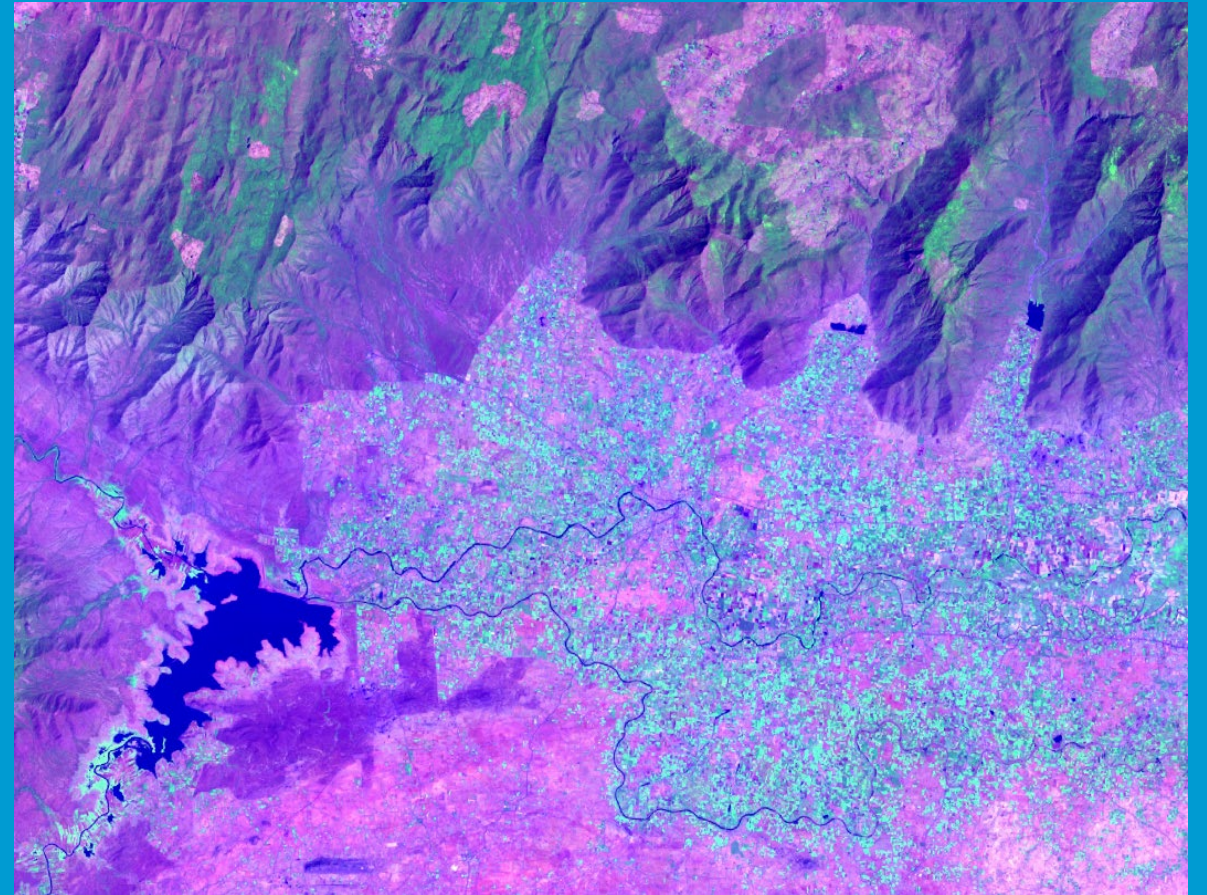


“Improved Water Allocation for Agriculture in the Arab Region”

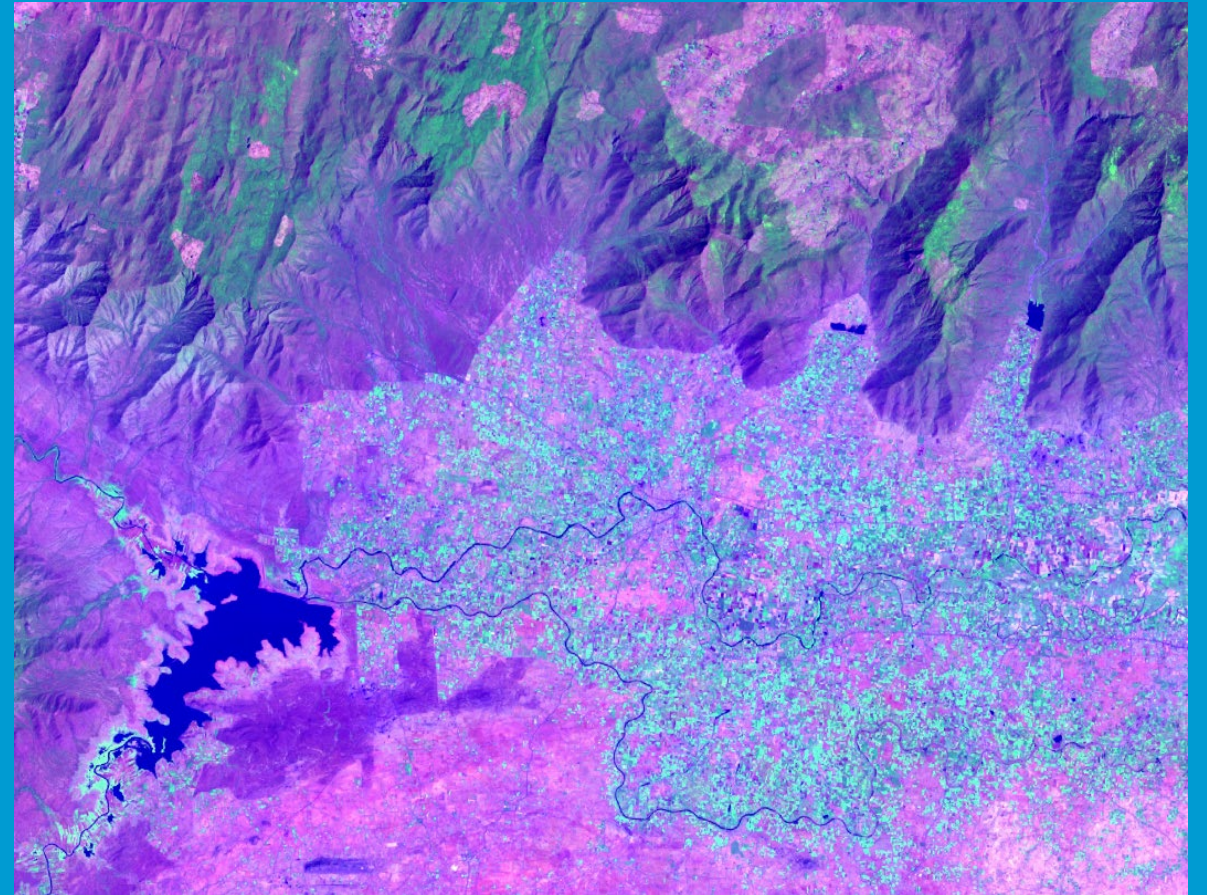
Technical meeting
26-27/09/2022

Water Accounting

Dr. Salvadore Elga



*We cannot plan and manage
what we do not measure*



Session 1: Water Accounting Principles and examples from past applications

What is Water Accounting?

What can I do with Water Accounting?

