%	5%	10%	15%	20%
A	5563	2419	12	0	278	556	834	1113
D	1866		2324	299	196	187	280	373
I	1233		4361	**1233**	**1233**	1040	760	399
H	726		917	**726**	627	466	289	194
R	702		54	0	35	70	105	140
E	1000		1423	161	50	100	150	200
OF_{12}				0.524	0.484	0.420	0.346	0.262



Equal weights (w_1=0.5 and w_2=0.5) given to both the objectives

Economic returns

Objective Function	OF_1	OF_2	OF_{12}
NER (US$)	2,113,843	8,133,377	6,966,834

As expected, the total economic benefit with compromise solution lies in between the two single objectives

Conclusions

- IWAM is a user-friendly tool for conflict resolution and capable of allocating water among sectors with the objective of
  - Either maximizing satisfaction
  - Or, maximizing NER
  - Or, maximizing both satisfaction and NER
- Applicability is demonstrated with an example
- Analyzes various water allocation problems in water scarce areas
- Useful to water managers and decision-makers in allocating water among user sectors

Water Resources Management (2005) 19: 693–712
DOI: 10.1007/s11269-005-3282-4

A Model for Optimal Allocation of Water to Competing Demands

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Abstract. The present study develops a simple interactive integrated water allocation model (IWAM), which can assist the planners and decision makers in optimal allocation of limited water from a storage reservoir to different user sectors, considering socio-economic, environmental and technical aspects. IWAM comprises three modules—a reservoir operation module (ROM), an economic analysis module (EAM) and a water allocation module (WAM). The model can optimize the water allocation with any of two different objectives or two objectives together. The two individual objectives included in the model are the maximization of satisfaction and the maximization of net economic benefit by the demand sectors. Weighting technique (WT) or simultaneous compromise constraint (SICCON) technique is used to convert the multi-objective decision-making problem into a single objective function. The single objective functions are optimized using linear programming. The model applicability is demonstrated for various cases with a hypothetical example.

Key words: multi-objective decision-making, net economic return, optimization, reservoir operation, simultaneous compromise constraint technique, water allocation, weighting technique

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Optimal allocation of bulk water supplies to competing use sectors based on economic criterion – An application to the Chao Phraya River Basin, Thailand

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SUMMARY

The study develops a model for optimal bulk allocations of limited available water based on an economic criterion to competing use sectors such as agriculture, domestic, industry and hydropower. The model comprises a reservoir operation module (ROM) and a water allocation module (WAM). ROM determines the amount of water available for allocation, which is used as an input to WAM with an objective function to maximize the net economic benefits of bulk allocations to different use sectors. The total net benefit functions for agriculture and hydropower sectors and the marginal net benefit from domestic and industrial sectors are established and are categorically taken as fixed in the present study. The developed model is applied to the Chao Phraya basin in Thailand. The case study results indicate that the WAM can improve net economic returns compared to the current water allocation practices.

1. Introduction

The peril of water scarcity is mainly caused by enduring and extensive overexploitation, pollution and increasing demand of water for economic development. There are instances of demand exceeding water availability leading to conflict among and within water use sectors. This threat may be mitigated by improved water management practices such as efficient allocation of available

marginal value of water for efficient allocation was recognized by Daubert and Young (1981). Noel and Howitt (1982) worked towards an optimal, spatial and intertemporal allocation with hydrologic and economic theories. Different economic approaches like assessing the potential of limited market institutions (Vaux and Howitt, 1984) and allocation with market transfers (Booker and Young, 1994) were developed to alleviate water scarcity. Further studies tried to better integrate allocation problems with eco-

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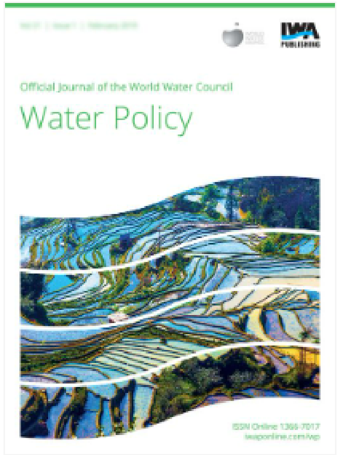

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Article Contents

RESEARCH ARTICLE | MARCH 01 2013

Marginal benefit based optimal water allocation: case of Teesta River, Bangladesh

Md. Reaz Akter Mullick; Mukand S. Babel; Sylvain R. Perret

Water Policy (2013) 15 (S1): 126–146.
https://doi.org/10.2166/wp.2013.004

Views   Share   Tools

This article describes a hydrologic–economic optimization model for allocating available river flow between competing off- and in-stream demands, based on the marginal benefits (MBs) of sectoral water uses in a segment of the Teesta River in Bangladesh. Irrigation, capture fishery and navigation are the main direct water uses considered. The value of irrigation water was estimated using the residual imputation method. Losses in yield caused by lowered irrigation supply, resulting from reduced river flow, formed the basis for establishing the total and MB functions for off-stream river water use (irrigation). Total and MB functions for in-stream water use (capture fishery, navigation) were developed using field survey data of beneficiaries' income as a function of river flow. Analysis was enhanced by applying AQUARIUS, which allocates water between users to maximize consumer surplus based on MB functions. Model results show that in-stream uses could not compete with off-stream uses in the case of the Teesta, as substantial benefit was obtained from irrigation. Environmental flow to safeguard river health and in-stream use was considered to be a constraint in the optimization, which results in a sizeable reduction in irrigation benefit with a small increase in in-stream benefit. The necessary trade-offs between economic efficiency and environmental protection are depicted, providing insight into a justifiable water allocation strategy for the Teesta.

Keywords: Hydro-economic model, In-stream and off-stream uses, Optimal water allocation, Teesta River, Bangladesh, Total and marginal benefit function

Thank you very much

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International Recognition: 2021 Reuters Hot List of 1,000 top climate scientists; 2019 top 2% scientists in the world for research impact; 2021 and 2022 top 2% scientists in the world by Elsevier BV and Stanford University
Experience: 35+ years of teaching, research and consulting
Geographical coverage: South and Southeast Asia

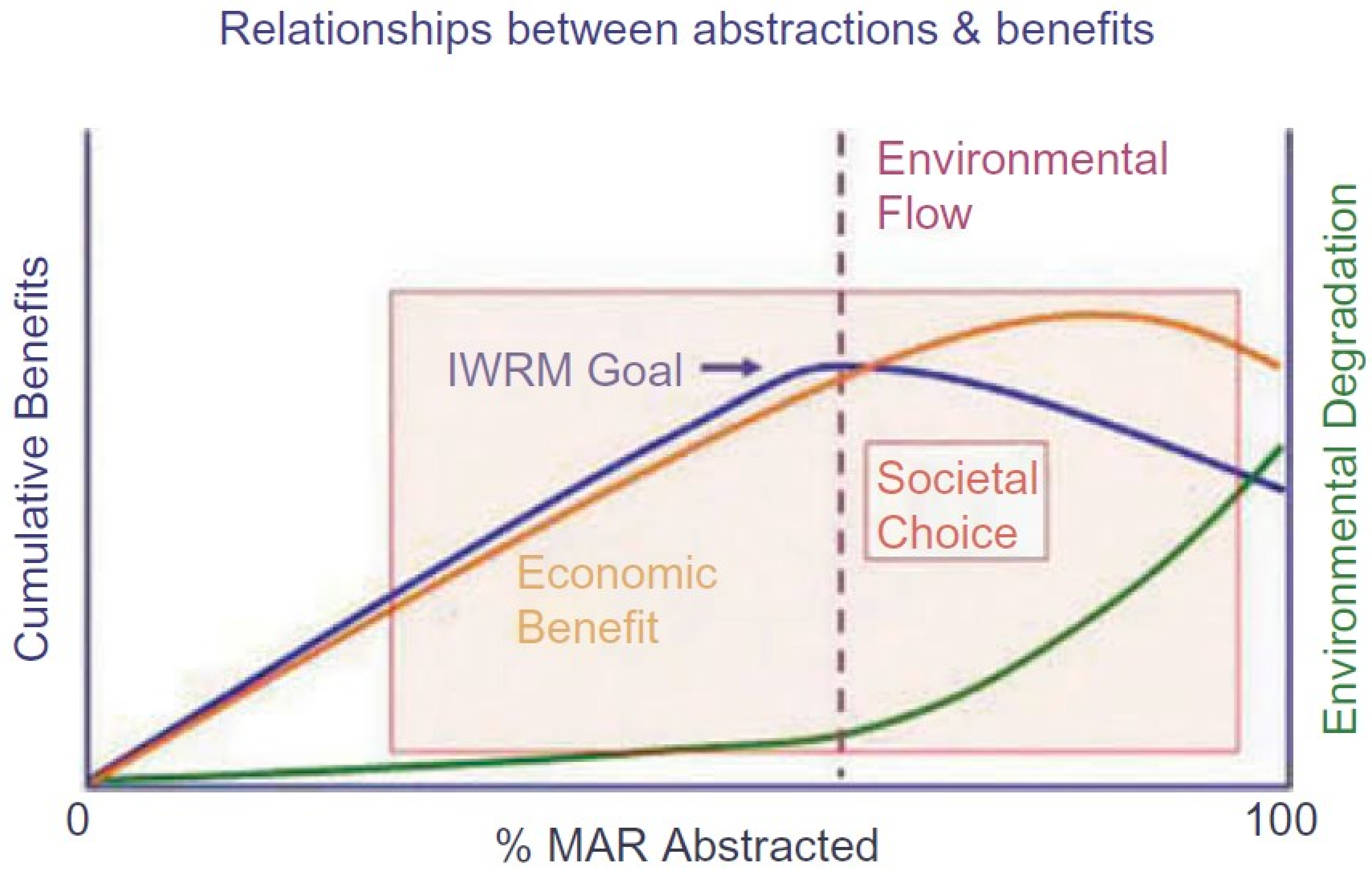
Metrics	Scopus	Google scholar
Articles	185	300
h-index (*i*10-index)	43	51 (129)
Citations	5249	8753

Case study

Socio-economic implications of E-flows

to In- and Off-stream Water Users: A case of Teesta River, Bangladesh

E-flows: Benefits and Tradeoffs



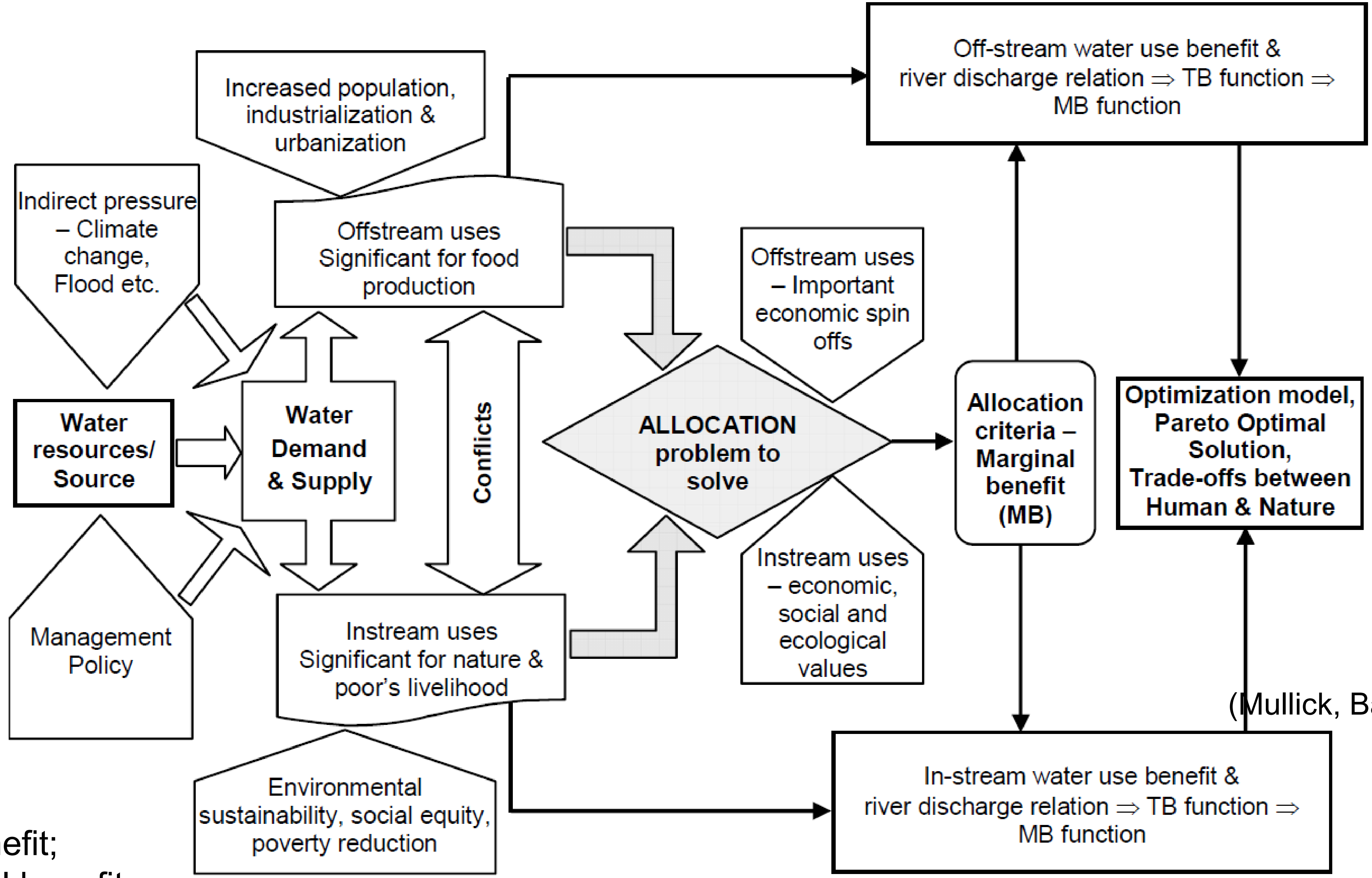
Percentage of mean annual runoff (% MAR) abstracted against cumulative benefits to society and the IWRM goal to maximize benefits as a societal choice (Overton et al. 2014 from Moore and Forslund 2008).

Socio-economic implications of E-flows: Teesta River

Objectives

- To assess the tradeoff while allocating the available flow among the competing off- and in-stream demands using an optimization model
- Marginal value of sectoral water use is applied as the allocation criterion

Conceptual framework for optimum water allocation



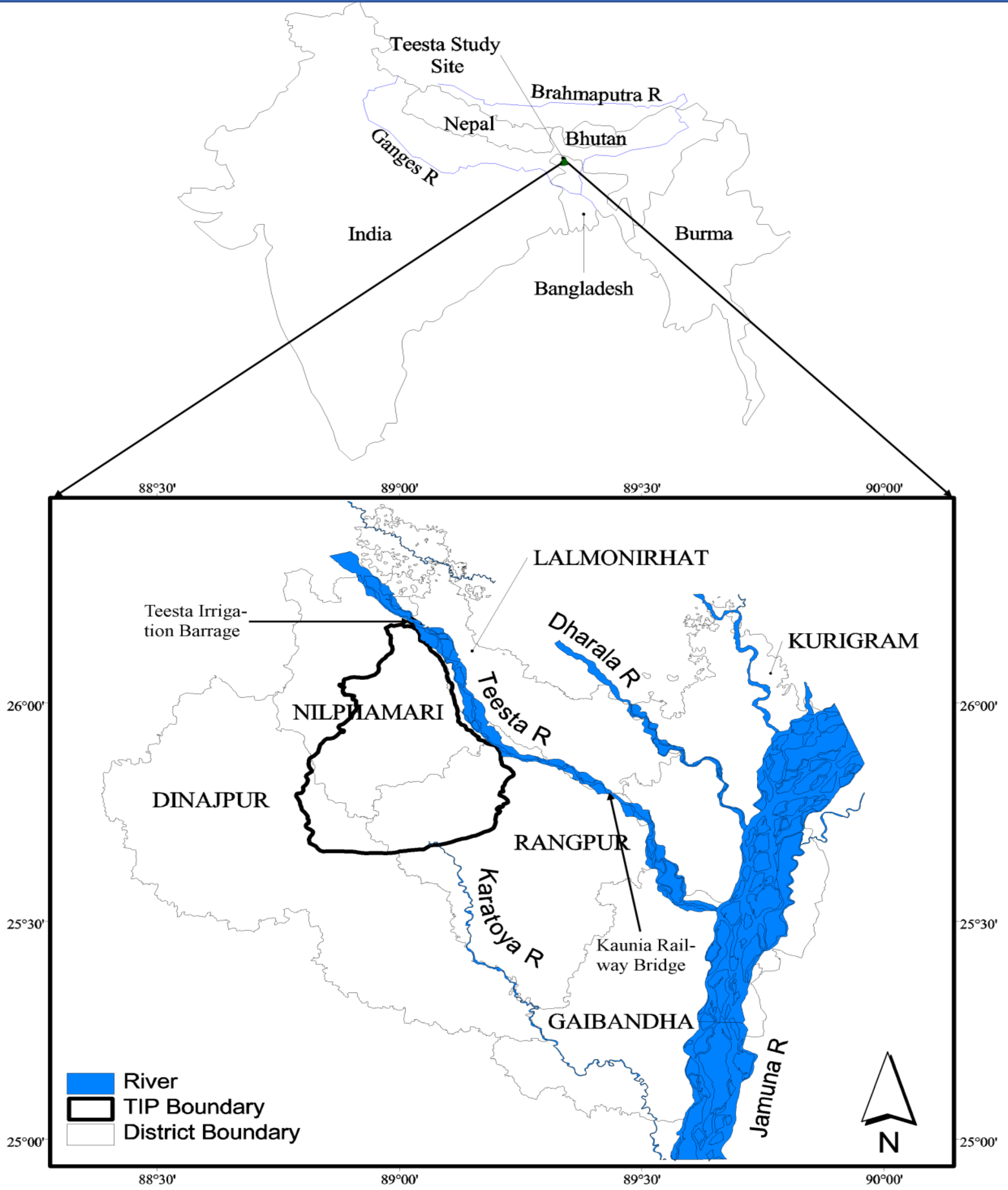
(Mullick, Babel, Perret, 2009)

TB: total benefit;
MB: marginal benefit

Socio-economic implications of E-flows: Teesta River

Teesta River in Bangladesh

- Teesta: 4th main river in BD
- Originated in Sikkim, India
- Enters BD at Chatnai, Nilphamari district
- Length around 113 km in BD
- Draining to the Jamuna
- High seasonal flow variability
- Main source of water for drought-prone NW of BD
- Flow regulated since 1987 when India constructed a barrage
- BD constructed another barrage in 1990 to supply irrigation water to Teesta Irrigation Project (TIP)