How can WA+ support IWRM?

What types of Water Accounting Systems exist?

The WA+ is a WA system based on Remote Sensing data

Examples

Data alone is not sufficient for effectively manage water resources

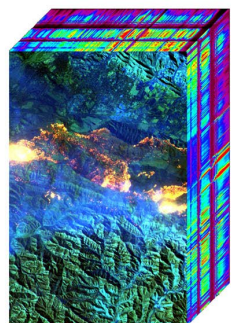


A	B	C	D	E	F	G	H	I	J	K	L	M	N
89	3/19/2008	Phu Chhai	Biang Nay	အိမ်စိုက်စိုက်	Tuoi Chhai Reservoir	အိမ်စိုက်စိုက်	0318049	52782	134780	M	n.a	1995	35
90	2/10/2008	Phu Chhai	Biang Nay	အိမ်စိုက်စိုက်	Threou Dai Reservoir	အိမ်စိုက်စိုက်	0318050	53010	134800	M	976	1999	38
91	08/14/2016	Phu Chhai	Boeng	အိမ်စိုက်စိုက်	Andoung Ang Reservoir	အိမ်စိုက်စိုက်	0318049	52782	134800	M	976	2005	1
92	1/16/2009	Phu Chhai	Men	အိမ်စိုက်စိုက်	Yeung Reservoir	အိမ်စိုက်စိုက်	0318073	53820	135320	M	976	2006	24
93	3/16/2009	Phu Chhai	Traseang Phu	အိမ်စိုက်စိုက်	Tumrap Arong Anoll	အိမ်စိုက်စိုက်	0318074	53948	135830	M	976	2009	1
94	07/11/10	Phu Chhai	Thoua Phou	အိမ်စိုက်စိုက်	Mai Vaa Reservoir	အိမ်စိုက်စိုက်	0318060	52849	134290	M	976	2003	1
95	1/16/2016	Phu Chhai	Traseang Phu	အိမ်စိုက်စိုက်	Phum Doung Reservoir	အိမ်စိုက်စိုက်	0318052	52962	135680	M	976	2005	1
96	1/16/2010	Phu Chhai	Phou Chhor	အိမ်စိုက်စိုက်	Toum Lim Reservoir	အိမ်စိုက်စိုက်	0318103	52568	135600	M	976	2009	1
97	3/17/2010	Phu Chhai	Kouath	အိမ်စိုက်စိုက်	Traseang Arong Reservoir	အိမ်စိုက်စိုက်	0318064	52791	134930	M	977	2005	1
98	1/16/2010	Phu Chhai	Traseang Phu	အိမ်စိုက်စိုက်	Kou Svay Reservoir	အိမ်စိုက်စိုက်	0318107	53659	135260	M	976	2006	1
99	1/16/2010	Phu Chhai	Traseang Phu	အိမ်စိုက်စိုက်	Phnom Poi Reservoir	အိမ်စိုက်စိုက်	0318108	53521	135070	M	976	2004	1
100	2/18/2010	Phu Chhai	Samreay	အိမ်စိုက်စိုက်	Tumrap Sang Threou	အိမ်စိုက်စိုက်	0318062	53667	133000	M	969	1977	4
101	1/16/2010	Phu Chhai	Men	အိမ်စိုက်စိုက်	Phka Phka	အိမ်စိုက်စိုက်	0318045	53469	133000	S	976	n.a	1
102	1/16/2010	Phu Chhai	Men	အိမ်စိုက်စိုက်	Phka	အိမ်စိုက်စိုက်	0318047	53467	132850	S	n.a	n.a	8
103	1/16/2010	Phu Chhai	Traseang Phu	အိမ်စိုက်စိုက်	Tsang	အိမ်စိုက်စိုက်	0318041	53241	133470	S	971	2002	1
104	2/16/2010	Phu Chhai	Sou Sam	အိမ်စိုက်စိုက်	Traseang Threou	အိမ်စိုက်စိုက်	0318043	53431	134810	S	980	1997	1
105	1/16/2010	Phu Chhai	Traseang Phu	အိမ်စိုက်စိုက်	Traseang Pheng	အိမ်စိုက်စိုက်	0318044	53286	135300	M	976	2003	1
106	0/0/2016	Phu Chhai	Men	အိမ်စိုက်စိုက်	Deum Sreng Reservoir	အိမ်စိုက်စိုက်	0318793	53318	132449	S	976	n.a	1
107	0/0/2016	Phu Chhai	Men	အိမ်စိုက်စိုက်	Karong Chok Reservoir	အိမ်စိုက်စိုက်	0318794	53467	132429	S	976	2004	9
108	1/16/2010	Phu Chhai	Men	အိမ်စိုက်စိုက်	Lak Kot	အိမ်စိုက်စိုက်	0318006	53003	132710	M	976	2005	2
109	1/16/2010	Phu Chhai	Men	အိမ်စိုက်စိုက်	Ratom Poi	အိမ်စိုက်စိုက်	0318008	53443	132332	M	976	2005	38
110	0/1/2008	Site Sampling	Phum Yem	အိမ်စိုက်စိုက်	Tumrap Doung or Tumrap Phou	အိမ်စိုက်စိုက်	0318049	53103	130710	M	990	1999	48
111	12/3/2010	Site Sampling	Phnom Phou	အိမ်စိုက်စိုက်	Tumrap Doung Site	အိမ်စိုက်စိုက်	0318105	53662	136600	M	996	n.a	32
112	2/13/2010	Site Sampling	Phnom Phou	အိမ်စိုက်စိုက်	Tumrap Cham Lak Cham	အိမ်စိုက်စိုက်	0318107	53589	136240	S	979	n.a	5
113	1/16/2010	Site Sampling	Boeay	အိမ်စိုက်စိုက်	Tumrap Cham Lak Cham	အိမ်စိုက်စိုက်	0318108	53492	136450	M	985	n.a	44
114	1/13/2010	Site Sampling	Tang Traleak	အိမ်စိုက်စိုက်	Tumrap Sang Threou	အိမ်စိုက်စိုက်	0318104	53662	135930	M	980	n.a	22
115	1/16/2010	Site Sampling	Phnom Sra	အိမ်စိုက်စိုက်	Andoung Sreng Reservoir	အိမ်စိုက်စိုက်	0318100	52287	134770	M	976	2008	65
116	2/10/2010	Site Sampling	Boeay	အိမ်စိုက်စိုက်	Boeay	အိမ်စိုက်စိုက်	0318203	53608	136800	M	976	1995	17
117	1/16/2010	Site Sampling	Chh Chh	အိမ်စိုက်စိုက်	Brossoung Reservoir	အိမ်စိုက်စိုက်	0318206	53420	136470	M	970	2003	46
118	1/16/2010	Site Sampling	Khor Sa	အိမ်စိုက်စိုက်	Kour Kamb Reservoir	အိမ်စိုက်စိုက်	0318208	52994	135950	M	989	1996	4
119	1/16/2010	Site Sampling	Kach Andoung	အိမ်စိုက်စိုက်	D Andoung and D Sang	အိမ်စိုက်စိုက်	0318210	52727	136370	M	976	n.a	29
120	1/16/2010	Site Sampling	Phnom Kanda	အိမ်စိုက်စိုက်	Phak Lees Cheu	အိမ်စိုက်စိုက်	0318213	53530	132320	M	971	2003	63
121	1/16/2010	Site Sampling	Phnom Phou	အိမ်စိုက်စိုက်	Phak Phou Pump Station 30.31	အိမ်စိုက်စိုက်	0318214	53203	130800	M	977	2001	34
122	1/16/2010	Site Sampling	Chhor Sa	အိမ်စိုက်စိုက်	Phnom Phou	အိမ်စိုက်စိုက်	0318216	53483	134600	M	989	2010	24
123	2/10/2016	Site Sampling	Phnom Phou	အိမ်စိုက်စိုက်	Karong Bobou	အိမ်စိုက်စိုက်	0318268	53730	136469	S	n.a	2014	10
124	2/10/2016	Site Sampling	Phnom Phou	အိမ်စိုက်စိုက်	Boeung Phum	အိမ်စိုက်စိုက်	0318270	53788	136933	M	n.a	2007	19
125	2/10/2016	Site Sampling	Phnom Phou	အိမ်စိုက်စိုက်	Phak Phou Pheng	အိမ်စိုက်စိုက်	0318271	53700	136726	S	979	1997	7
126	0/14/2016	Site Sampling	Phnom Phou	အိမ်စိုက်စိုက်	Mou Phum	အိမ်စိုက်စိုက်	0318272	53747	134822	M	976	2007	16
127	0/14/2016	Site Sampling	Kach Andoung	အိမ်စိုက်စိုက်	D Pheng	အိမ်စိုက်စိုက်	0318273	53841	137347	S	976	2008	16
128	1/16/2010	Site Sampling	Boeay	အိမ်စိုက်စိုက်	Boeay	အိမ်စိုက်စိုက်	0318274	53800	136900	M	n.a	2008	1

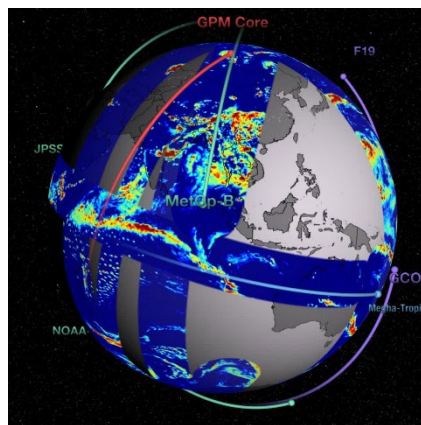
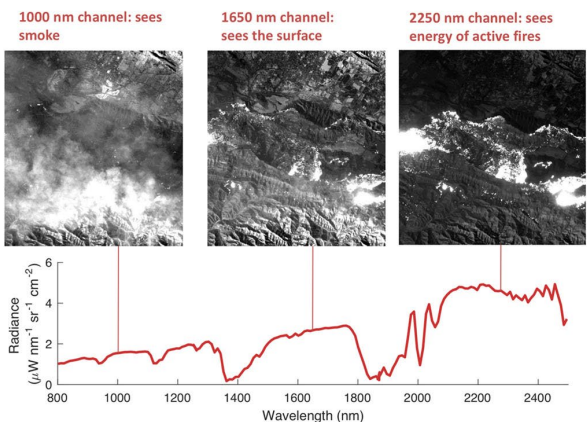
Have decision makers access to the necessary data?

Can decision makers work with these datasets?

Are these datasets alone sufficient for making water allocation plans?



False color image from AVIRIS data cube acquired on Dec 5 2017. The front face shows: (red) active fires at 2250 nm; (green) surface at 1650 nm; and (blue) smoke at 1000 nm.



What is water accounting?



Water accounting is a tool to support decision making

Name comes from financial accounting

Identification and tracking of sources of revenue and expenses

“Water Accounting makes sense of how much water is available and how to use it”

*“Water Accounting is the systematic **quantitative assessment** of the **status and trends** in water supply, demand, distribution and accessibility”*

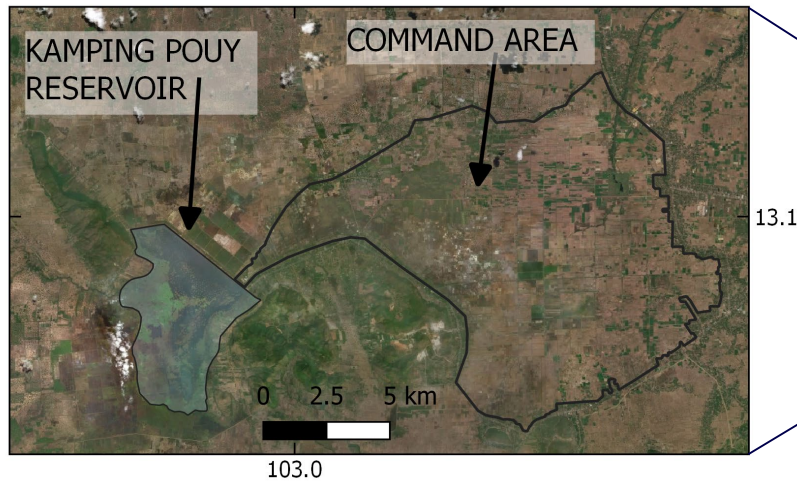
Definitions from: FAO, Water Accounting for Water Governance and Sustainable Development

Reporting system to translate data to useful information

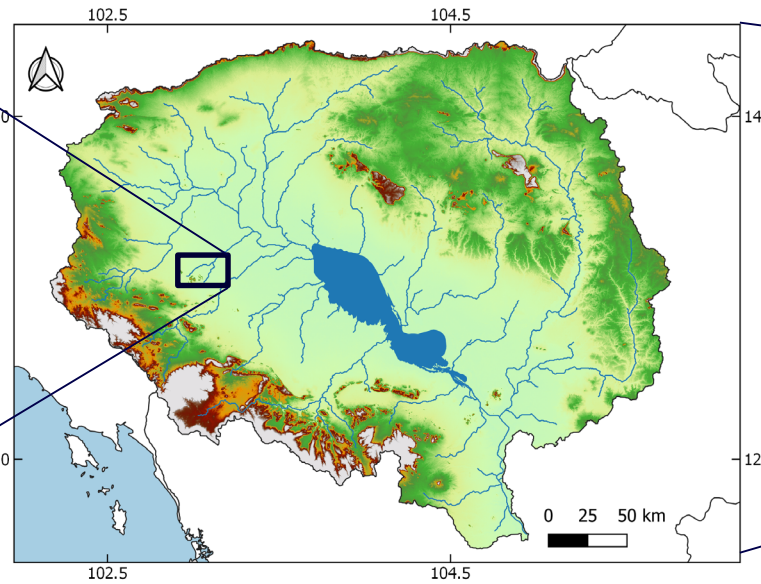
What is Water Accounting

Water Accounting analyses water resources and their use in a specific geographical domain