Socio-economic implications of E-flows: Teesta River

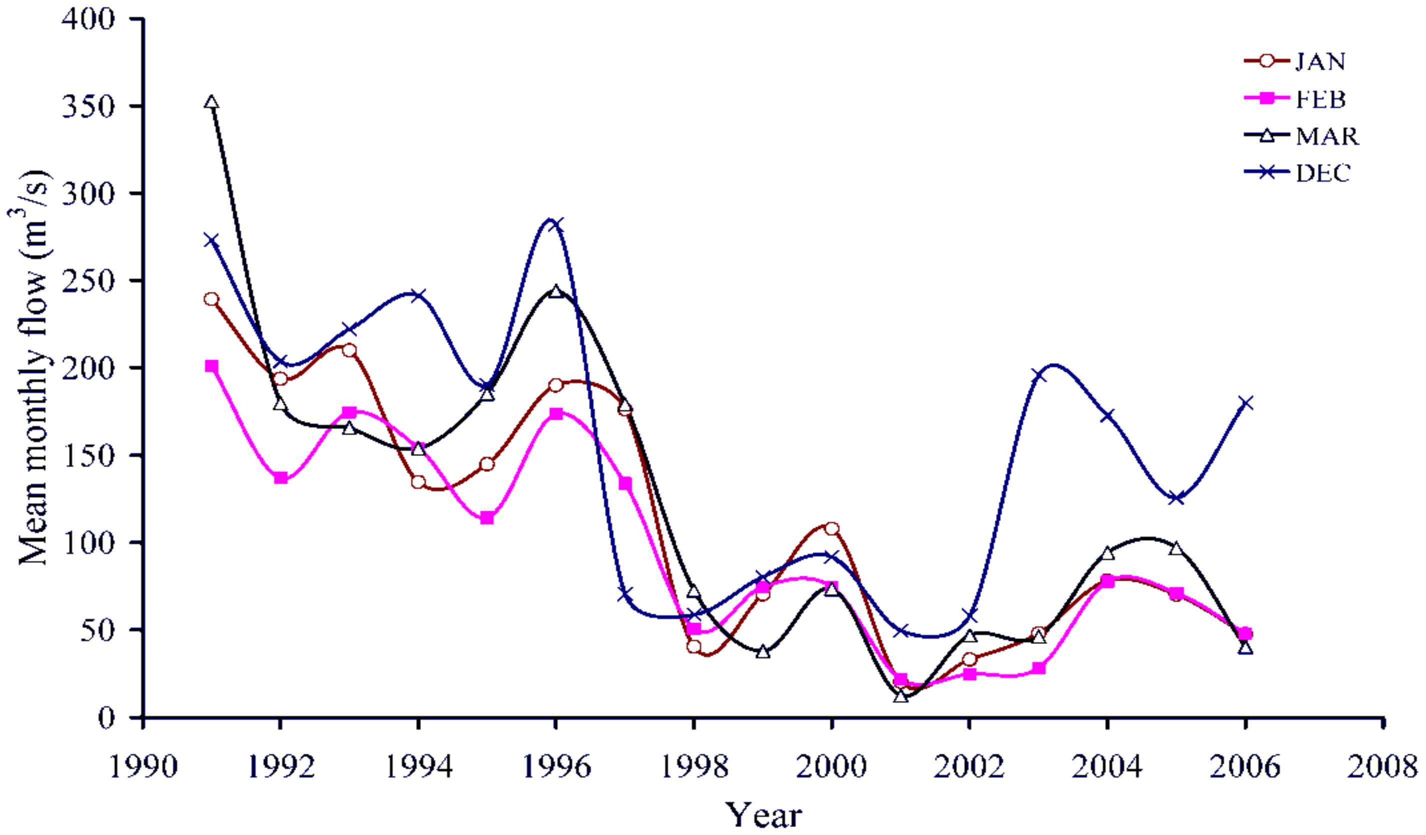
Water uses in the Teesta

- The river supplies water to TIP
  - Irrigated area 111,732 ha; right side of Teesta, only one diversion point
  - Monsoon rainfall, >90% in May to Oct, Irrigation required for Nov to Apr
  - No return flow to Teesta
- In-stream uses are
  - Capture fishery
  - Small scale navigation
- In-stream uses are livelihoods for a large part of riparian poor

Socio-economic implications of E-flows: Teesta River

WRM for Teesta

- Drastic flow reduction in the Teesta observed
- Alarming situation for both agriculture and in-stream users
- In-stream water requirements set forth in different management plans based on crude judgment only
- Therefore, water allocation between off- and in-stream uses is a critically important issue



Flow above the Teesta Barrage

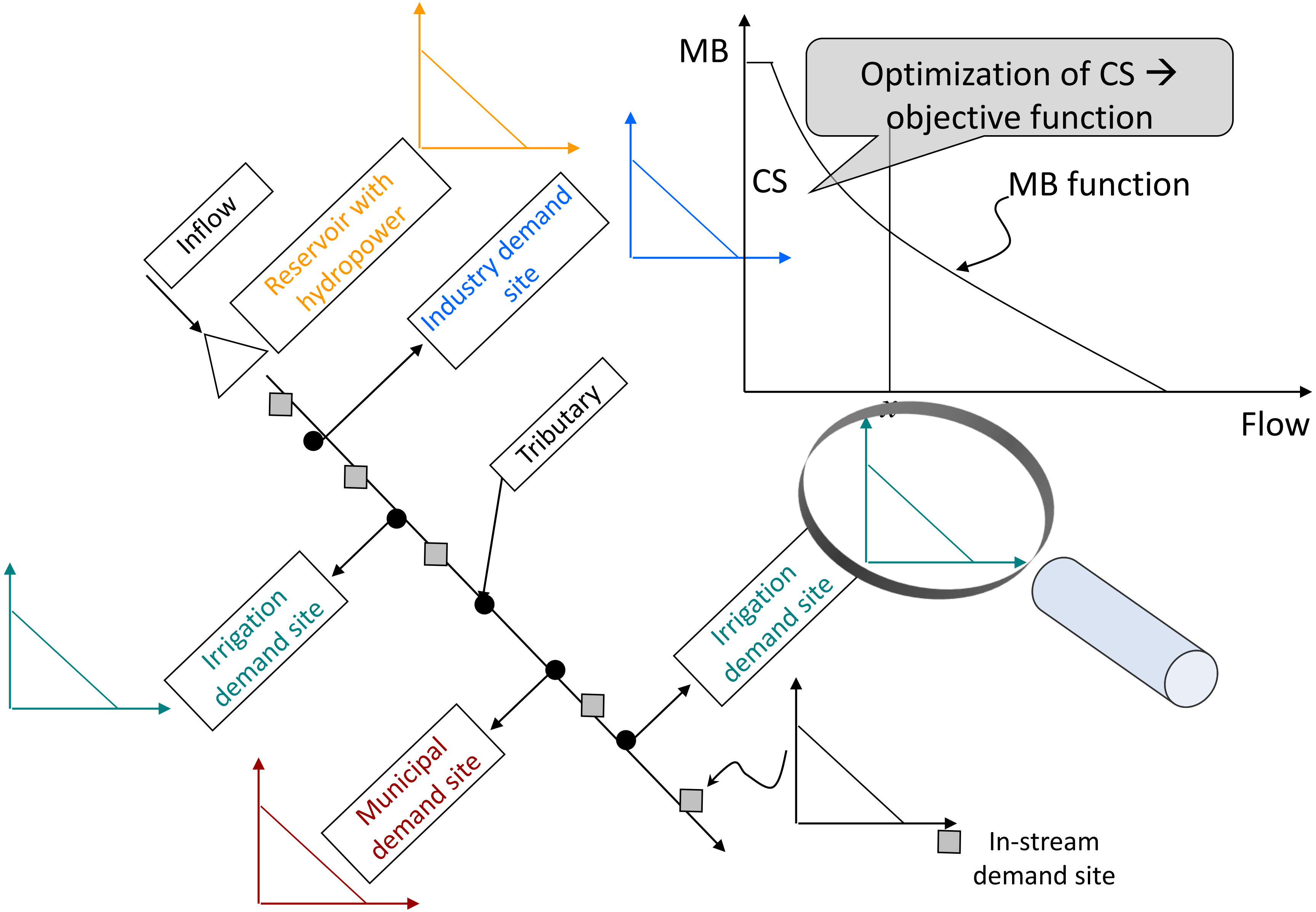
Socio-economic implications of E-flows: Teesta River

Methods

- A hydro-economic modeling approach
- Three module: economic, hydrologic and optimization
- Economic module establishes MB function for water uses
- Model schematized as a node-link network
  - Nodes represent the demand sites and links represent the linkage between river reaches for hydrologic simulation
  - Flow balances are calculated for each node at each time period
- Consumer surplus of each water use maximized in the optimization module from the pre-established MB functions
- Monthly EF requirements are estimated using IHA software and considered as constraint

Socio-economic implications of E-flows: Teesta River

Methodology



Socio-economic implications of E-flows: Teesta River

Economic module

- Establishes the relationship between stream flow and net economic benefit from each water-use
- A quadratic relationship with respect to stream flow is considered as the total benefit (TB) function for river water use
- TB function metaphors a production function

$$TB_u = \beta_0 + \beta_1 * flow_i + \beta_2 * {flow_i}^2$$

- The first order derivative of the TB function with respect to *flow* gives the marginal benefit (MB) function

*TB*u is the total benefit of any sectoral water use at a flow level *i*, *β0* is the constant, *β1*, *β2* are the coefficients; "flow" indicates mean monthly stream flow (m^3s^{-1})

Estimating TB & MB for irrigation

- First estimated IWR for rice using water balance approach
- CROPWAT 4.3 for other dry season crops
- Irrigation water benefit is estimated by residual imputation method

$$TVP = \sum_{i} VMP_i * Q_i + VMP_w * Q_w$$

- A water-crop production-function is used to establish the TB function
  - estimating the crop yield in relation with varying level of assumed water shortage

TVP is the total value of the commodity produced; *VMPi* is the value of marginal product of input *i*; *Qi* indicates the quantity of input, *i* used in production; w for irrigation water

Socio-economic implications of E-flows: Teesta River

Estimating TB & MB for instream uses

- The concept of flow-habitat-fish production relation employed for valuing water for fishery in the Teesta
- Individual fishermen income data obtained from primary survey provided the basis to form TB
- Value of the fish production is considered equal to fishermen income for a certain time period
- The boatmen income is considered as the gross benefit from navigation
- Only short-run benefit is estimated, operating cost is considered negligible

Hydrologic and optimization module

- Hydrologic module is embedded with optimization module with the flow balance at each node in the river network

$$Flow_{d/s,t} = Flow_{u/s,t} - withdrawal_t + \Delta Q_t$$

- Objective function for optimization module

$$\begin{aligned} Max\_Obj &= \sum_m CS_{o\_s} + \sum_n CS_{i\_s} \\ &= \sum CS_{irr} + \sum \left(CS_{fish+nav}\right) \end{aligned}$$

  - Where *CS* is the consumer surplus, *o_s* and *i_s* represent respectively the summation of the spatially distributed all off-stream (m) and in-stream (n) use sectors
- The optimization is subjected to hydrological, and EF requirement constraints

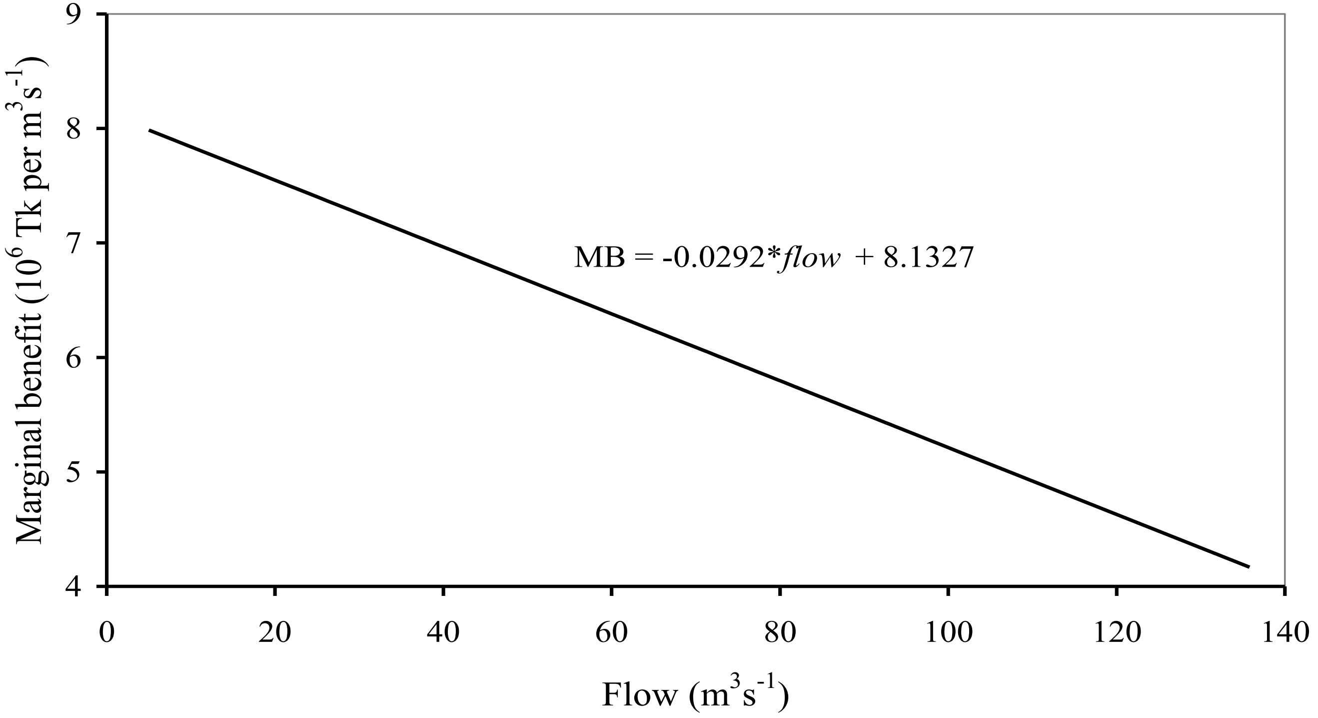
Solution of the optimization problem

- “AQUARIUS” used to solve optimal water allocation problem
- Considers temporal and spatial allocation of flows among in- and off-stream water uses in a river basin
- Aquarius considers the economic efficiency criterion i.e. reallocating of stream flows until the net marginal returns in all water uses are equal
- Optimization problem is solved using sequential quadratic programming (SQP)

Results - Irrigation water use benefit function

- Max water requirement 1890 mm ≈ 136 m^3/s
- Max benefit 587 million Tk per month
- The TB function

$$TB_{irr} = -0.0146 * flow^2 + 8.1327 * flow - 247.97$$



MB function for Irrigation water use

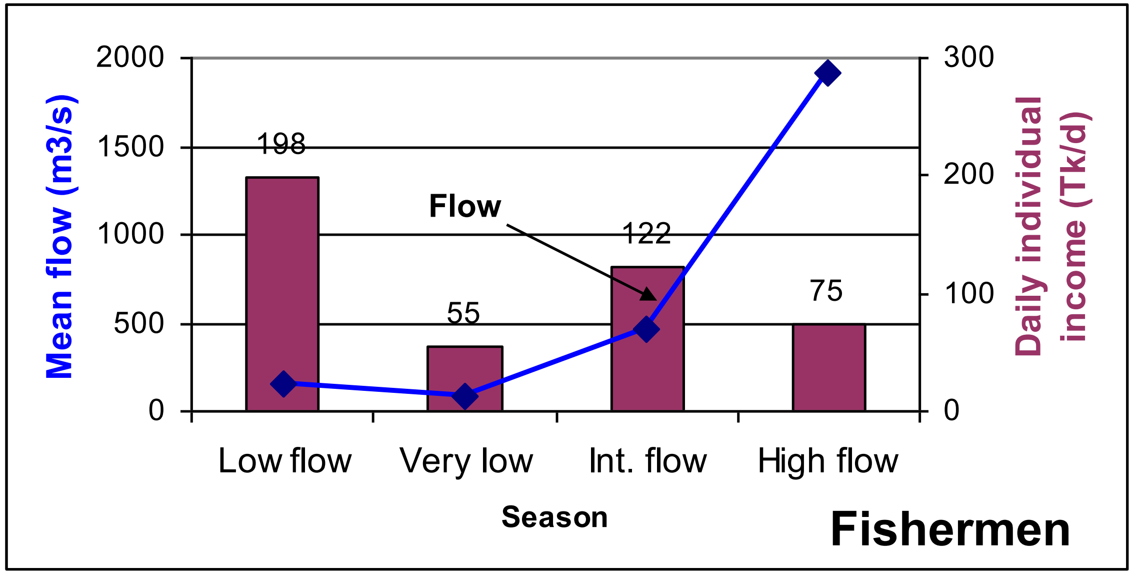
Socio-economic implications of E-flows: Teesta River

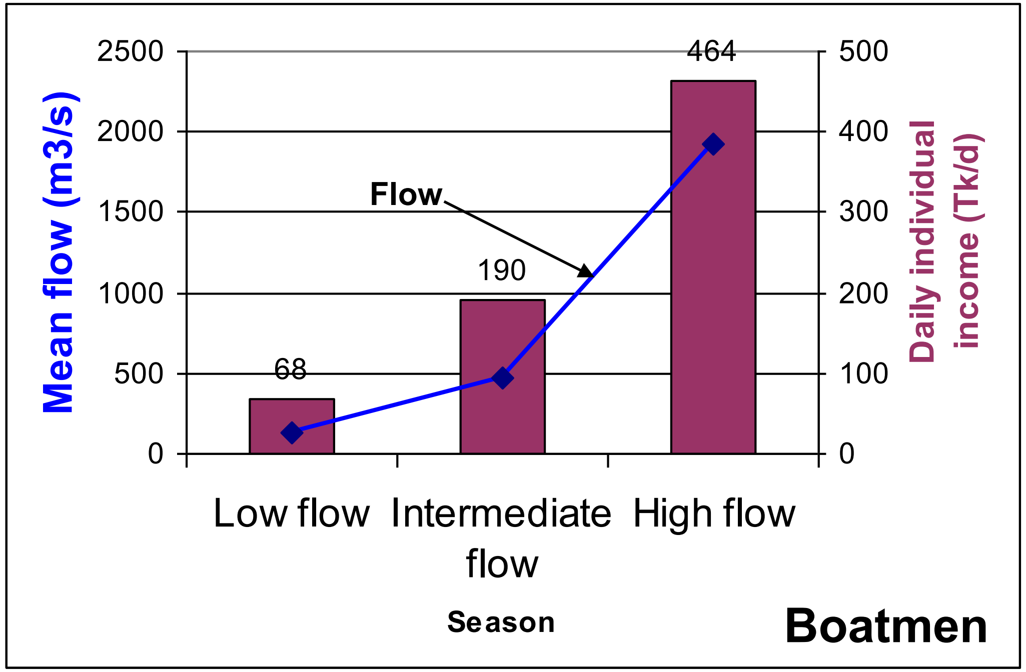
Estimating TB & MB for in-stream water use