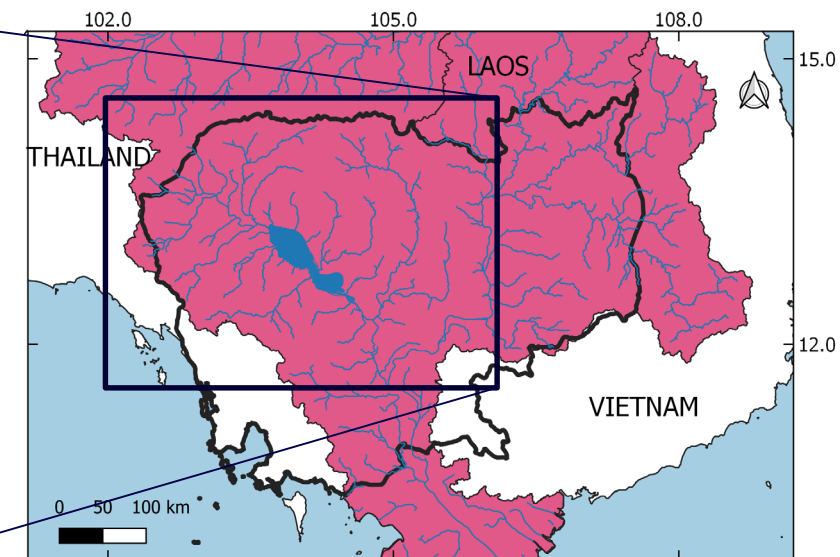
Irrigation Scheme Level



Basin Scale



Country Scale

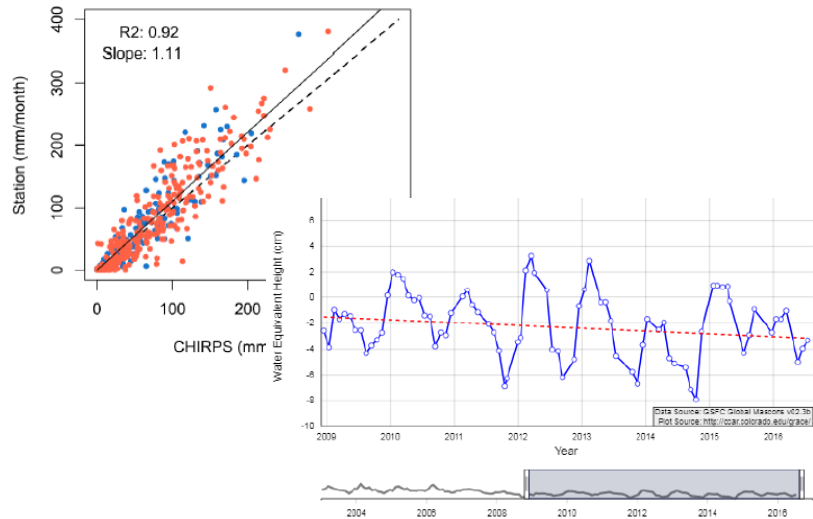
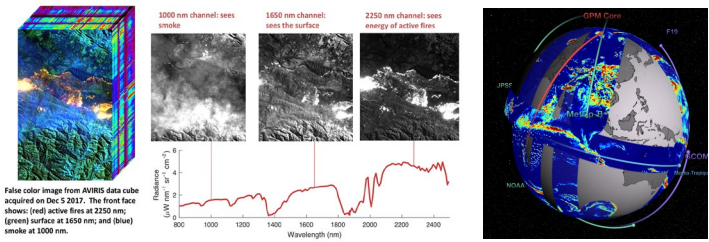


Bing VirtualEarth and data from the Irrigated Agriculture Improvement Project (Cambodia)

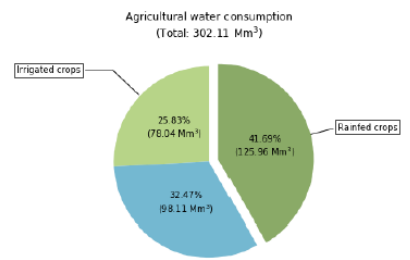
Tonle Sap basin elevation, HydroSHED data

Cambodia and the Mekong river system

Water Accounting uses a three-step approach



Crop										Agricultural water consumption
Cereals	Non-cereals			Fruit & vegetables		Oil-seeds	Food crops	Beverage crops	Other crops	ET
15.28	3.64	17.54	-	-	5.85	55.49	-	28.16	-	125.96
	Root / tuber crops	Leguminous crops	Sugar crops	Merged Vegetables & melons	Fruits & nuts	Merged				ET from rainfall
16.29	8.18	13.74	-	-	9.82	28.55	-	1.46	-	78.04
23.22	11.14	19.94	-	-	14.68	28.27	-	0.87	-	98.11
39.51	19.32	33.67	-	-	24.50	56.82	-	2.33	-	176.15
										Total ET



Session 1: Water Accounting Principles and examples from past applications

What is Water Accounting?

What can I do with Water Accounting?

How can WA+ support IWRM?

What types of Water Accounting Systems exist?

The WA+ is a WA system based on Remote Sensing data

Examples

Water Accounting: A simple idea to track a complex system

How much is the water use?

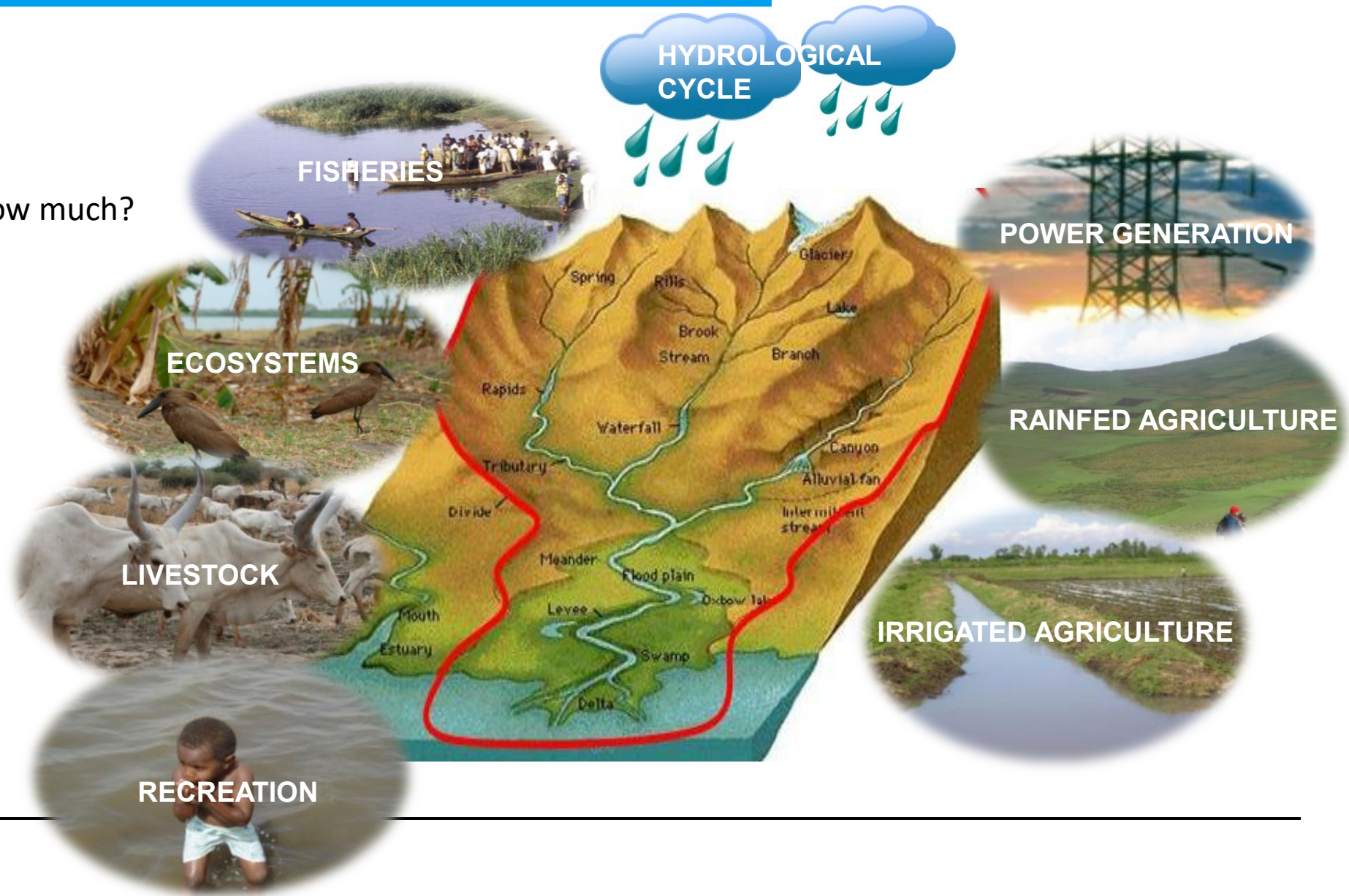
Which sector is consuming how much?

Demand vs. Supply

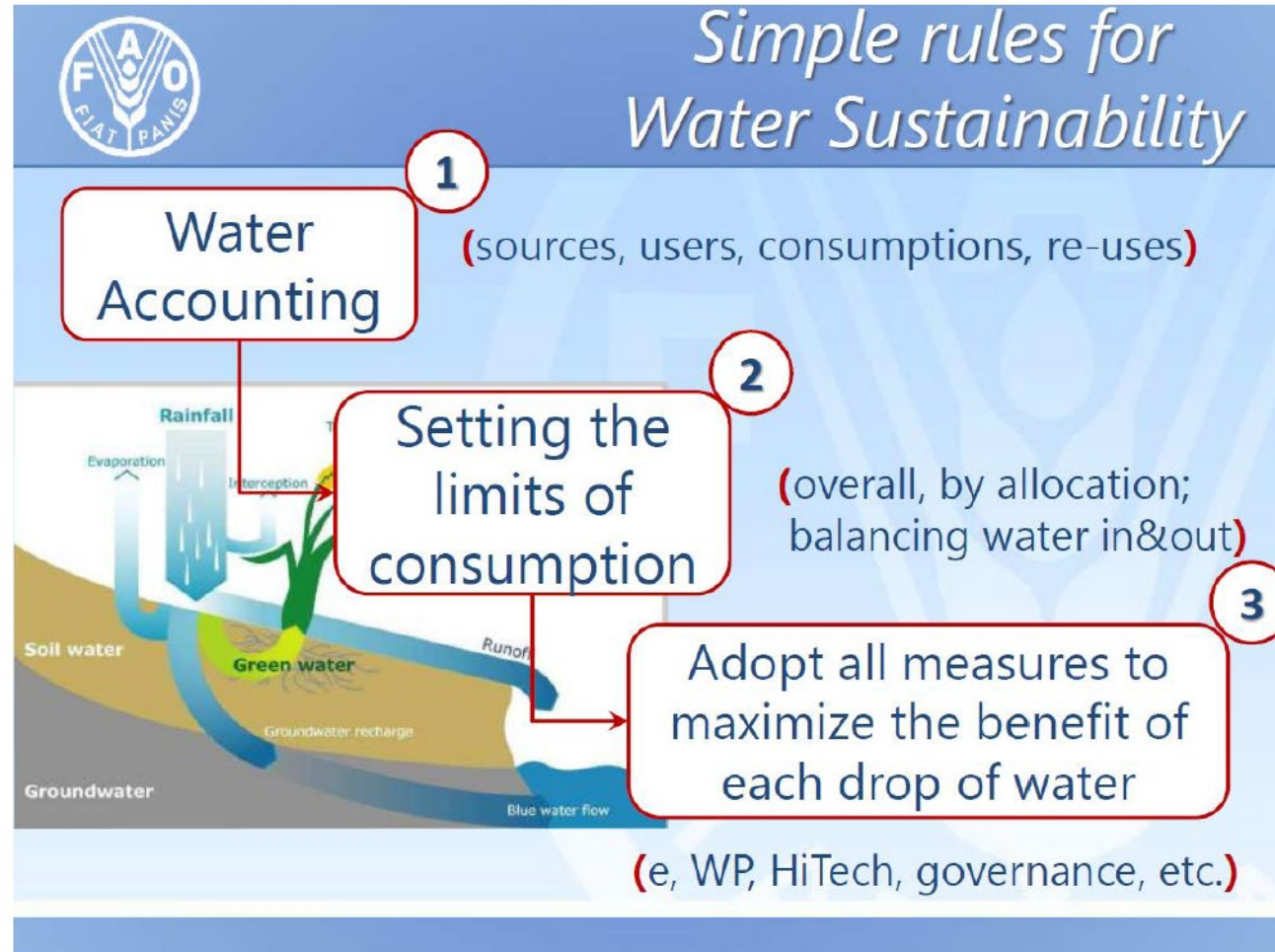
Availability driven by the hydrological cycle and infrastructure