- Respondents identified 3 seasons/year while answering the questions related to income:
  - Dry or low flow (Dec to Mar),
  - Wet or high flow (Jun to Sep) and
  - Intermediate flow season (Apr, May, Oct and Nov)
- Average daily income in a season of an individual is considered uniform over the entire season
- For boatmen
  - Highest income in high flow season and the lowest in the dry season
- For fishermen
  - Dry season is favorable and wet season is not favorable

Socio-economic implications of E-flows: Teesta River

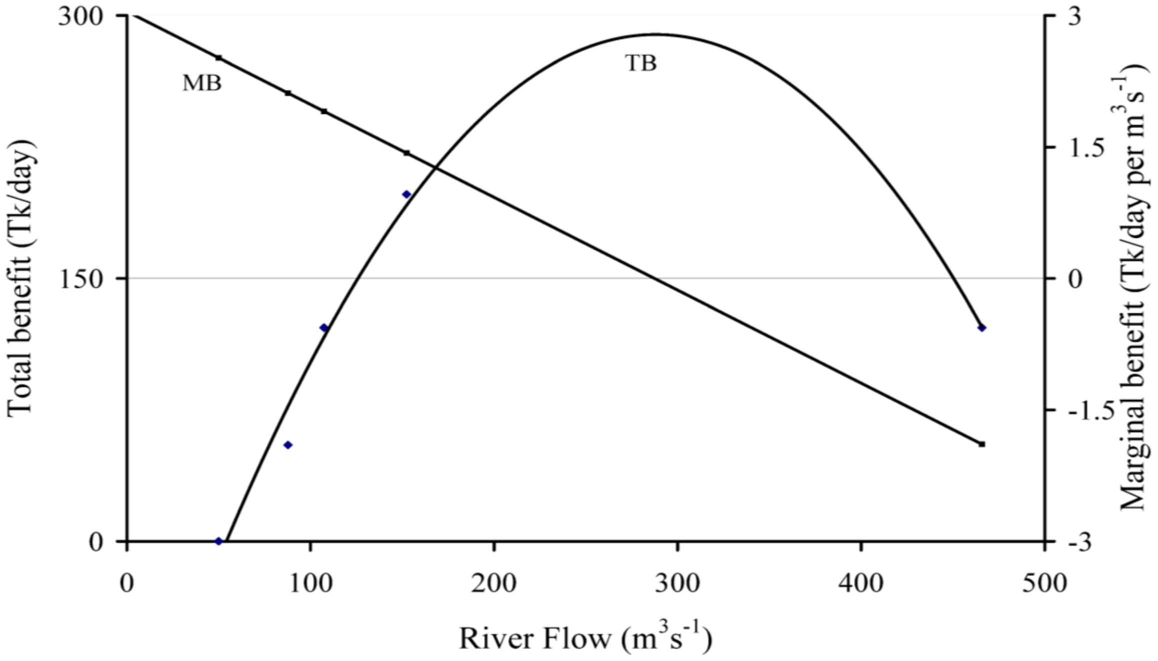
Income pattern for boatmen and fishermen





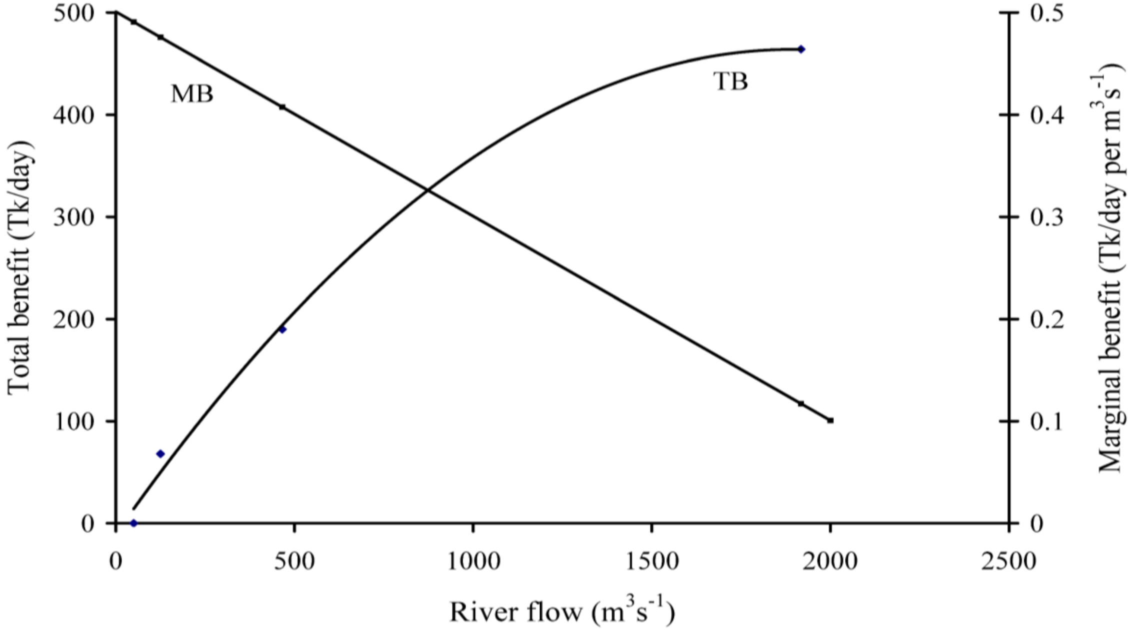
Socio-economic implications of E-flows: Teesta River

Benefit function of instream water uses



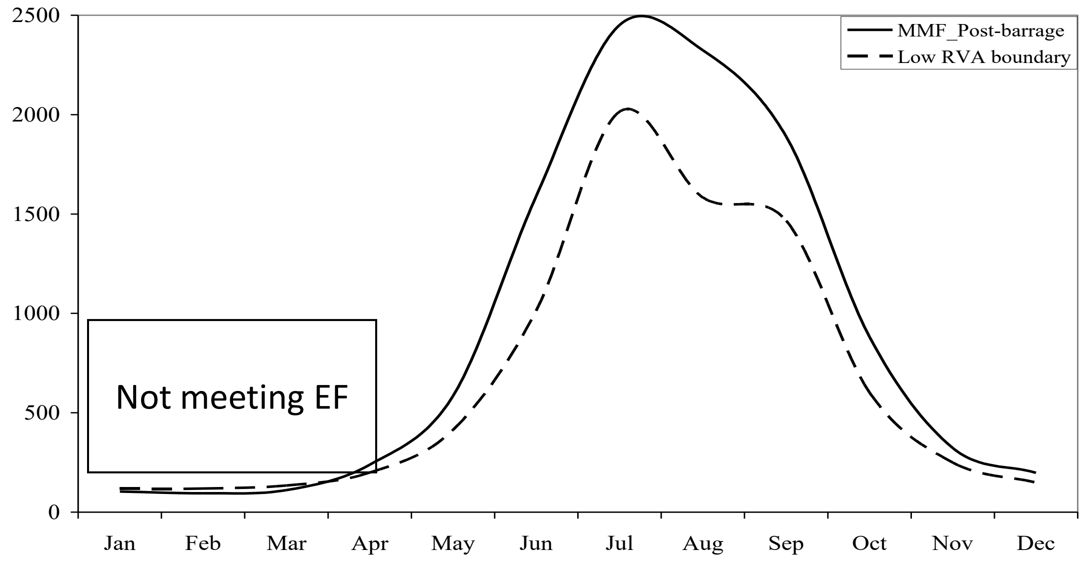
TB & MB for navigation

TB & MB function for instream fishery



Socio-economic implications of E-flows: Teesta River

Benefit from water allocation & Tradeoff



Flow at downstream of Teesta

Benefits obtained in water allocation without and with provision of EF

	Total Irri supply (mm)	Irri benefit (10^6 US$)	Instream benefit (10^6 US$)	Total benefit (10^6 US$)
Without EF	**1,637**	**43.242**	**0.588**	**43.830**
With EF	**1,325 (↓19%)**	**33.893 (↓ 22%)**	**0.690 (↑ 17%)**	**34.583 (↓ 21%)**

Socio-economic implications of E-flows: Teesta River

Discussion and Conclusion

- Off-stream benefits observed considerably higher than in-stream benefits for Teesta case; however,
  - In-stream flow is critically important for local and regional socio-economy
    - In-stream flow provides livelihood to 1,000 people without requiring massive capital investment nor O&M cost
    - In contrary irrigation project needs massive investment and O&M cost
  - Even allowing minimum EF helps sustaining livelihood of local people, which eventually leads to pro-poor water management
- Cost of water allocation with environmental or river health protection is about 9.25 million US$ annually
  - However, indirect and non-uses benefits of in-stream water have not been accounted

Socio-economic implications of E-flows: Teesta River

Discussion and Conclusion

- Arguing for e-flow as in-stream is in fact indicative of the resistance to allow water for in-stream uses. Consequently,
  - River ecosystems struggle with low flow and ultimately decline, which subsequently affects both the poor's livelihood and the environment
- TIP provides livelihood to around 0.3 million farmers which indicates per capita income of 0.4 $ daily whereas per capita per day income of in-stream (direct) users is 1.61 $
  - Such figures will help realizing the actual value of water for each use and subsequently guarantee river flow for all uses
- Indirect benefits usually drawn from EF (biodiversity value, socio-cultural value, river ecosystem services etc.) are not considered
  - Those may generate high benefits to society and change drastically the diagnosis on EF socio-economic scope, magnitude and impact

Way forward

- Environmental flows must have clear objectives and scenarios built on multi-stakeholder consensus
- The success or failure to mainstream environmental flows in water management will depend on whether it has a place in national legislation
- Establishing adaptive management, based on a 'learning by doing' approach is a critical aspect of environmental flows
- Environmental flows will only ensure a healthy river if they are part of a broader package of measures on a river basin scale
- A pilot study may be taken up for data collection and field work to assess the socio-economic impacts/benefits

Greater Mekong Subregion Sustainable Agriculture & Food Security Program

Food and Agriculture Organization of the United Nations

Session 2: Water accounting to lay foundation for managing water security

Water accounting in the 3S and 4P Basins

Dr Srinivasan Ancha

Principal Climate Change Specialist, Southeast Asia Regional Department (SERD), ADB

“Water Accounting in Karnataka, India”

- Pathway to Water Secure future

Dr P Somasekhar Rao
Director (Technical)

Water accounting in the GMS - Policy implications for water, food and energy security in a changing climate

4th July 2023

Advanced Centre for
Integrated Water Resources Management (ACIWRM)
Water Resources Department, Government of Karnataka

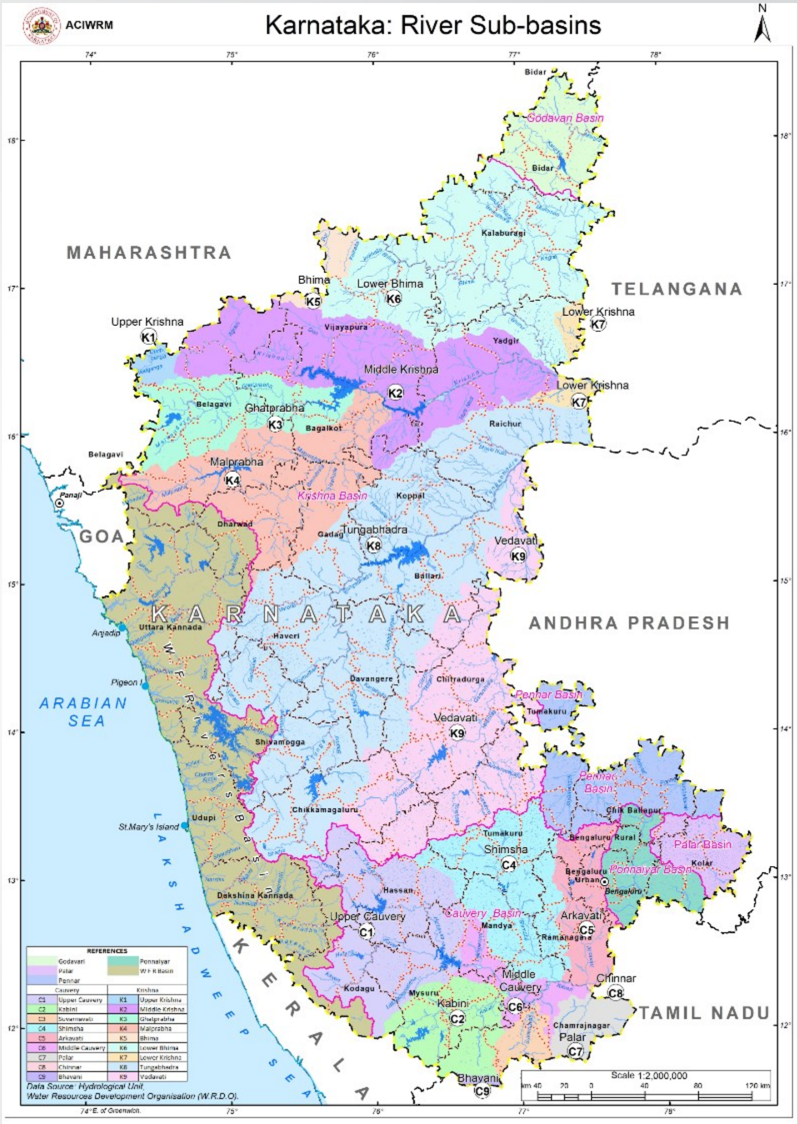
India – Overlaid with Krishna Basin Map

Karnataka – Overview Water Resources

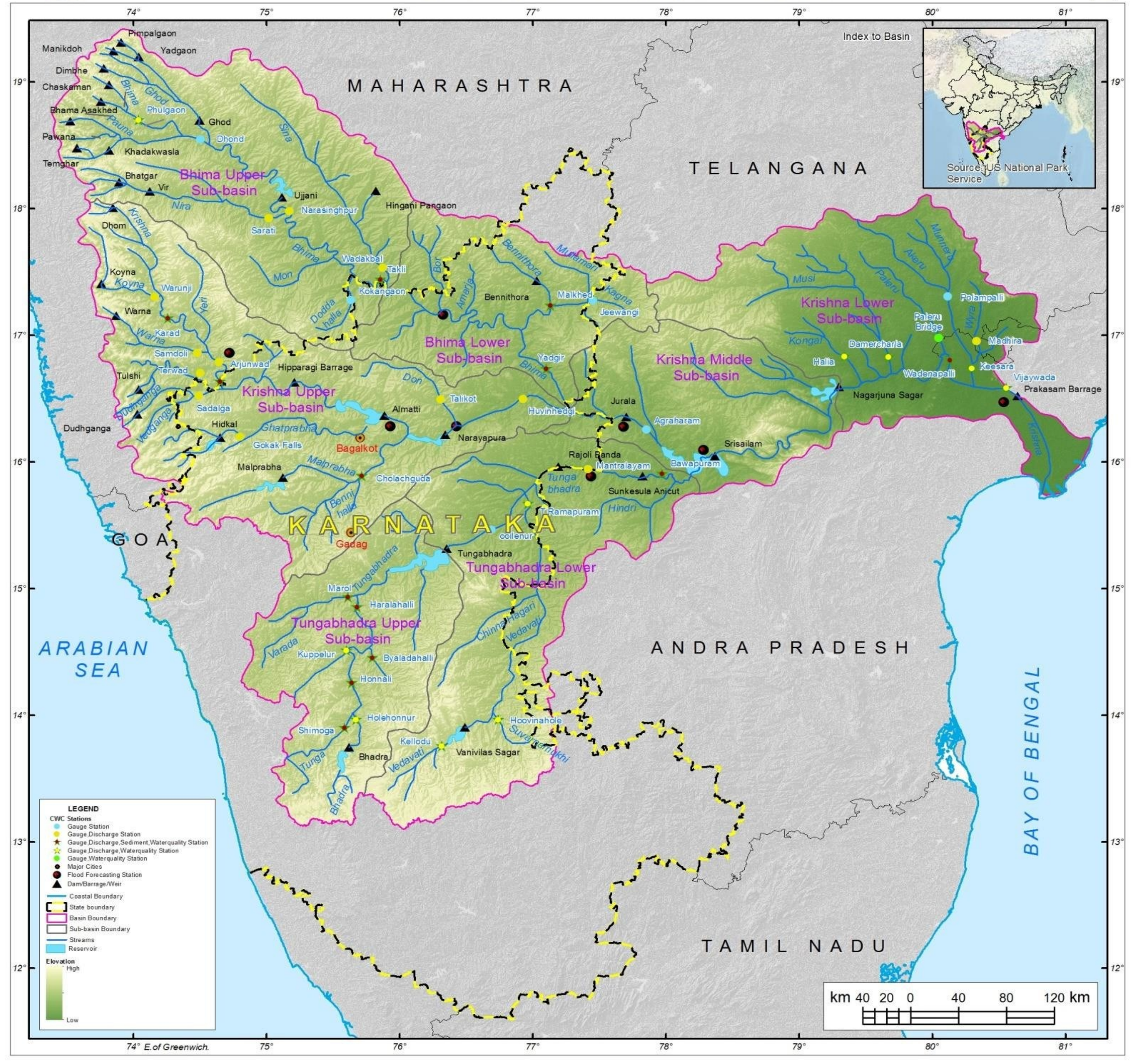
Seven (7) major basins

and

Divided into several sub-basins

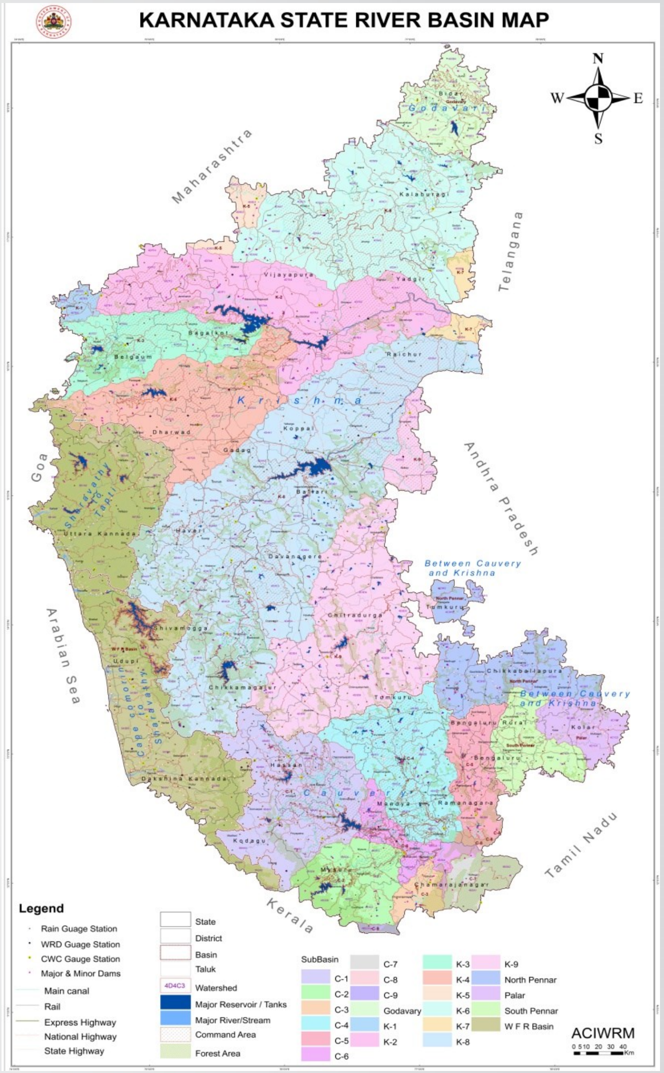


Karnataka:Krishna Basin



Water Accounting & Remote Sensing Tools – Karnataka's Journey

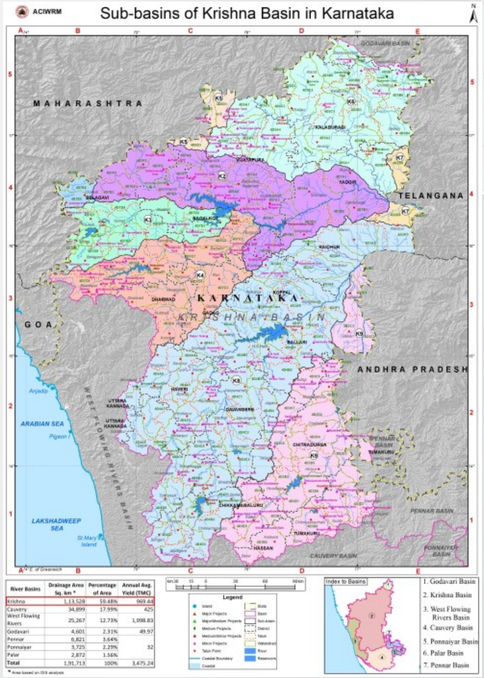
- ADB supported program – KISWRMIP – 2014
- Partnership with IHE, Delft, The Netherlands – 2016
- Introduction workshop on Water Accounting & RS tools - 2017
- Capacity Building of WRD Engineers by IHE faculty
  – 2017 / 2018 / 2019
- Water Accounting of Tungabhadra sub-basin - 2018
- Creation of ET maps for Karnataka State for 2000 – 2014 (15 yrs) – first time ever
- Water Accounting of other sub-basins (K2, K3 & K4) in Krishna sub-basin in Karnataka State – 2019 / 2020



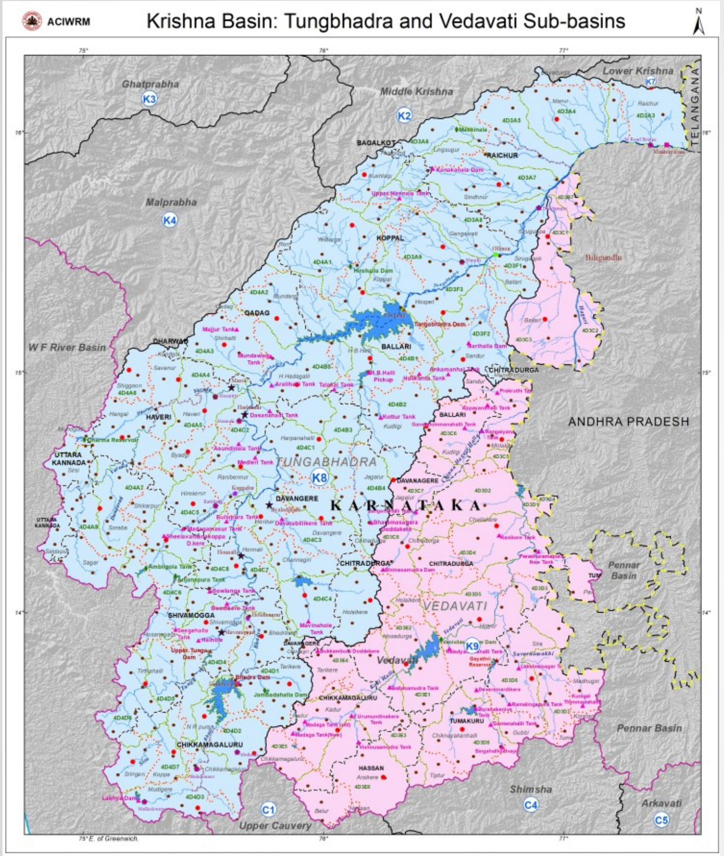
Water Accounting +: 4 sub-basins assessed in Karnataka, India

- First on pilot basis the Water Accounts were done for Tungabhadra (K-8) sub-basin of Krishna basin

- Then further developed Water Accounts for three river sub-basins in Karnataka – Middle Krishna (K2), Ghataprabha (K3) and Malaprabha (K4) sub-basins
  - all part of the larger Krishna basin in India

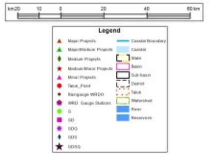


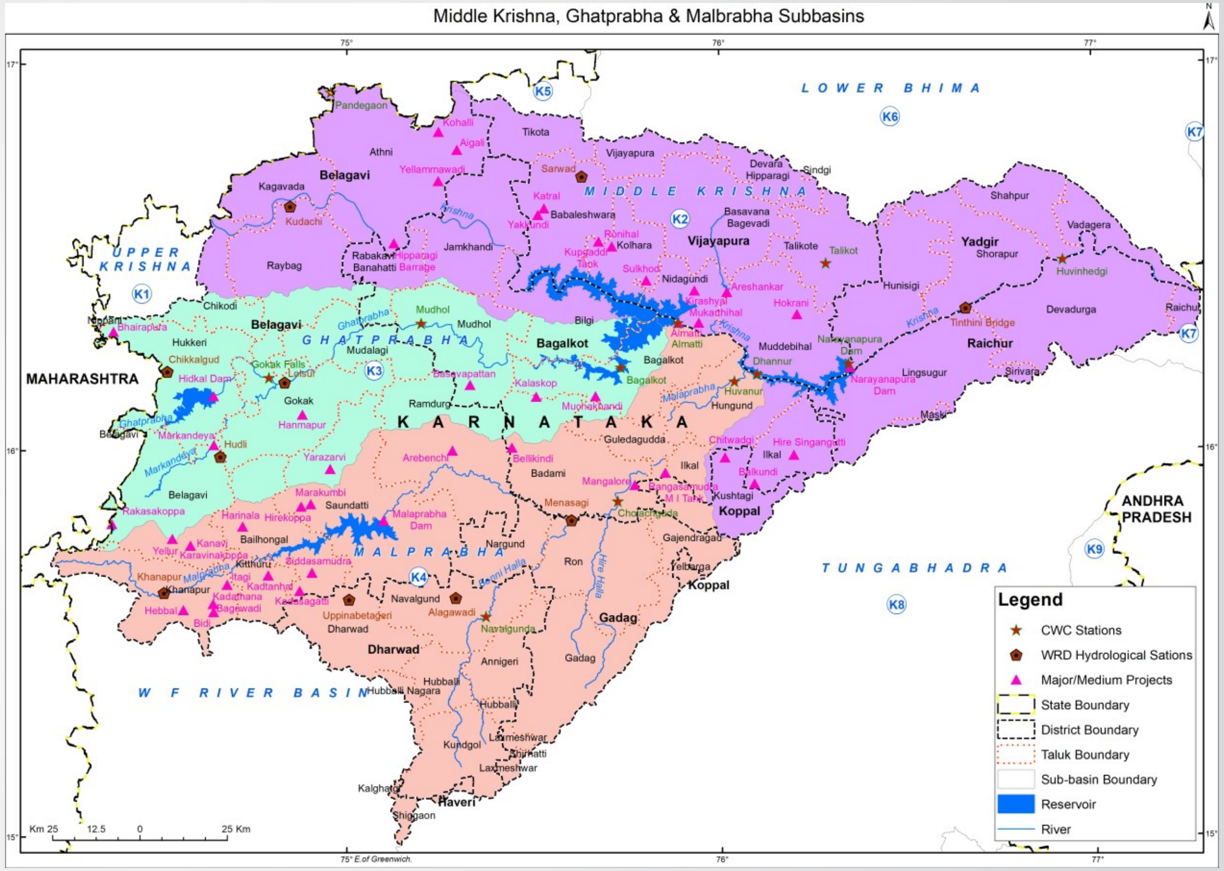
Water Accounting + 4 Sub-basins – Karnataka's Journey



Sub-basin Name	Sub-basin Code	Drainage Area* sq.km	Percentage of Area	Population in Million
Upper Krishna	K1	821	0.72%	0.4
Middle Krishna	K2	15,829	13.93%	3.87
Ghatprabha	K3	6,833	6.02%	2.76
Malprabha	K4	11,780	10.38%	3.09
Bhima	K5	1,256	1.11%	0.27
Lower Bhima	K6	18,100	15.94%	4.13
Lower Krishna	K7	1,393	1.23%	0.38
Tungabhadra	K8	39,106	34.45%	10.07
Vedavati	K9	18,409	16.22%	4.13
	Total	1,13,528	100%	29.10

*Area based on GIS analysis.

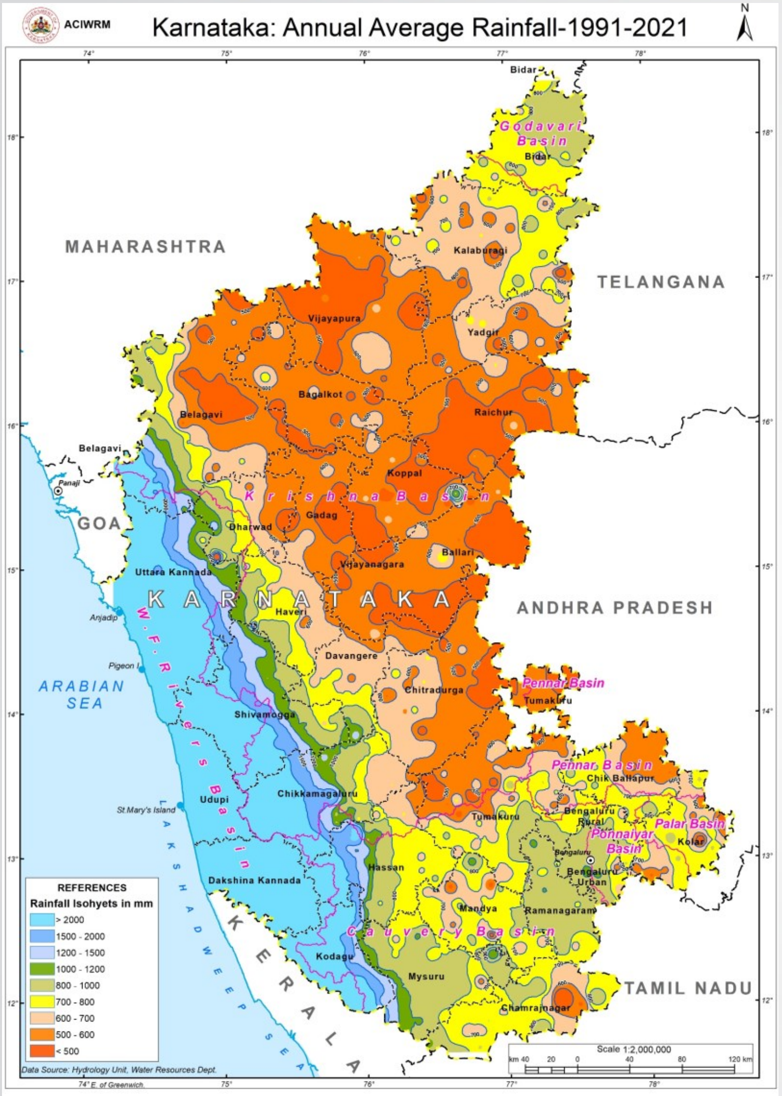




EMERGING CHALLENGES - WATER RESOURCES

- ✓ Ambitious economic growth models – water intensive
- ✓ Ever increasing demand for energy, food & urban agglomerates
- ✓ Increase in frequency of floods & droughts – low resilience
- ✓ Shrinking aquifer storages due to over dependance on groundwater
- ✓ Distorted river flow regimes
- ✓ Altered/reduced groundwater recharge – change in land use

Average (30 years) Annual Rainfall(1991-2021)



Rainfall in mm	Area in Sq.km	Area in %	Cumulative %
>2000	27,629	14.41	
1500-2000	4,497	2.35	18.83
1200-1500	3,995	2.08	
1000-1200	4,977	2.60	14.00
800-1000	21,839	11.39	
700-800	29,581	15.43	
600-700	29,365	15.32	67.17
500-600	47,798	24.93	
<500	22,055	11.50	
Total	**1,91,741**		

Average rainfall of 750 mm heightens the susceptibility to drought;

In Karnataka 67% area falls in this category

How much is the water use?

Which sector is consuming how much?

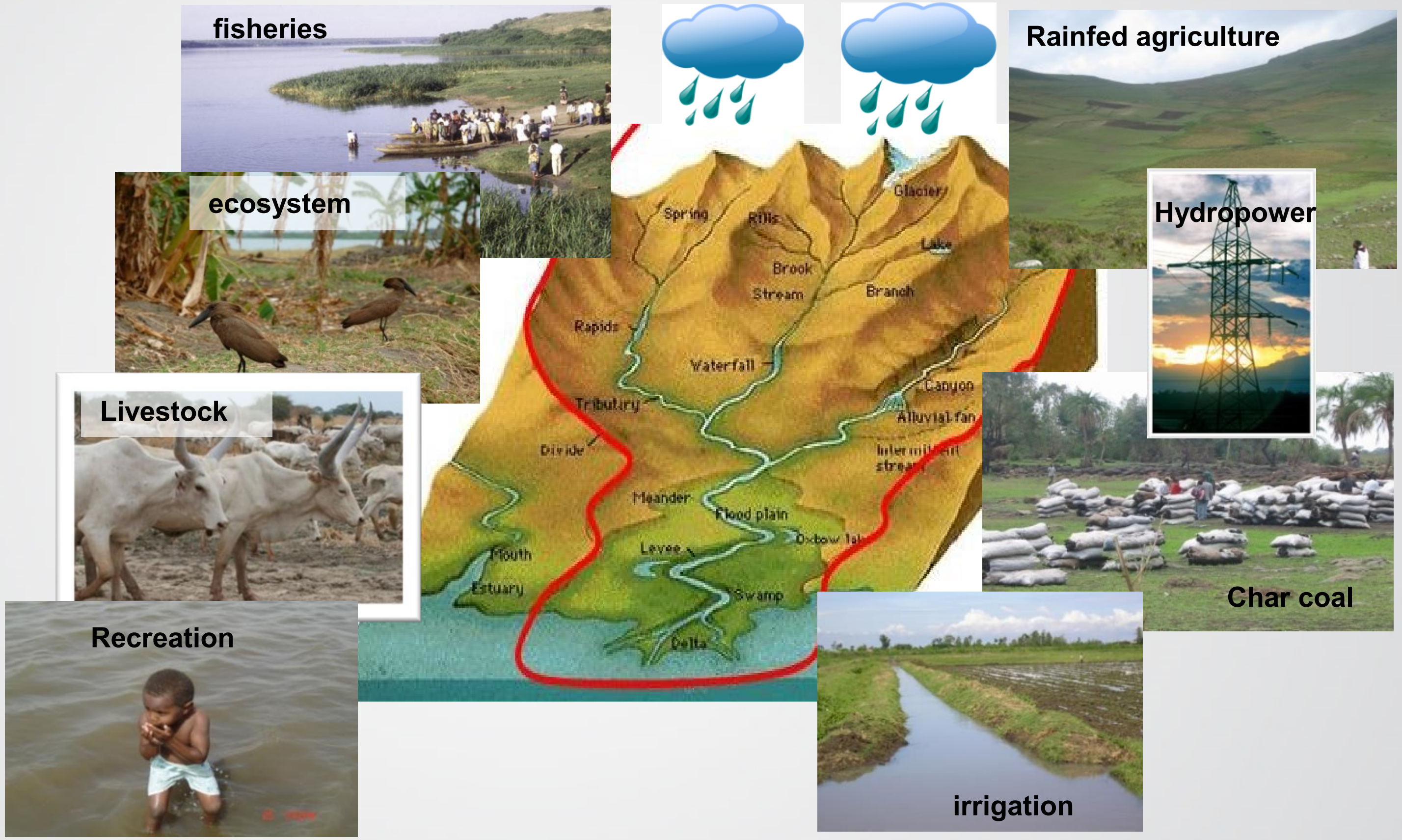
Demand v.s. Supply

Consumptive
Non-consumptive use

Water Security –

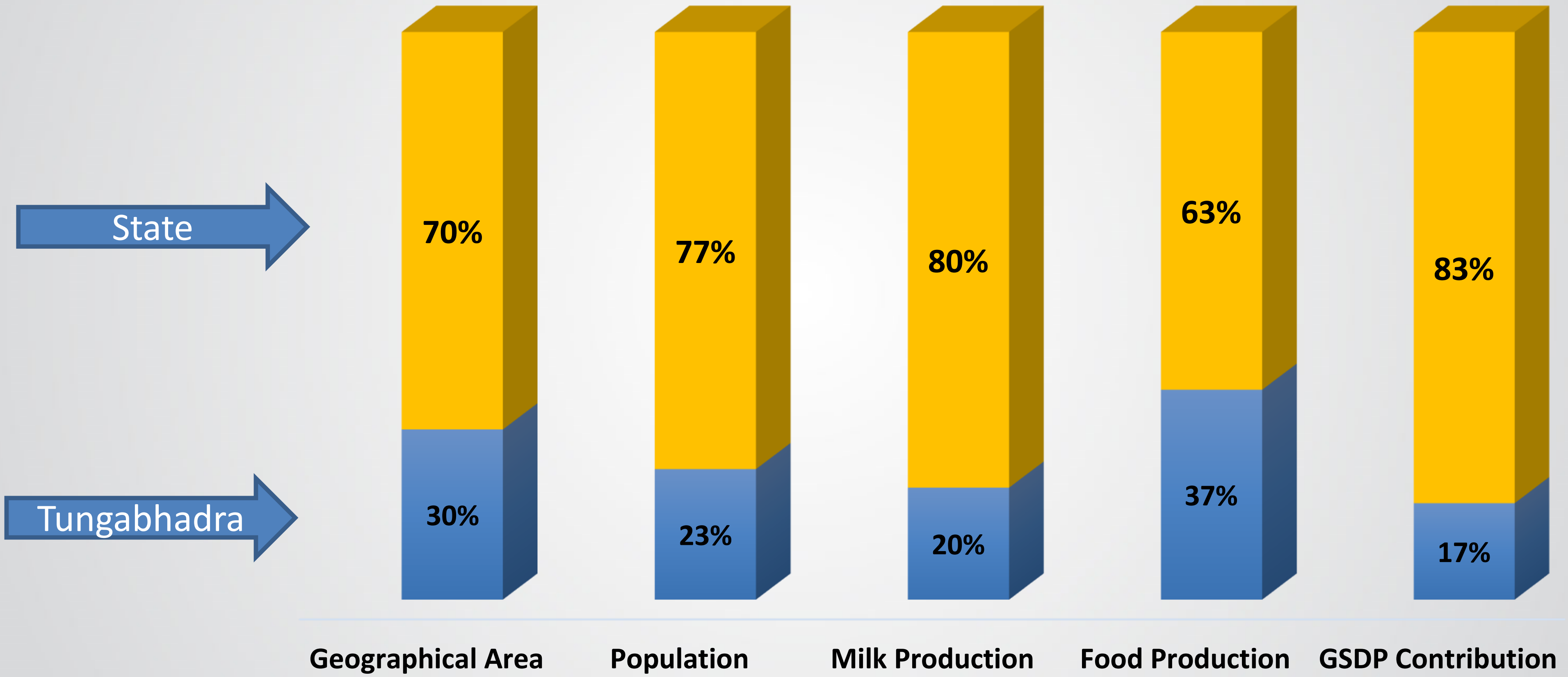
Key for Food and

Economic security



Significance of Tungabhadra Basin in Karnataka

The average per capita income is **Rs. 61,756** /- (as per constant prices 2019-20)