Consumptive

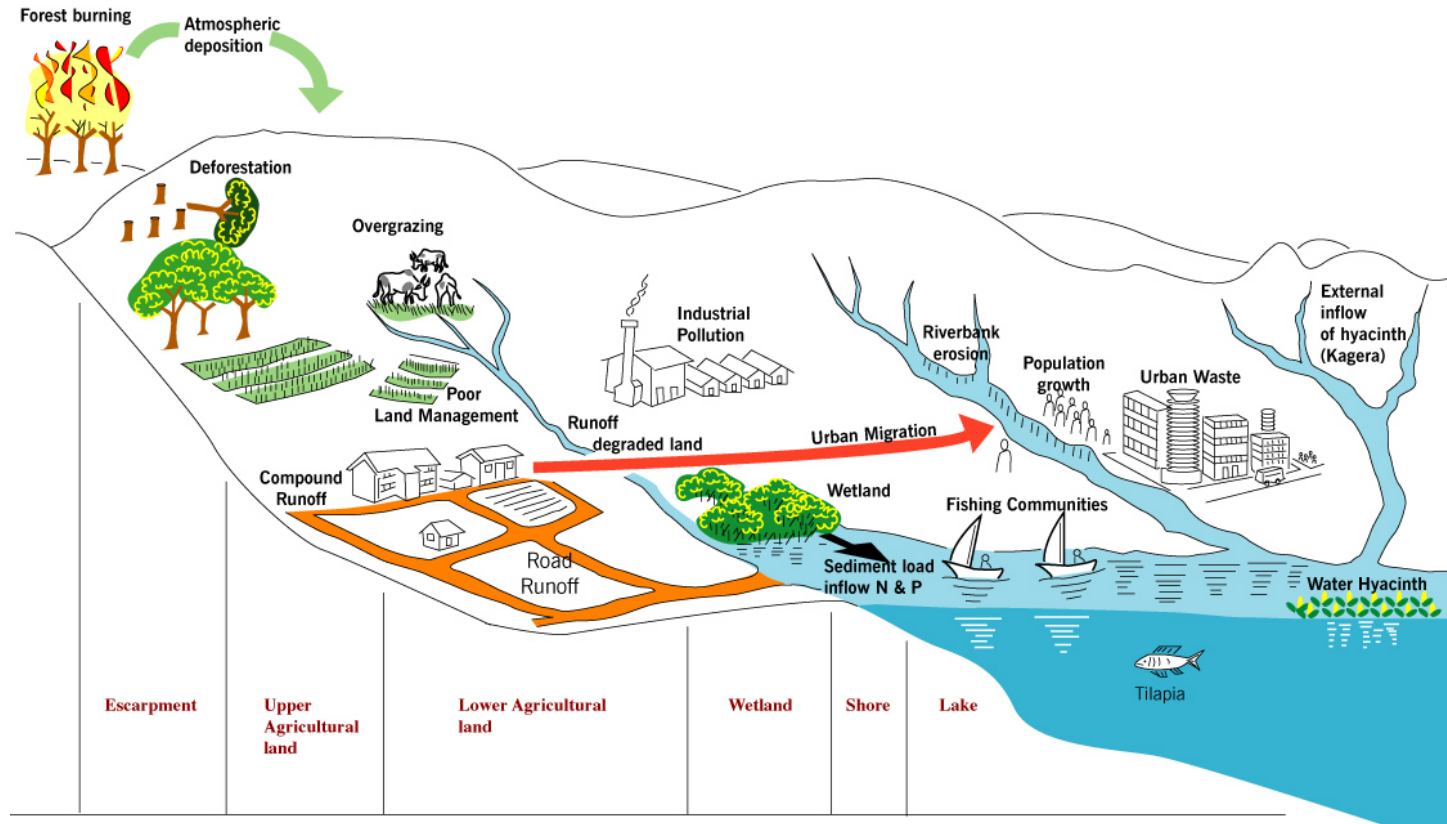
Non-consumptive use



Water Accounting: A simple idea to track a complex system



Integrated Water Resources Management



All water flows are embedded in drainage basins
creating interdependencies between uses and users

IWRM definition

Global water partnership (2000) defines IWRM –

*“IWRM is a process, which promotes the coordinated development and management of water, land and related resources, in order to maximize the resultant **economic** and **social** welfare in an **equitable** manner without compromising the **sustainability** of vital ecosystem.”*

- Water Resource Management of a river basin requires monitoring
 - water availability and
 - water demand
- To monitor water availability and demand:
 - Accurate identification and delineation of catchment and river channels
 - Characteristics of the basin – soil and vegetation, lakes and reservoirs, aquifer/groundwater storage
 - domestic, agricultural, and industrial within the basin
- Organized data and information at river basin level are key factor in order to implement Integrated Water Resource Management

Water Accounting: A multi-stakeholders platform

Water managers
Farmers
Irrigation specialists
Mayors
Lawyers
Energy utilities
Environmentalists
Industry representatives