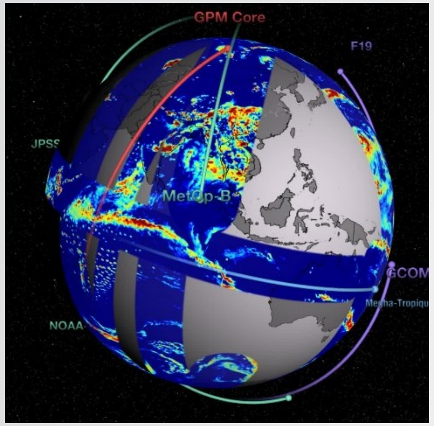
Karnataka – moving towards River Basin Planning

ACIWRM has completed a number of activities related to the preparation of the River Basin Plans:

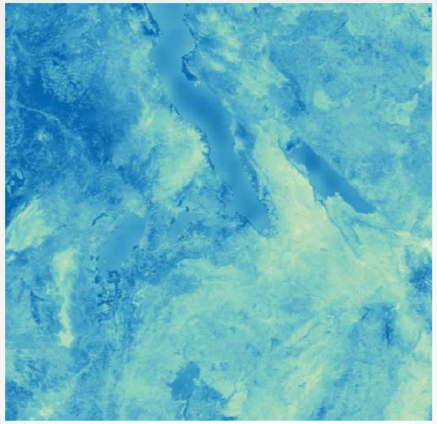
- River Basin Profile of each Sub-basin – an Inventory of basins;
- Studies to Enhance River Basin Profile;
  - Water Quality, River Health
- Economic Analysis of River Sub-basin;
- Water Accounting+ and Water Use Productivity Studies;
- River Basin Modeling; Climate Change Modelling scenarios
- River Basin Planning & River Basin Governance

WA+ Key components in water accounts

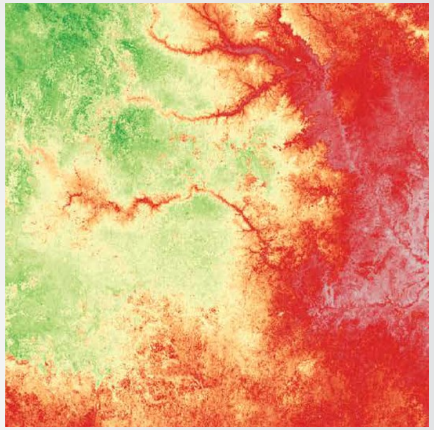
Rainfall



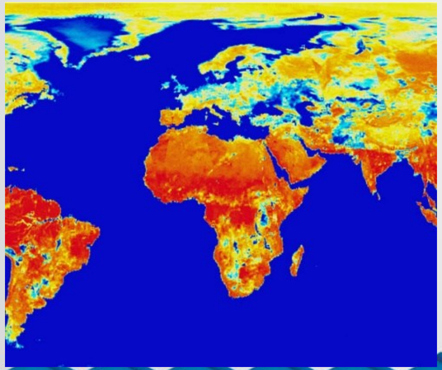
Evapotranspiration



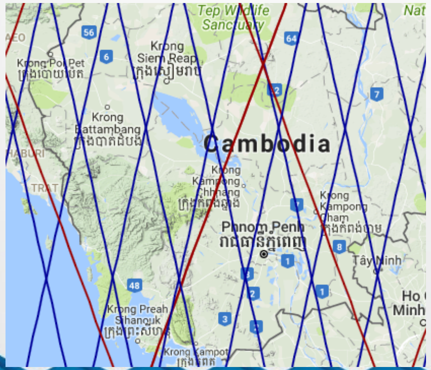
Biomass



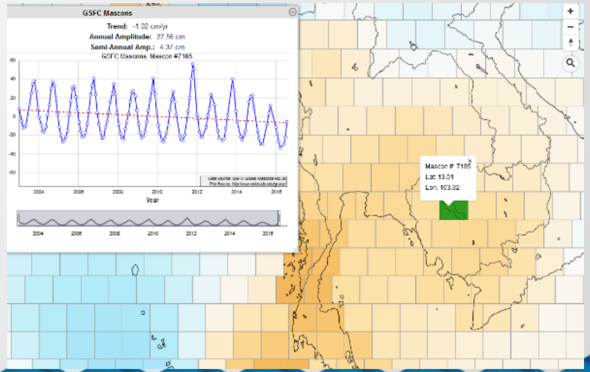
Soil Moisture



Water Levels

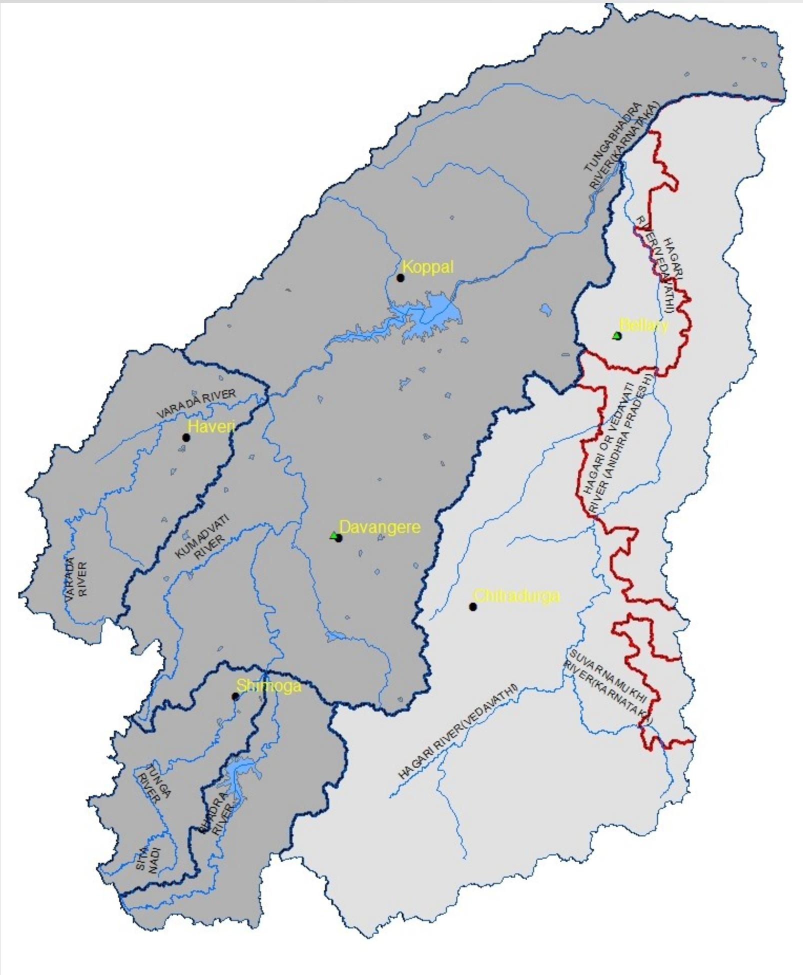


Groundwater



Rainfall, GPM: NASA Goddard Space Flight Center from Greenbelt, MD, USA [Public domain]
Evapotranspiration, and biomass WaPOR: FAO, IHE-Delft.WaPOR quality assessement
Soil Moisture, SMAP: NASA/JPL-Caltech/GFSC. https://www.jpl.nasa.gov/spaceimages/details.php?id=PIA18057

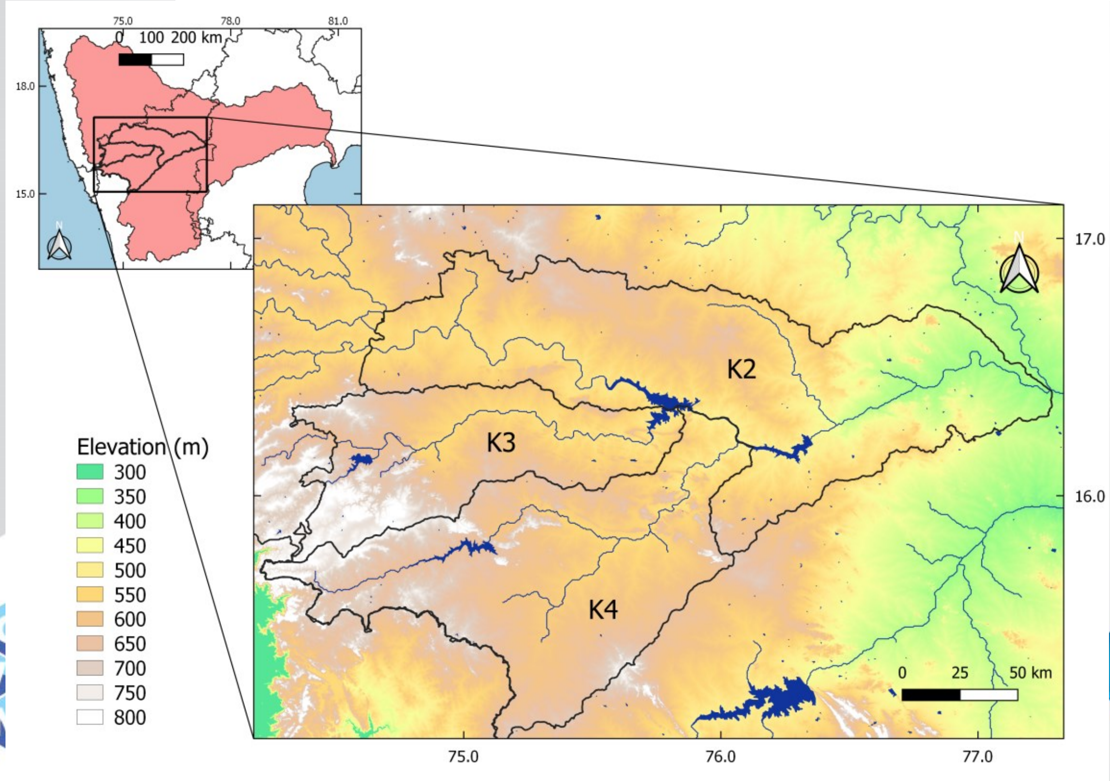
Major Rivers of the Tungabhadra basin

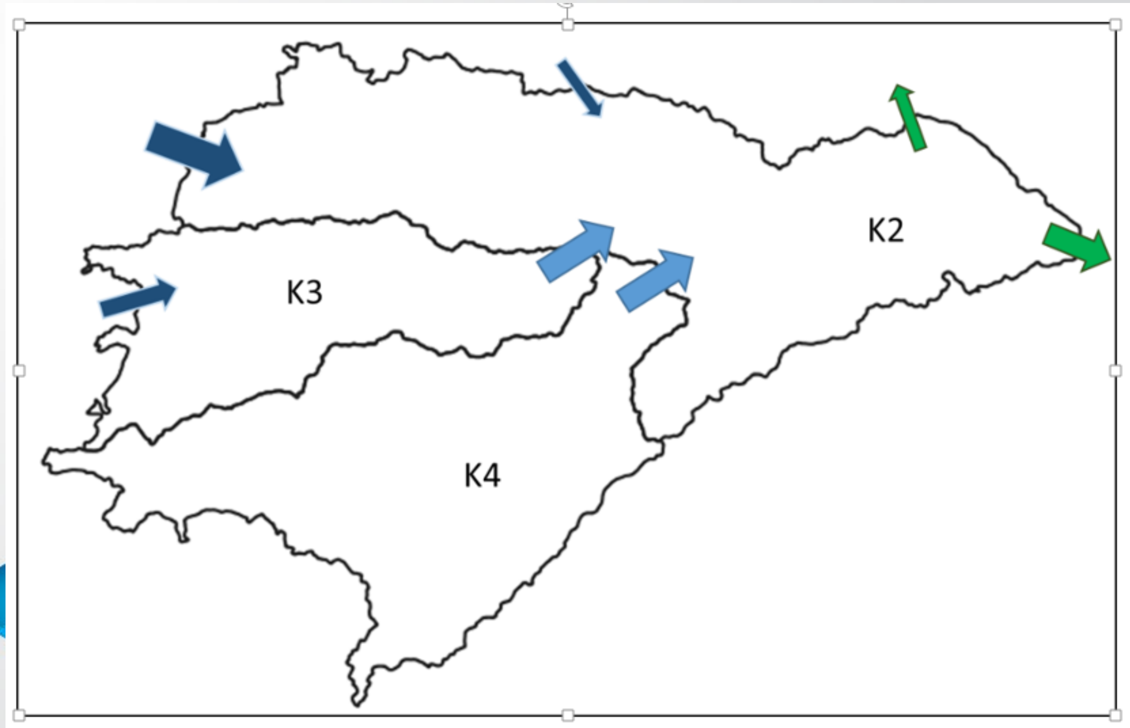


River Name	Rainfall in mm	Annual Avg Flow TMC	CA (Sq. Km)	Runoff (Depth, m)
Bhadra River	1400	62.04	3,421	0.513
Tunga River	3130	196.51	2,974	1.870
Tungabhadra River	660	310.00	27,447	0.320
Varda River	1320	73.22	5,264	0.394
Vedavati River	590	25.70	18,442	0.039
	1420	667.47	57,548	0.63

WA+ in Karnataka: K2, K3 and K4 basins

Sub-basin	Area in Karnataka (km^2)	% area of Krishna basin in Karnataka		Average elevation (m) (min and max)	Average yearly rainfall (mm/yr), CHIRPS (2006-2018)
K2: Middle Krishna	15,829	13.93%		530 (308-796)	594
K3: Gatprabha	6,833	6.02%		633 (484-1024)	714
K4: Malprabha	11,780	10.38%		627 (167-1022)	671
Total:	**34,442**	**30.33%**	**Average:**	**583 (167-1024)**	**644**

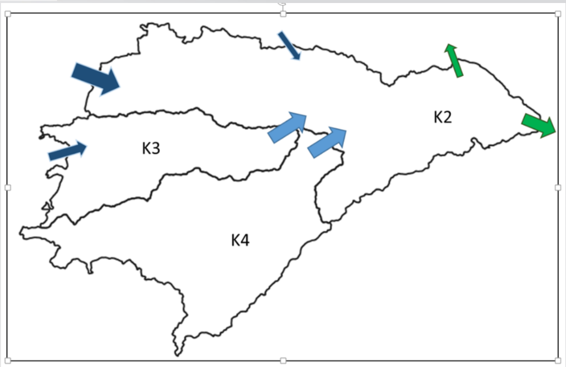




Annual Average Water Balance K3 2010/2011 – 2017/2018

Total ET
4.5 km^3/yr
158.92 TMC/yr

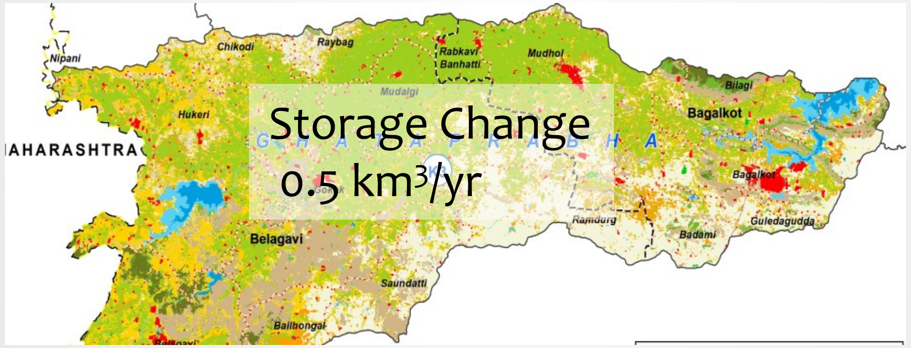
K3 6833 km^2



P
4.6 km^3/yr
162.45 TMC/yr

Rainfall ET

Incremental ET



Storage Change
0.5 km^3/yr

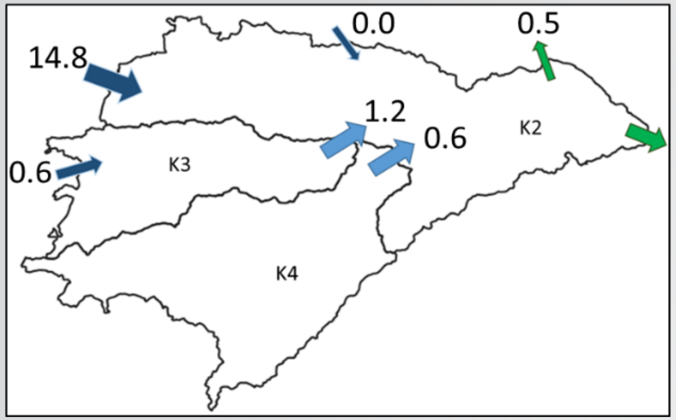
Inflow
0.6 km^3/yr
21.9 TMC/yr

Outflow
1.2 km^3/yr
42.38 TMC/yr

Available 2.1 km^3/yr
74.16 TMC/yr
Utilized flow 0.9 km^3/yr
31.78 TMC /yr

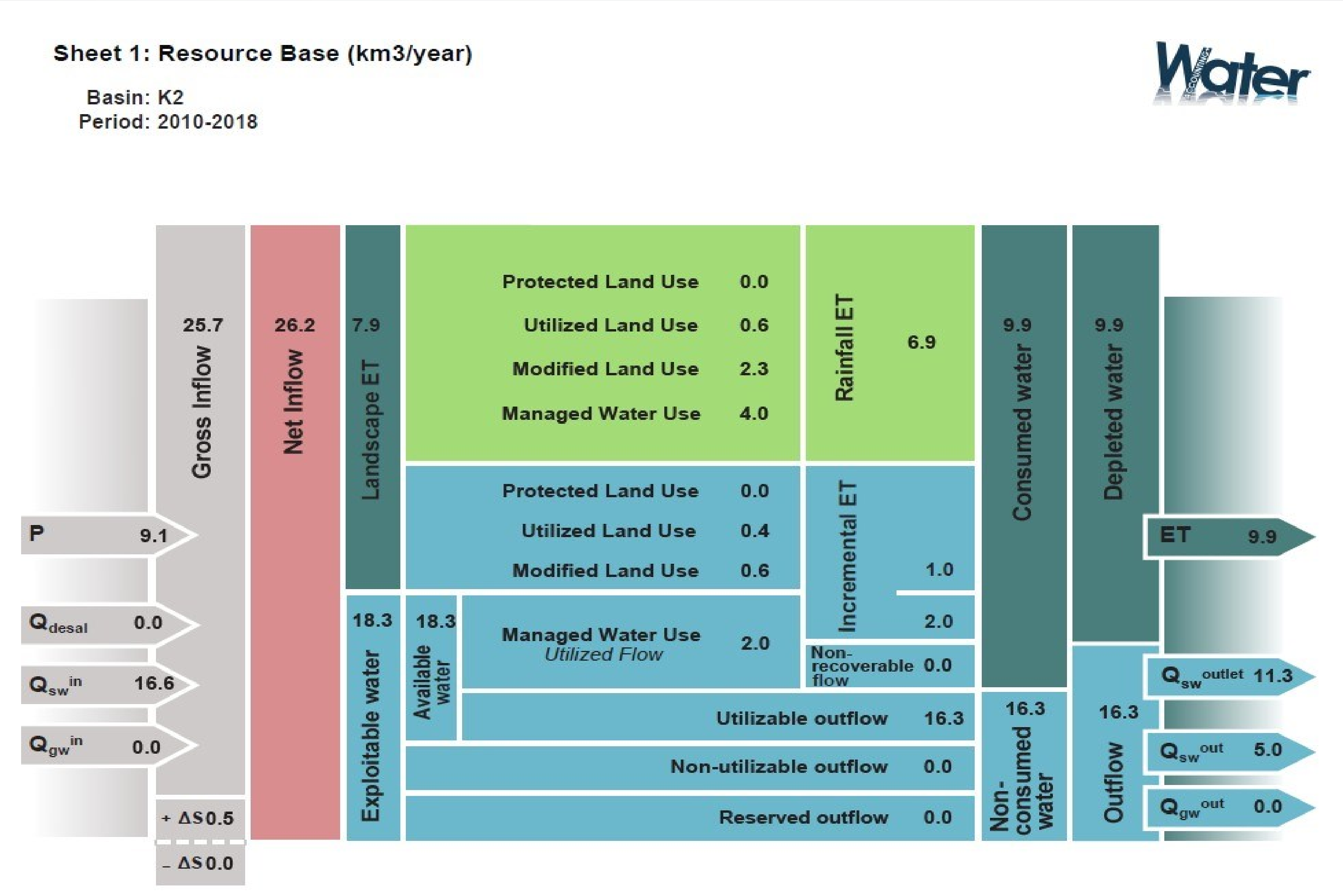
WATER ACCOUNTING

studies on yield assessment

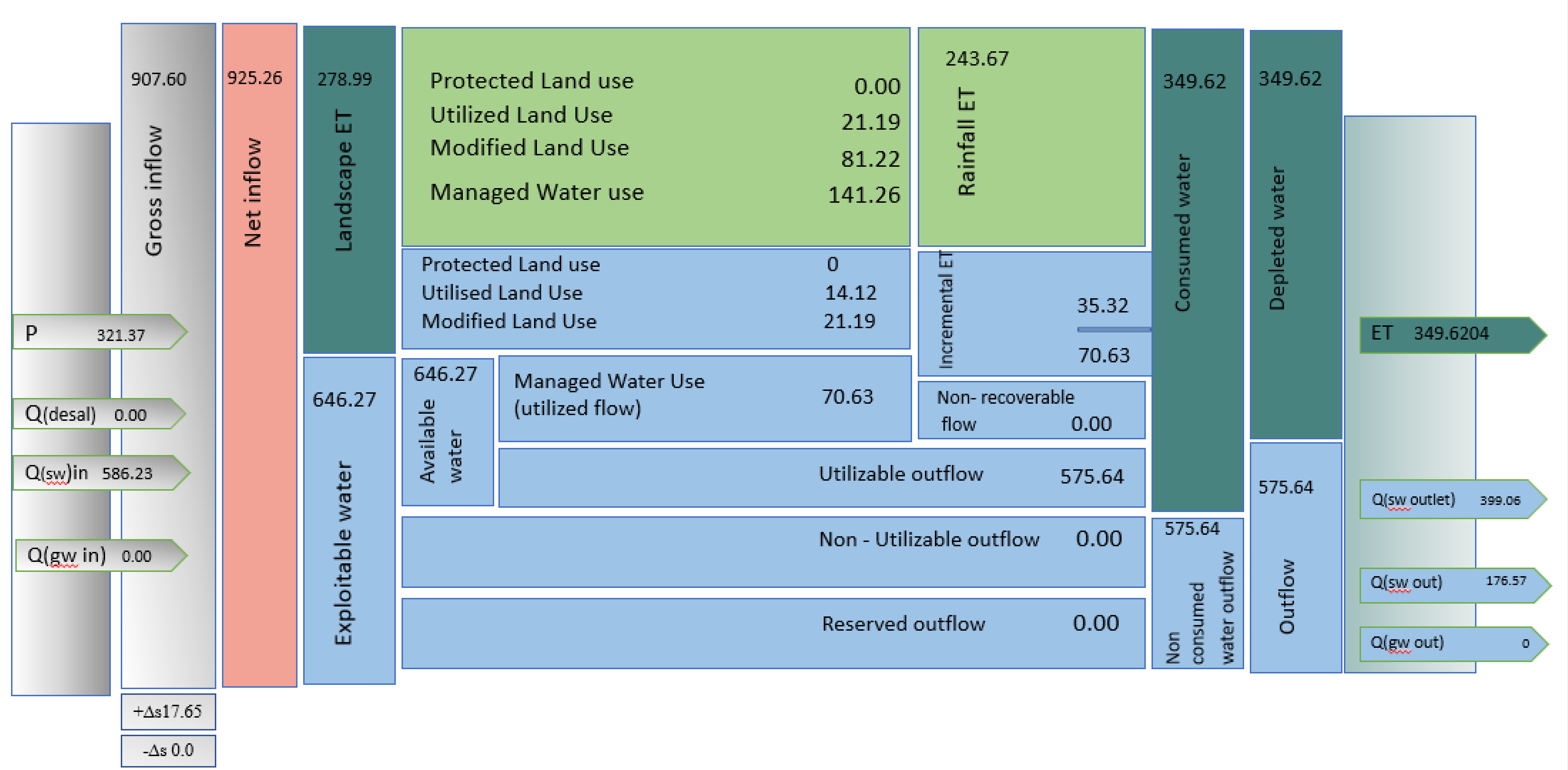


Surface Flow Values are expressed in Km^3/ year as average of the simulated period (2010 - 2018)

Surface Water Flow for Middle Krishna Sub-basin (2010-2018)		
	KM^3	TMC
Inflow from K1	14.80	522.66
Inflow from K3	1.20	42.38
Inflow from K4	0.60	21.19
Inflow from Doni	0.00	0.00
Outflow to K5	0.50	17.66
Outflow	11.30	399.06



Resource base : TMC/Year



CONCLUSIONS AND RECOMMENDATIONS from WA+

- We have analysed three basins (K2, K3, K4) using RS data in a 8 year period
  2010-2011 → 2017-2018
- The three basins are highly modified by human activity (agriculture)
- Monsoon climate and high spatial variability of rainfall
- The upstream areas generate most of the runoff while agriculture and reservoirs are net consumers
- P-ET is negative in K2 and positive in K3 and K4
  → K3 and K4 generate water, part of which is then consumed in K2

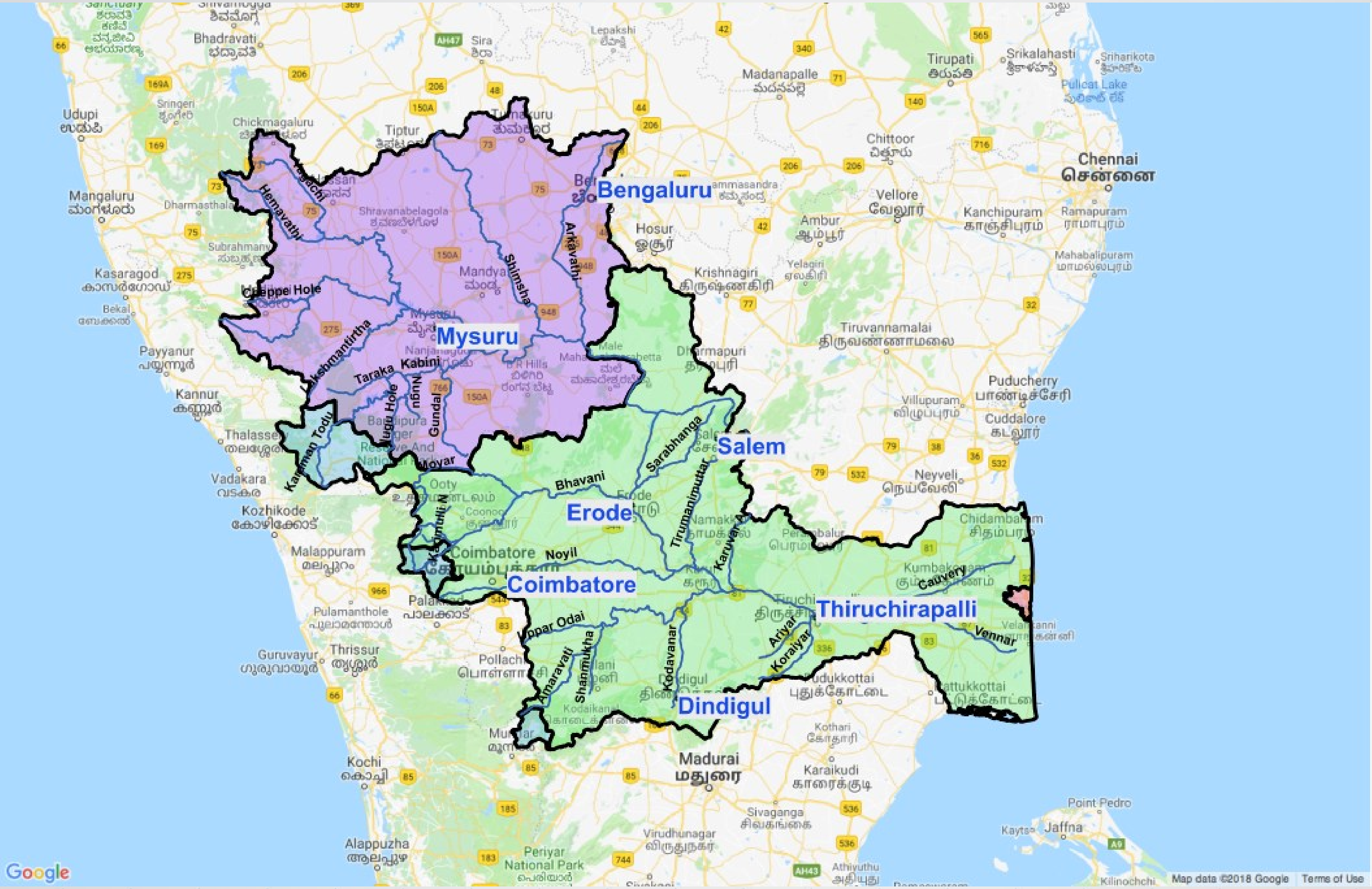
CONCLUSIONS AND RECOMMENDATIONS from WA+

- The three basins are highly dependent on upstream flows (72% of the available water resources in K2). Evaluation of scenarios where inflows are reduced should be tested.

- There is a strong seasonal variability due to the monsoon climate.
  The storage change (both surface and groundwater) should be carefully monitored at monthly/seasonal scale.

- The amount of non-beneficial water consumption is high in all basins
  (up to 70% of the total ET) → unproductive soil evaporation.
  Measures limiting soil evaporation should be considered.

Cauvery Basin – WA+ Study



The WA+ team

CWC, CGWB, NIH, NRSC

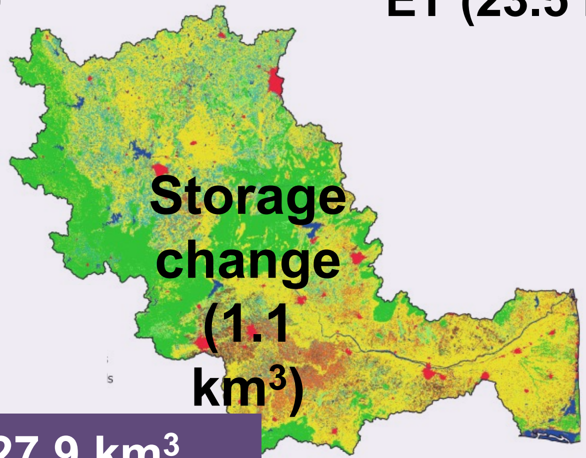
Cauvery Basin
Annual Average Water Balance

Total ET
(77.1 km^3)

Rainfall ET
(53.6 km^3)

Incremental
ET (23.5 km^3)

Inflow
(82.6 km^3)



Storage
change
(1.1
km^3)

Outflow
(4.4 km^3)

- ✓ Dry year outflow
  (0 km^3)
- ✓ Wet year outflow
  (7.9 km^3)

Exploitable: 27.9 km^3
Available: 27.2 km^3
Utilized:
25.8 km^3
Utilizable: 1.4 km^3

How can WA+ be used for water resources policy making ?

- Determine the impact of climate change on the blue water resources in general (diminished surface water and groundwater stocks)
- Computation of the water yield generated from within Karnataka that can be allocated to expand irrigation systems (and for water allocation plans in general)
- Monitoring impact of drought on agricultural production
- Estimating amount of extra local water storage (small scale waterharvesting) needed to mitigate water shortage in dry and wet season
- Improved water governance
- Assess environmental flow requirements for maintenance of wetlands
- Definitions of maximum allowable groundwater abstraction using spatial information on groundwater recharge

New State Water Policy 2022

Key Elements :

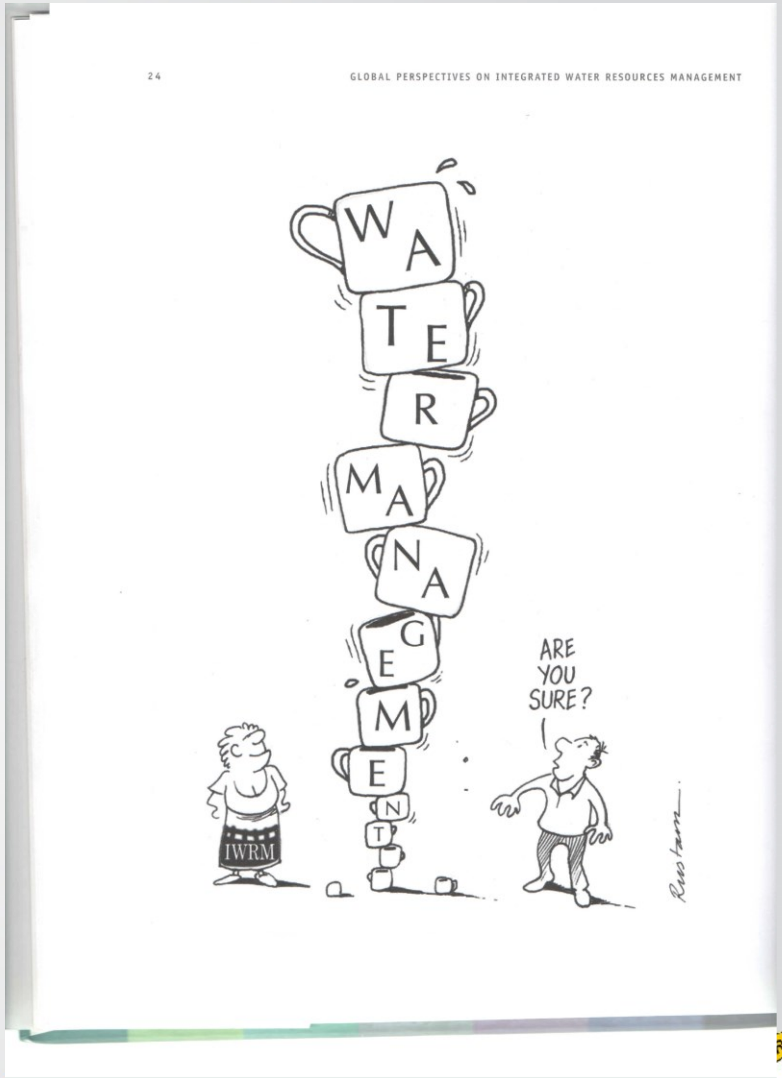
- ❖ Need to increase Water Use Efficiency / Productivity
- ❖ Need to focus on improving Water Quality
- ❖ Good data base required for better MOM of Water Resources
- ❖ Adoption of IWRM approaches
- ❖ Conserve, value and judicious usage of water at individual level

Water Accounting – Support for Water Resources Management ….. 1/2

- Understanding ET (Evapotranspiration) across various places (spatially) in the basin will provide new insights for better water resources management
- ET is the next important component to Rainfall in water cycle
- Availability of water in local areas across basin can be easily identified
- Inter-sectoral competion of water resources in a basin can be addressed with WA+ results
- On-farm water management can be facilitated better
- Outflows of the basin including groundwater can be better understood in real time and past years

Water Accounting – Support for Water Resources Management ….. 2/2

- Computation of the water yield generated from within Karnataka that can be allocated to expand irrigation systems (and for water allocation plans in general)
- Estimating amount of extra local water storage (small scale waterharvesting) needed to mitigate water shortage in dry and wet season
- Determine the impact of climate change on the blue water resources in general (diminished surface water and groundwater stocks) Improved water governance
- Monitoring impact of drought on agricultural production
- Assess environmental flow requirements for maintenance of flora / fauna
- Definitions of maximum allowable groundwater abstraction using spatial information on groundwater recharge



Water Accounting & Remote Sensing Tools – Future

- Need to build more capacity within WRD to use open source satellite data & Water Accounting tools
- Setup a dedicated team of WRD staff (within ACIWRM?) to prepare water accounts for each sub-basin, every year
- Facilitate capacity development in the private sector – to enable various departments/agencies to use the tools
- Prepare better communication products (about use of WA+ results) to the policy level and practicing engineers in the field
- Create capacity in every Chief Engineer (Zone) office for all large projects / sub-basins

Karnataka Water Security Index

No	Key Dimension	Scores
1	Key Dimension 1 - Household Water Security	6.7
2	Key Dimension 2 - Economic water security	9.0
3	Key Dimension 3 - Urban water security	11.25
4	Key Dimension 4 - Environmental water security	17.3
5	Key Dimension 5 - Resilience to water-related disasters	5.25
	WS Score for Karnataka	49.5

Asian Water Development Outlook (AWDO) methodology

ADVANCED CENTRE FOR INTEGRATED WATER RESOURCES MANAGEMENT

- a think tank to the Government on Water Resources
- engaged in policy analysis, policy research, develop knowledge base within the state
- integrate various outputs and the results fed into the policy and working of the WRD
- also serve as a platform for coordination among main departments, NGOs, private sector firms, water user associations and other organizations dealing with the water sector