Data Democracy

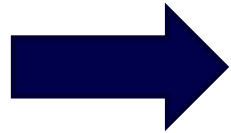
Standardized Framework

River basin reports

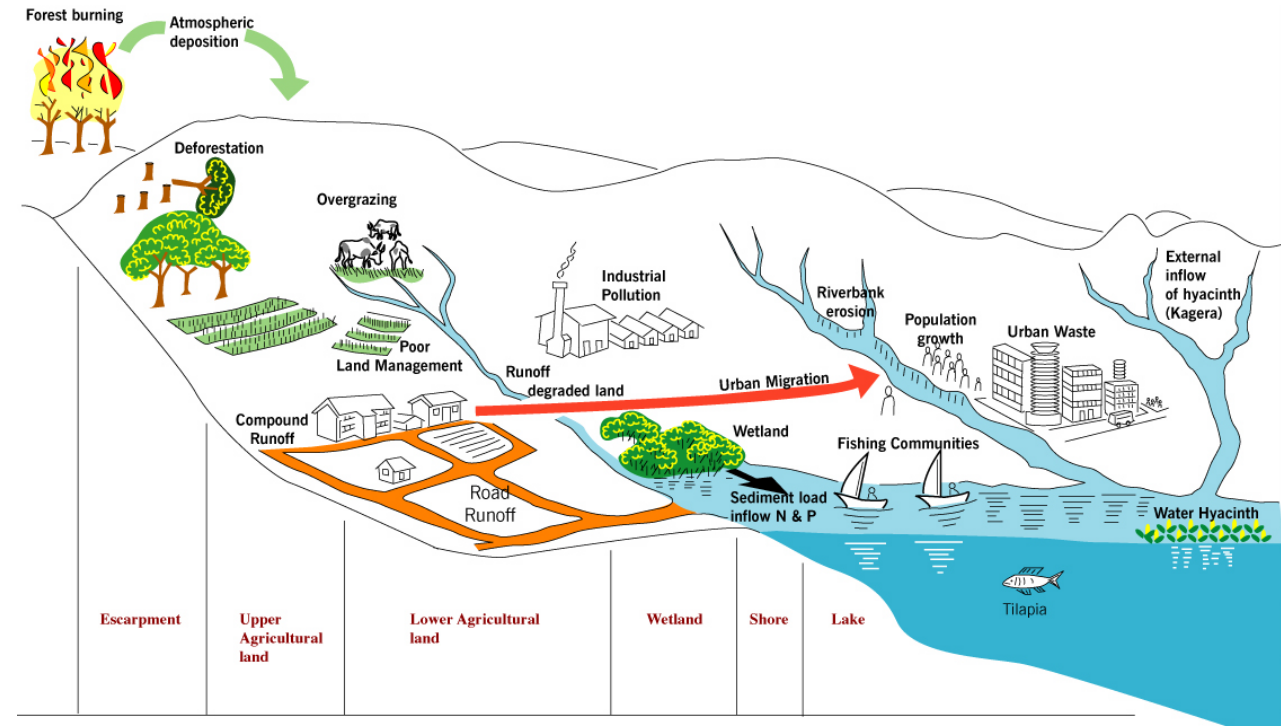


Data requirements

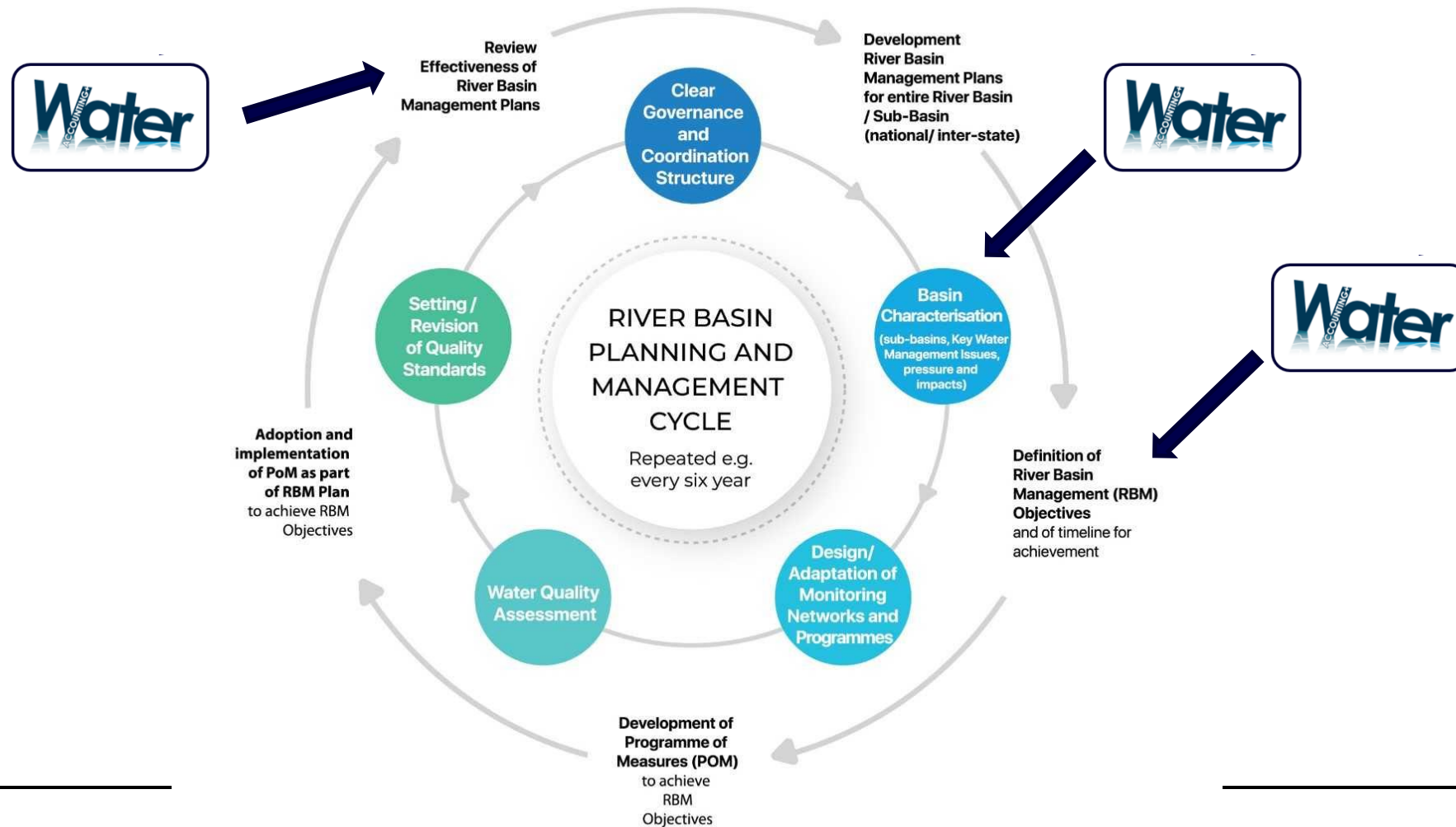
- To manage water resources you need to know
 - How much water is available
 - How much is being used and by which sector
 - Where is the water used
 - How efficient is water being used
 - ...



Requiring spatial disaggregated data on water availability and utilisation



Water Accounting is a tool for long-term planning



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The WA+ is a WA system based on Remote Sensing data

Examples

Main Differences between WA frameworks

Scale of application

Type of data used

Overall approach: what are they tracking and how

Main Categories of WA frameworks

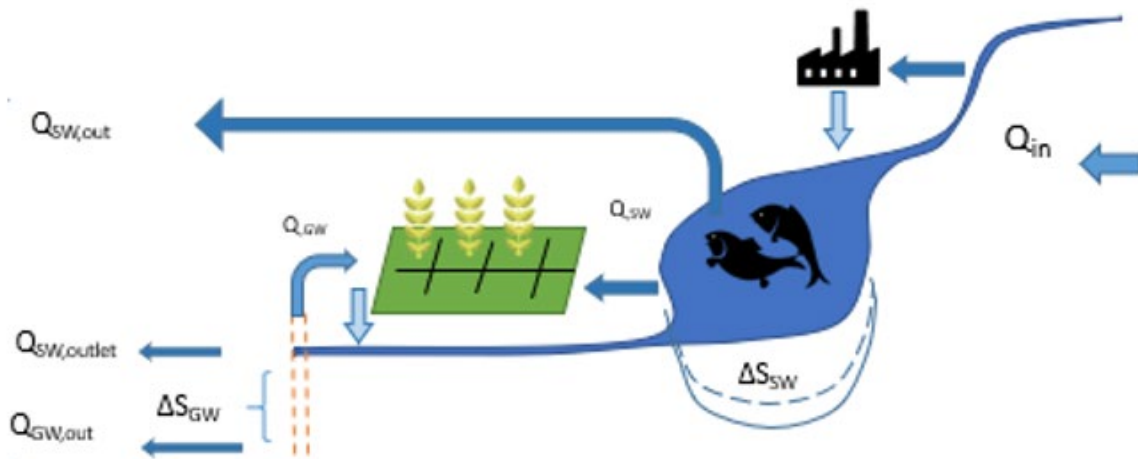
Two main categories:

FLOW ACCOUNTING: tracking and accounting actual flows, deliveries, and abstractions

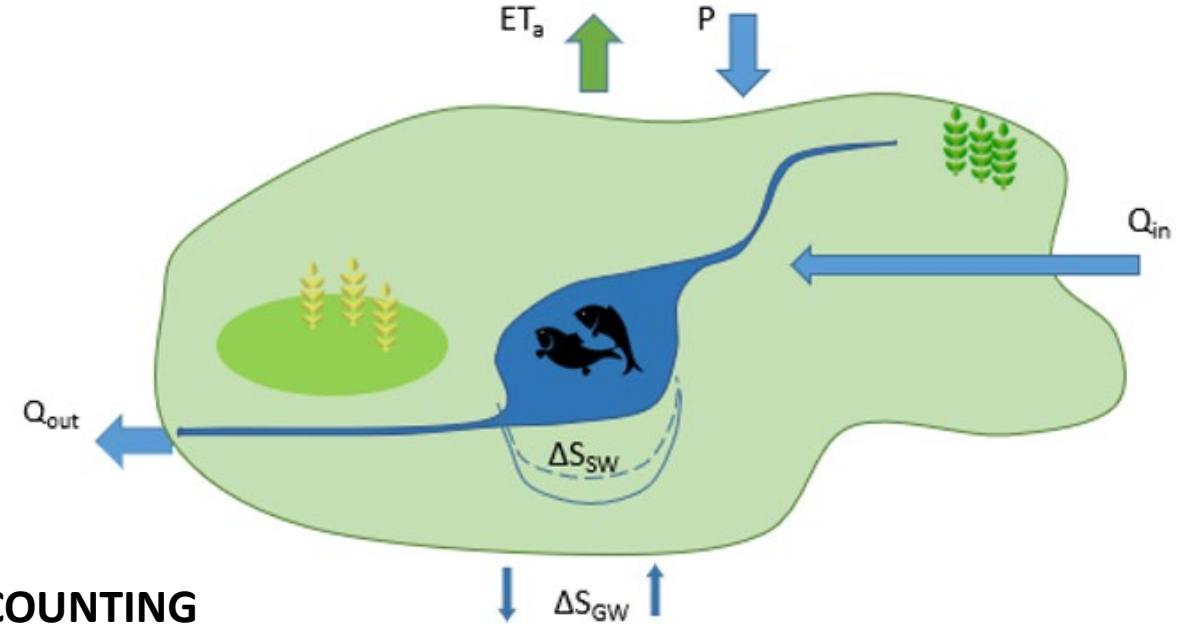
focusing mostly on blue water in cross-sectoral context