ಸಮಗ್ರ ಜಲಸಂಪನ್ಮೂಲ ನಿರ್ವಹಣಾ ಉನ್ನತ ಕೇಂದ್ರ

Advanced Centre for Integrated Water Resources Management

Thank You

ADB

Greater Mekong Subregion Sustainable Agriculture & Food Security Program

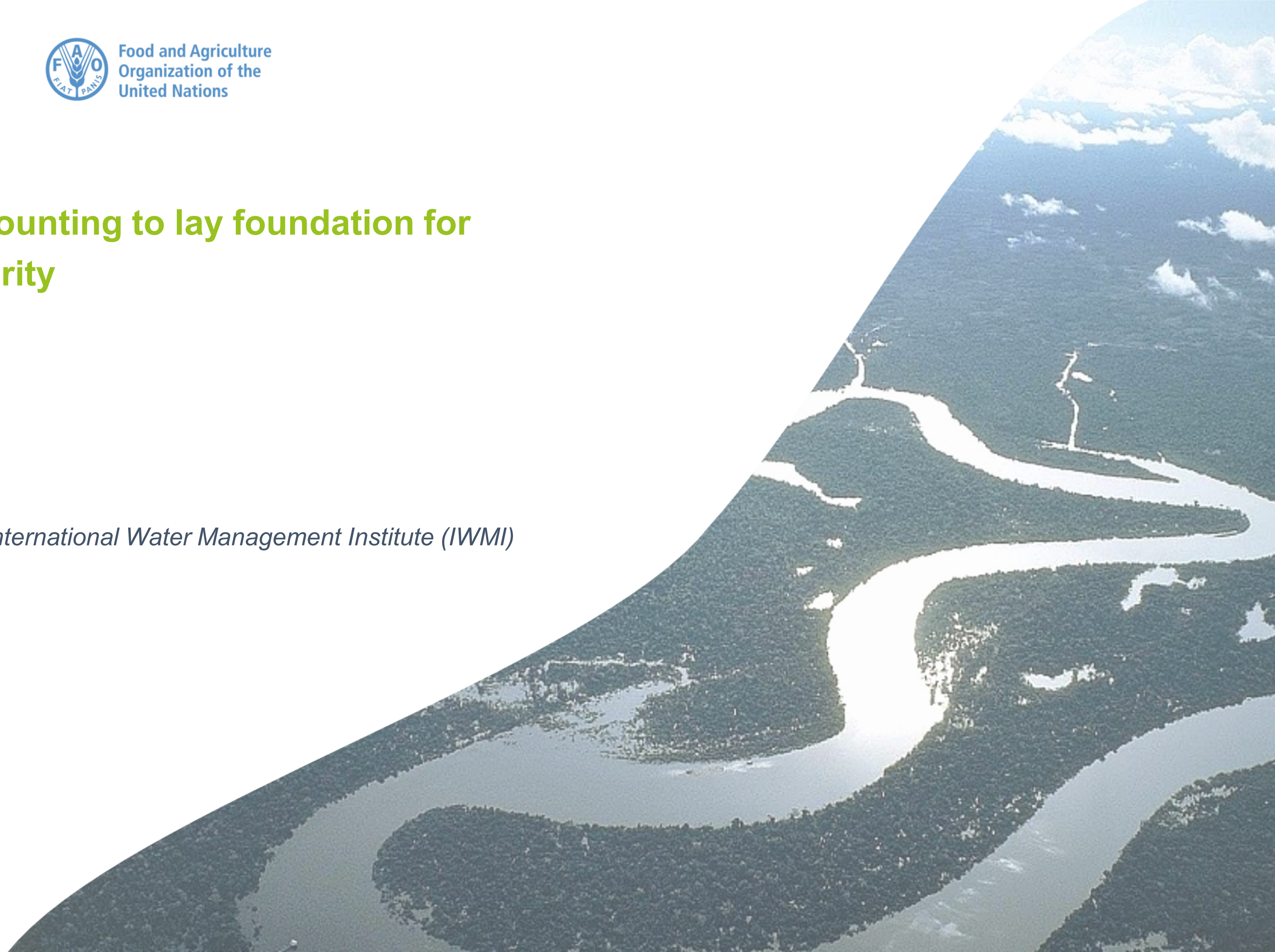
Food and Agriculture Organization of the United Nations

Session 2: Water accounting to lay foundation for managing water security

The WA+ framework

Mansoor Leh

Researcher Spatial Hydrology, International Water Management Institute (IWMI)



IWMI International Water Management Institute

CGIAR

Water Accounting in the GMS- Policy implications for water, food, and energy security in a changing climate

July 4-5, Bangkok, Thailand

The WA+ Framework

Mansoor Leh

Researcher

Water accounting

A system that provides a clear view of water resources in a river basin; it shows where water is going, how it's being used, and how much remains available for further use (IWMI).

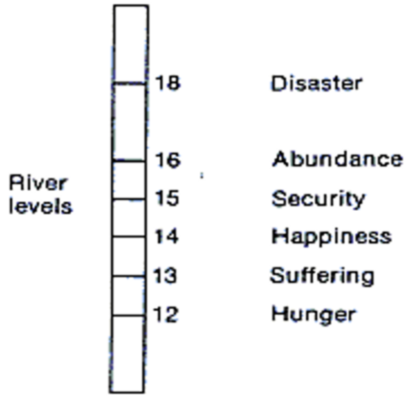
Other definitions:

- A systematic study of the current status and future trends in water supply, demand, accessibility and use within a specified spatial domain (FAO)
- A process of communicating water resources related information and the services generated from consumptive use in a geographical domain, such as a river basin, a country or a land use class; to users such as policy makers, water authorities, managers (FAO, IWMI, IHE, UN)
- A systematic process of identifying, recognising, quantifying, reporting, and assuring: information about water; the rights and other claims to that water, and the obligations against that water (Aus Gov)

Water accounting as a discipline is not new!!

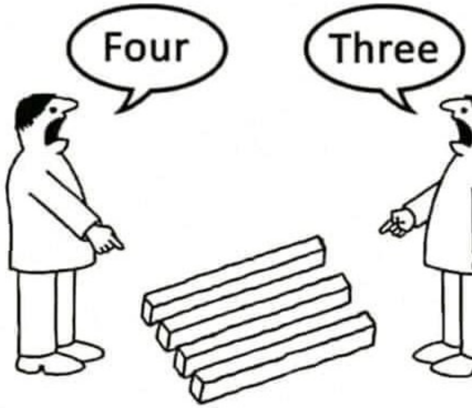
- Only the approach is different

Pliny-the-elder's classification (23 AD) of river stages



Eagleson (1994) Advances in Water Resources

Nilometer, Egypt
Built in 715 AD.

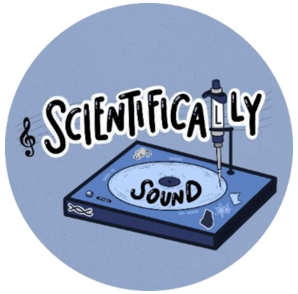


More accurate water accounting aids a stronger dialogue about water

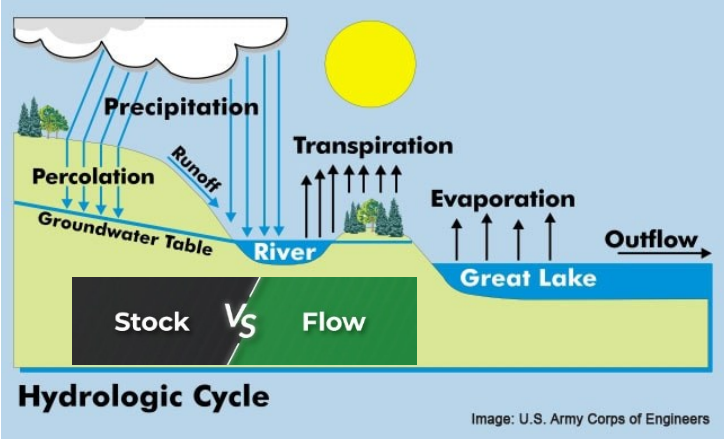
Water Accounting Approach

Independent Assessment

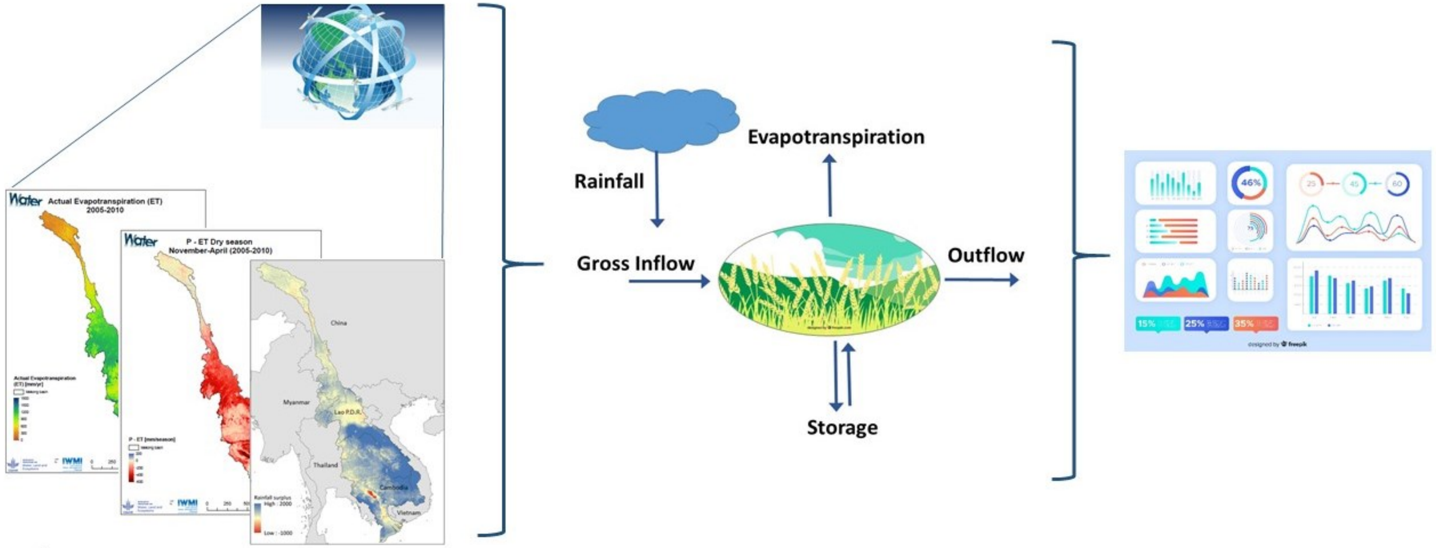
International standard



Scientifically sound



The Water Accounting Plus (WA+) framework:



Water Accounting+ can provide a basic understanding of a basin's water accounts and establish a baseline.

Limited data? No problem! WA+ relies largely on remote sensing imagery, making it a feasible tool for data scarce basins and a reliable source for transboundary waters.

Using open-source code (meaning anyone can access it!), WA+ uses pre-written code to analyze the remote sensing data.

WA+ produces organized results, categorized into: Resource Base, Evapotranspiration, Agricultural Services, Utilized Flow, Surface Water, Groundwater, Ecosystem Services, & Sustainability.

WA+ outputs can be used to ignite well-informed, transparent discussions on water resource issues.

The Water Accounting Plus (WA+) framework:

Flow accounting

- Actual flows, deliveries, and abstractions
- Tracks “Blue water”

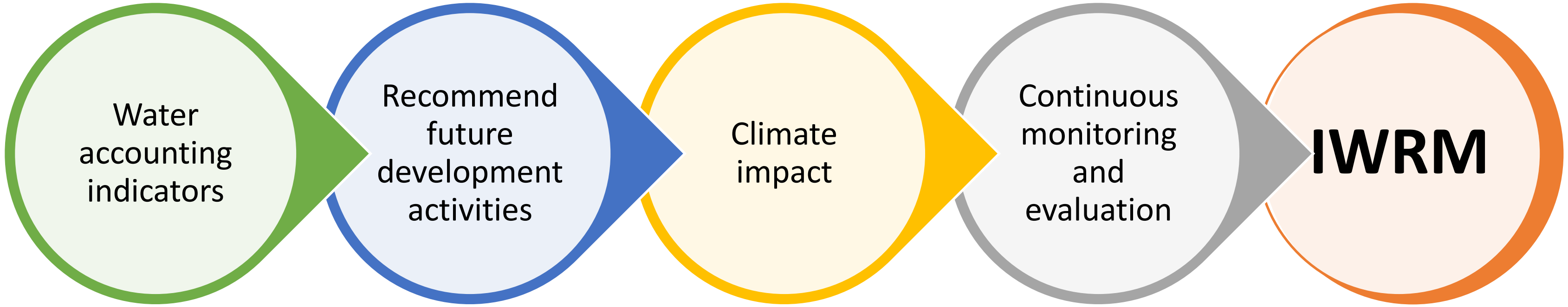
Depletion accounting

- Water consumed by the landscape
- Tracks “Green water”

WA Method	SEEA-W	AQUASTAT	AWAS	IWMI	ICID	WA+
Type	Flow Accounting			Depletion Accounting		Both

WA+ Applications

WA+ outputs can be used to develop many applications for integrated water resources management (IWMR).

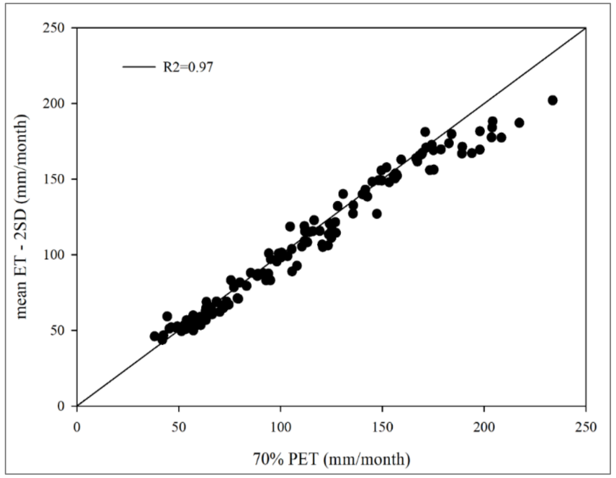


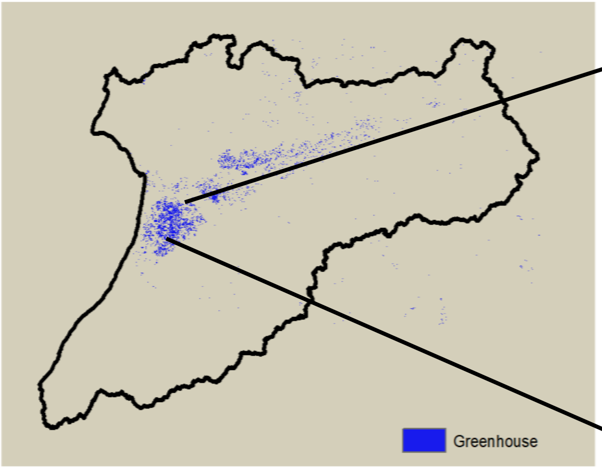
For example,

1. Accounting for water use in large-scale greenhouse operation in Morocco
2. Sustainable scaling of solar irrigation in Mali
3. Sustainable Rural Infrastructure and Watershed Management in Lao PDR
4. Integrating WA+ with other hydrologic models (SWAT), Mekong

1. Accounting for large-scale greenhouse water use in Morocco

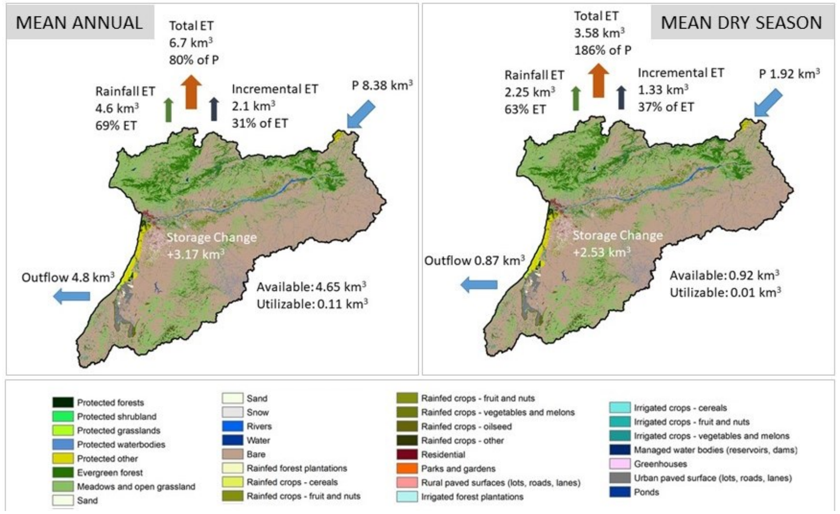
- Green House (GH) agricultural production is wide-spread (~180 km²) in the Souss-Massa Basin in Morocco.
- Unmetered extraction of groundwater for GH is common which have led to decline in GW levels in the region.
- One of the objectives of the study was to quantify GH water use.





1. Accounting for large-scale greenhouse water use in Morocco

- 300 Mm^3 per year of managed water use; 200 Mm^3 per year of green house water use.
- ~67% of the managed water use is from green houses in the Souss Massa basin, Morocco.
- There is 370 Mm^3 of utilizable flow that is available and leaving the basin every year.
- So if managed properly, surface water can contribute to the GH water use and reduce the dependency on groundwater resources.



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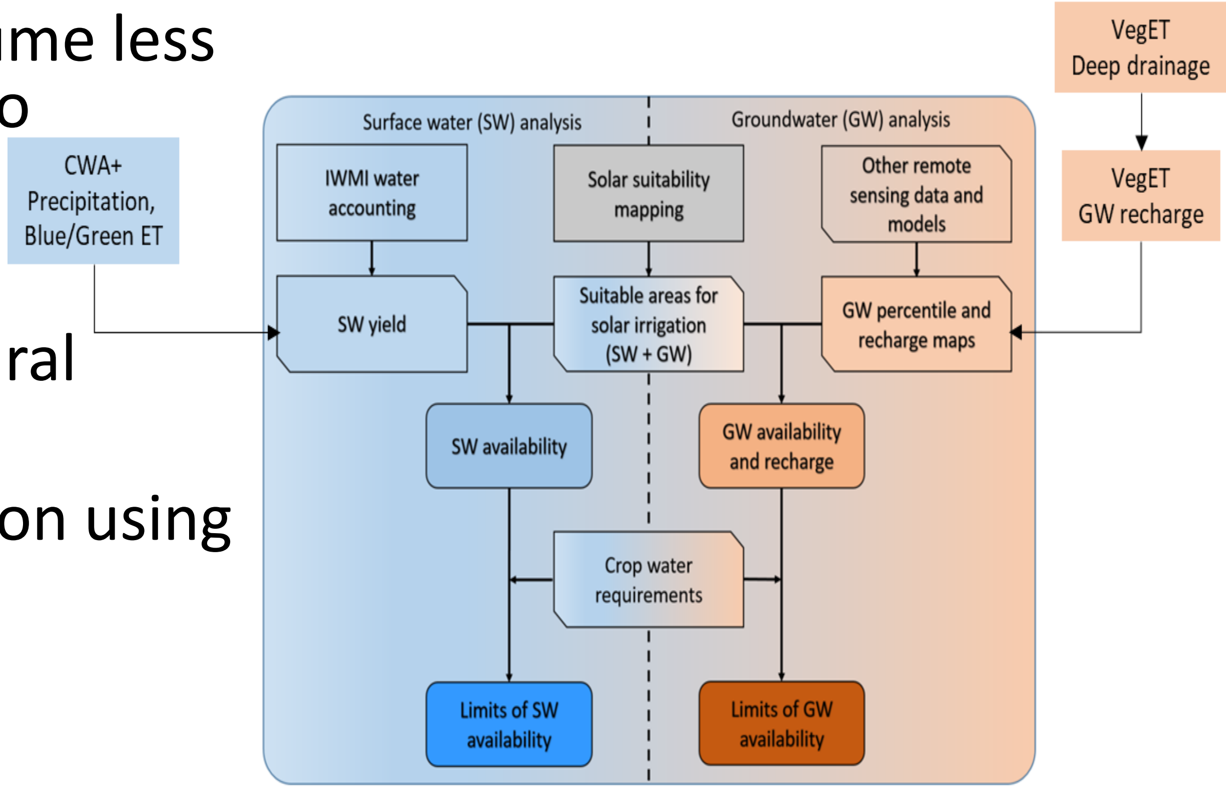
F2R-CWANA: From Fragility to Resilience in the Central and West Asia and North Africa

2. Integrated Modeling for Scaling Agricultural Production in Mali

- How much water is available for scaling agricultural production using solar irrigation in Mali?
- Small-scale agricultural practices consume less water but collectively this can add up to significant water withdrawals.
- Do we have enough water for agricultural expansion?
- Can we identify limits of water extraction using WA+ modeling results?



2. Integrated Modeling for Scaling Agricultural Production in Mali

Limits on scaling

Wet season (SW) – 145,000 ha

Dry season (SW+GW) – 80,000 ha

(a) Ségou

Area suitable for small-scale solar-powered irrigation systems (SPIS)
The total area identified as suitable for SPIS in Ségou is 145,000 ha.

Water requirement for SPIS
Assuming an average crop water requirement of 350-550 mm/season (for major vegetable/cereal crops) and an irrigation efficiency of 60%, the total irrigation water required is about 600-920 mm/season.

Area feasible for SPIS
Based on the irrigation requirement, we estimate that it would be feasible to irrigate crops with a low to medium water requirement.

Surface water availability (wet-season)
Surface water yield up to 800 mm is available during the wet season. Surface water can meet most crop water requirements during the wet season (for a crop with a low to medium water requirement) on 100% of the land identified as suitable for solar irrigation.

Groundwater availability (dry-season)
All the areas identified as suitable for solar irrigation have medium (41-60) to medium-high (61-80) percentile groundwater availability. Irrigation from groundwater sources is essential to avoid crop failures. In Ségou, groundwater resources can support crops covering an area of about 80,000 ha.

A farmer using a solar pump to irrigate her crops in Africa (*photo:* David Brazier/ IWMI).

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INNOVATION LAB FOR Small Scale Irrigation

CGIAR RESEARCH PROGRAM ON Water, Land and Ecosystems

3. Sustainable Rural Infrastructure and Watershed Management in Lao PDR

- Support the GOL National Economic and Social Development Plan goal of achieving Sustainable and Inclusive rural development
- Increase Irrigated area -farmers with increased income from high value crops and livestock
- land use management within PRI
- upgrade infrastructure to be climate resilient, efficient for sustainable operation and maintenance

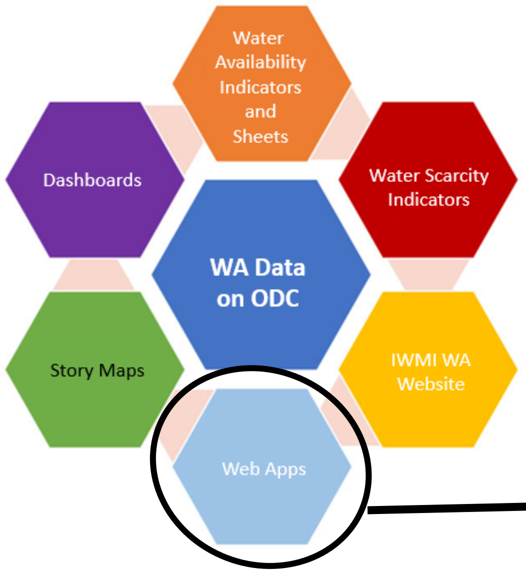
3. Sustainable Rural Infrastructure and Watershed Management in Lao PDR

- Each of the watersheds are highly sensitive to changing climate conditions
  - intense rainy season, the watersheds may be susceptible to abrupt changes in hydrologic regime
- there is a scarcity of water during the dry season and with an intense dry season under climate change, water shortages may be exacerbated
  - **Need for managing dry season flows**

4. Integrating WA+ with other models: MRC Decision Support Framework (DSF) and WA+ for Water Use Monitoring System

WA+ data visualization

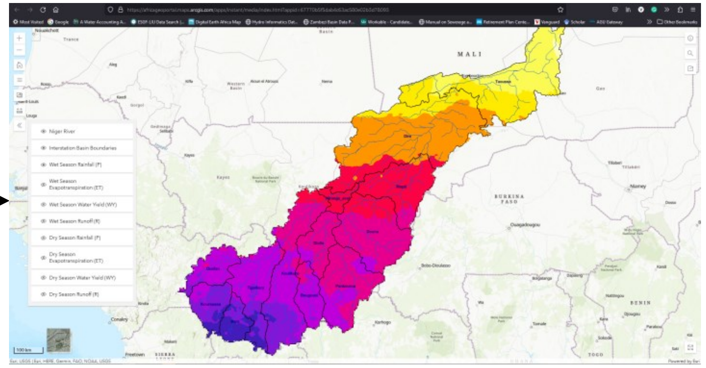
WA+ data visualization



WebApps using ESRI technology

Web apps - A *Web application* (*Web app*) is an application program that is stored on a remote server and delivered over the Internet through a browser interface.

WebApp



Enables users to retrieve information from the maps

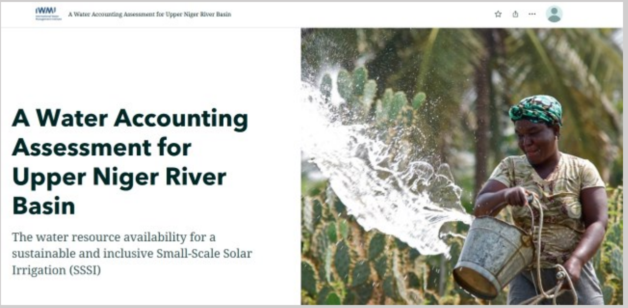
Example: [Upper Niger Basin seasonal water balance]

WA+ data visualization

Story maps using ESRI technology

Story Map – is a web-based application that allows share maps in the context of a narrative text and other multi-media content.

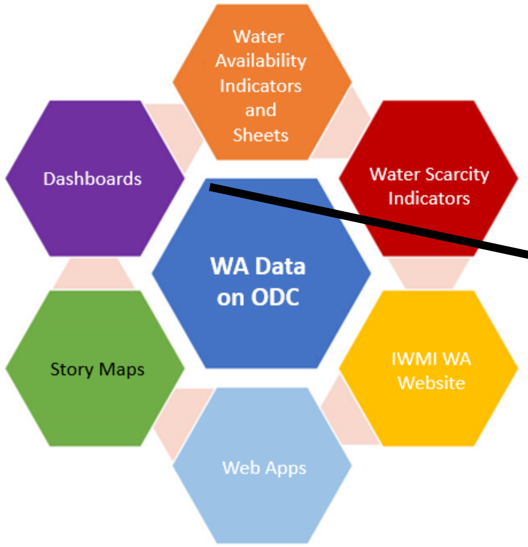
Story Map



Helps to support a narrative using interactive maps and figures

[Volta basin water accounting]

WA+ data visualization



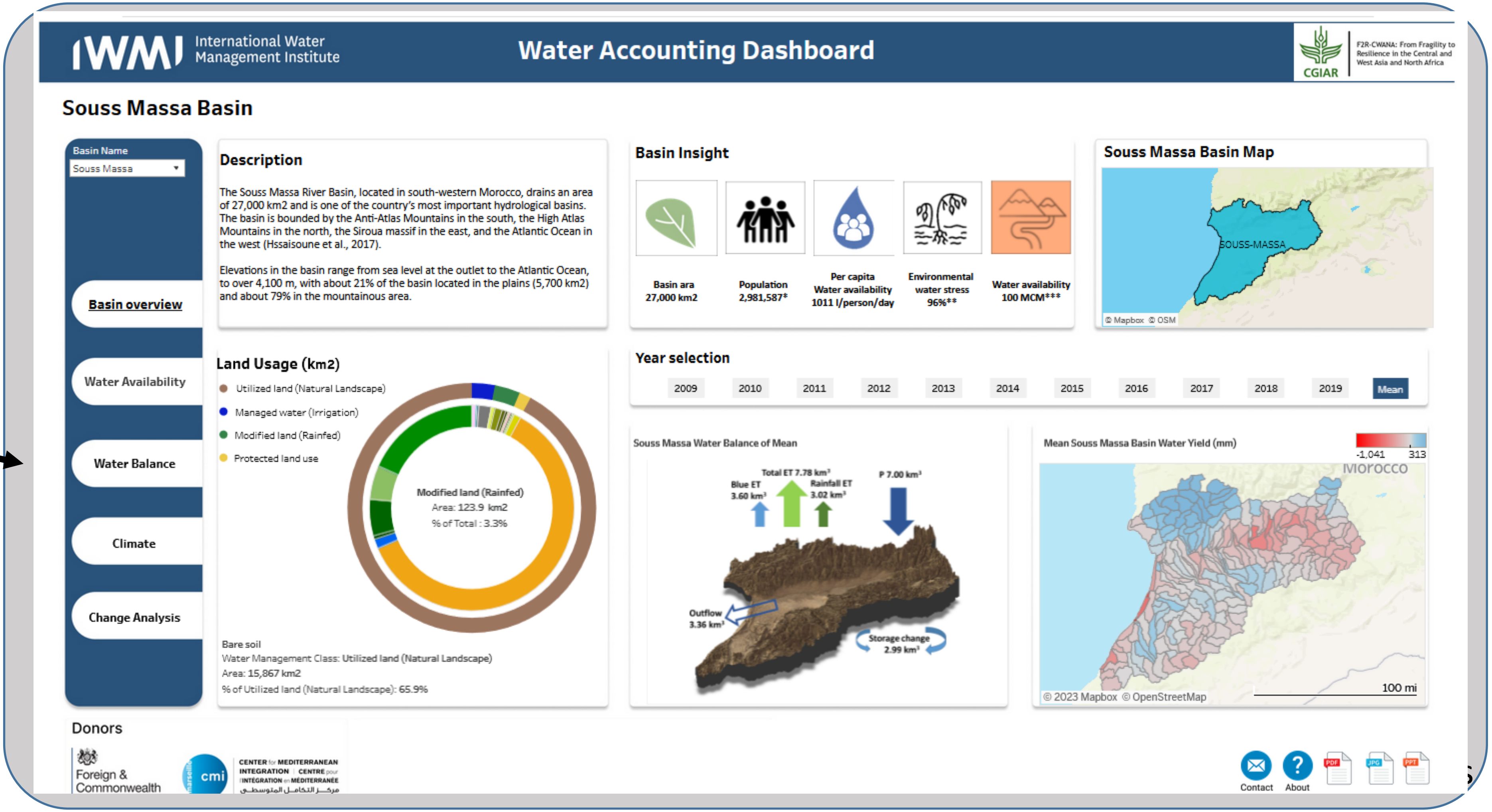


Tableau based   [Water Accounting dashboard](#) (work in progress)

Multi-scale water accounting

Time Period: 2000-2020
Resolution: 250 m
Pixels: ~2 million

Sub-basin (WA+) 2022

White Volta, Oti
Upper Mekong, Mid-Mekong, Lower Mekong, 3S

Time Period: 2000-2020
Resolution: 250 m to 1 km
Pixels: ~8 million

Basin (WA+) 2020-2021

Volta, Lake Tana, Rift Valley Lakes
Mekong

Time Period: 2000-2020
Resolution: 1 km
Pixels: ~30 million

Continental Water Accounting (CWA+)

2022-2023

Africa
SE Asia…

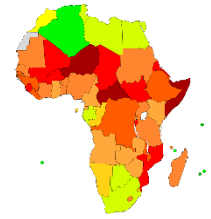
Motivation for Continental WA+ (CWA+)

Current status	By the end of 2023	Near Future
Conventional Basin water accounting **WA+ approach** Rapid WA+ → 6 months WA+ → 1 year More $$$$$ River basin approach 1-km data	Continental water accounting **CWA+ approach** WA+ → 1-2 months Less $$ Boundary WA approach (Continent, Country, County and Catchment) 1-km data	Online Water Accounting (OWA+) **CWA+ approach** WA+ → On the fly Free Boundary WA approach (Country or River basin level) 1km data

National Database | websites | Cloud | Reports | Publications

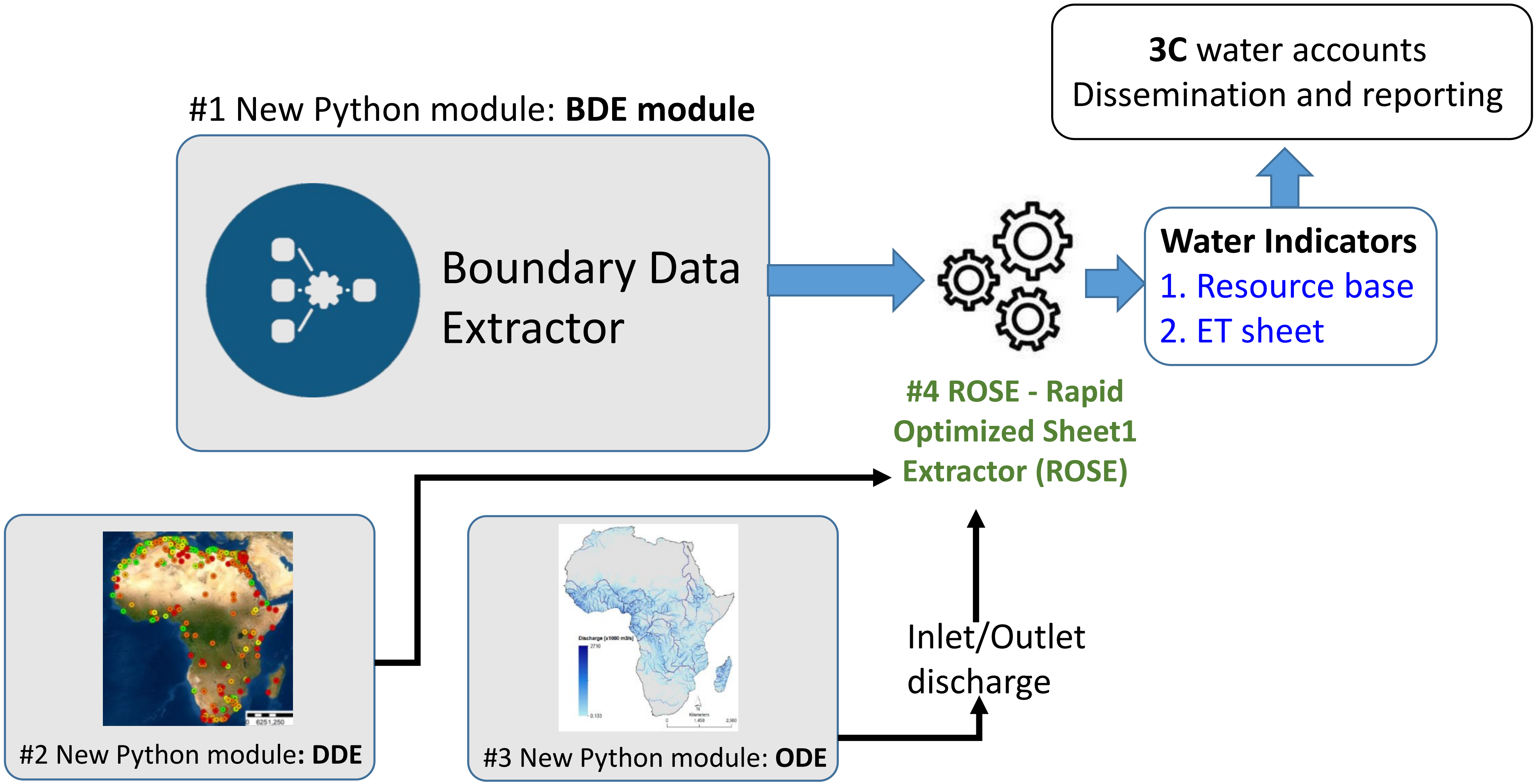
Data is scattered

Different methods, Different formats, Different scales



Data is mostly lumped

CWA+ Catchment > Country > County (3C) Rapid water accounts



International Water Management Institute

Questions or comments

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Thank you!

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Greater Mekong Subregion Sustainable Agriculture & Food Security Program

Food and Agriculture Organization of the United Nations

Session 2: Water accounting to lay foundation for managing water security

Panel 2: Water accounting frameworks in the GMS

with Virak Chan (World Bank), Mansoor Leh (IWMI), Hugh Turral (FAO), Dr Somasekhar Rao Polisetti (ACIWRM), and Geoffrey Wilson (ADB)

Panel 2
Q1 & Q2

1. What are the priorities in developing water accounting at **national scale** within the GMS, and within the boundaries of the relevant river basins?
    a. How are they different – between the parts within any given basin and outside it?
    b. How are they different between the countries?
    c. Who are the key users and what will be the main policy and management questions to be addressed?
2. How does the **NEXUS** (food, water, environment and energy) play out in each country with regard to future water demand, water availability, climate impacts?
    a. What are the 5 most important challenges, and how does water accounting help in managing them?

Panel 2
Q3 and Q4

1. In light of questions 1 and 2, is water accounting useful at **river basin scale** in the Mekong?
   a. What are the main challenges and purposes that water accounting can help manage and address?
2. What steps can be taken to **operationalise basin scale water accounting** for coordinated water management between the riparian countries?
   a. How can national water accounting be integrated with a river basin perspective?
   b. Can this be done in a technical and generic policy-focused way that can inform and support integrated and sustainable management?
   c. What steps are feasible?

Greater Mekong Subregion Sustainable Agriculture & Food Security Program

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Session 2: Water accounting to lay foundation for managing water security

Break-out group discussion - Identifying sector benefits

Considering increasing water security risks, how would a regional water accounting framework help your sectors (water/environment, food, and energy)?

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End of day 1