DEPLETION ACCOUNTING: focusing on water consumption with a landscape prospective

depleted water: ET, sinks, water in products



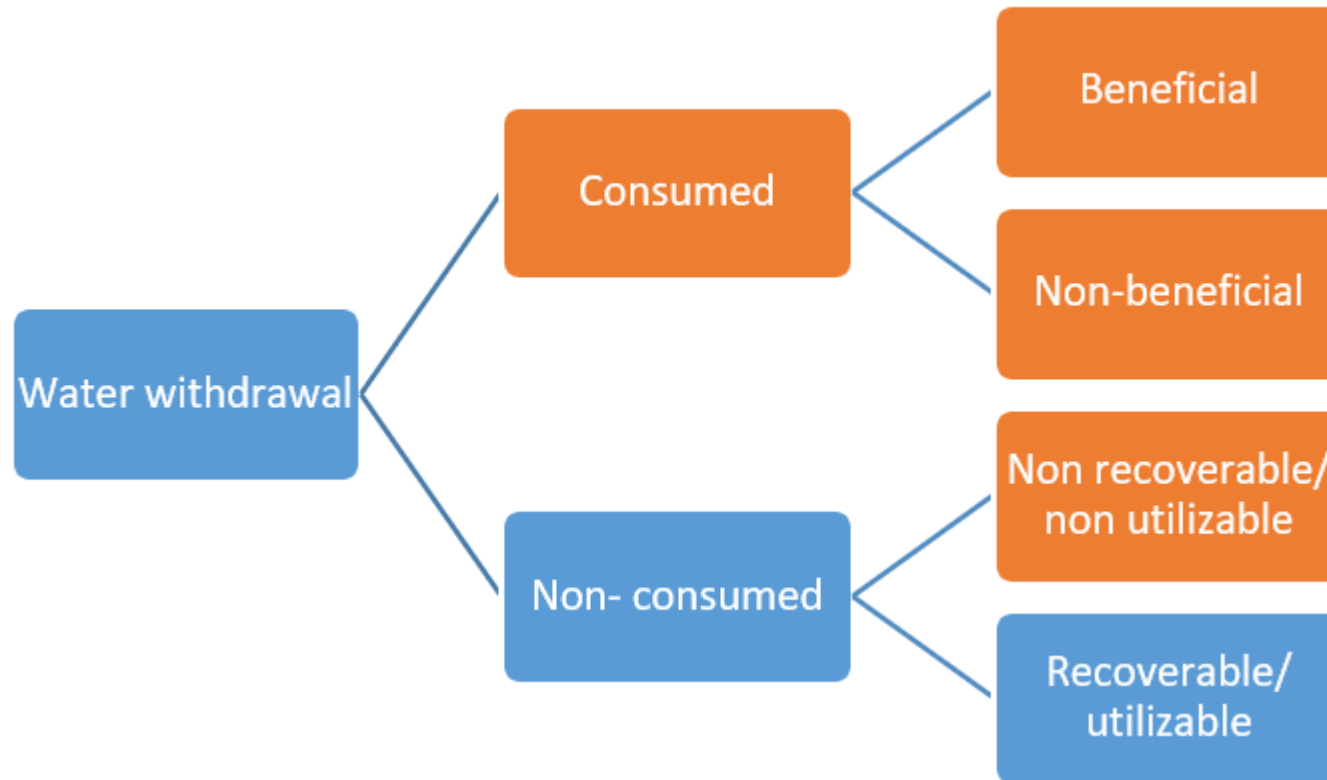
FLOW ACCOUNTING



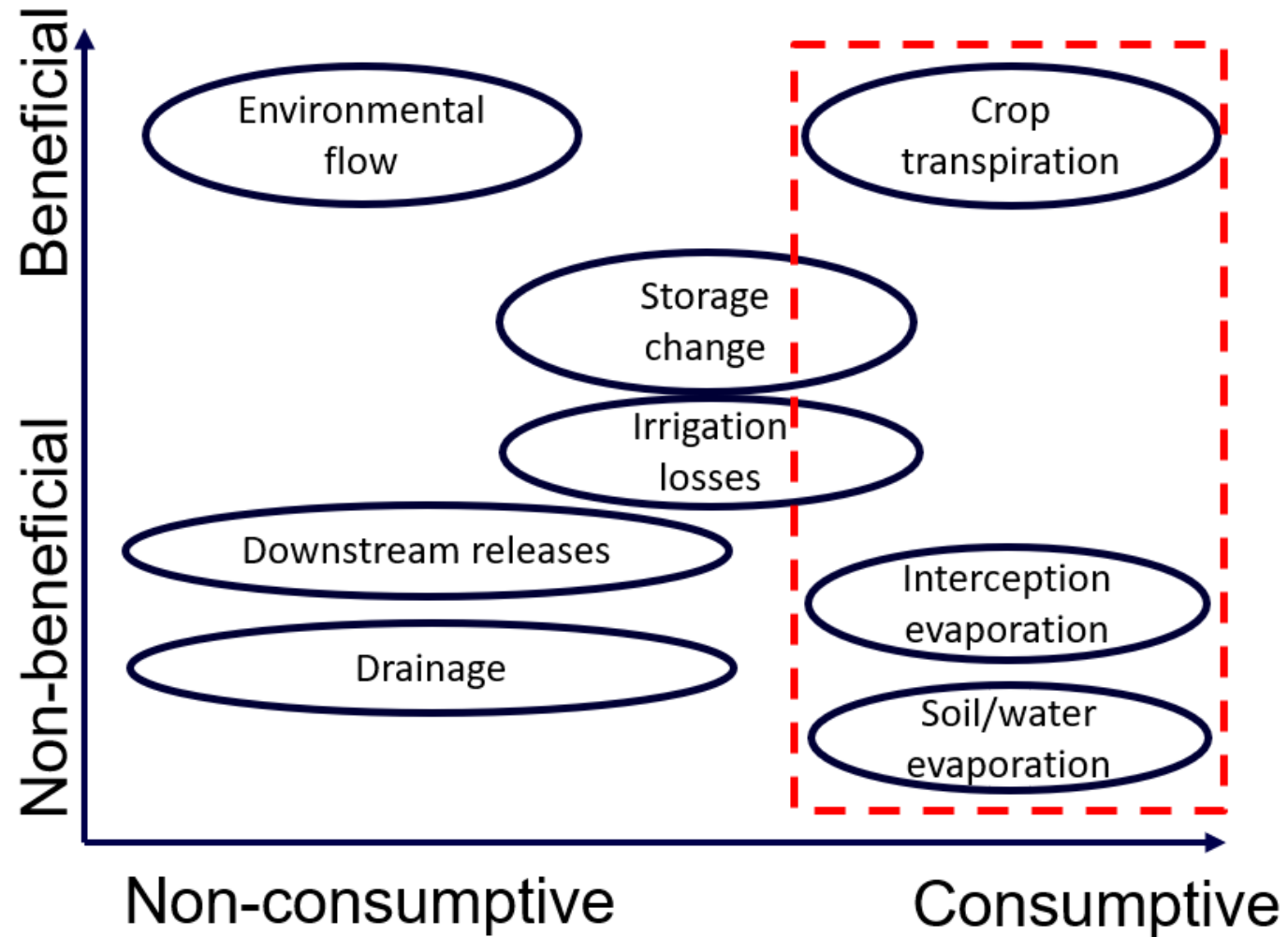
DEPLETION ACCOUNTING

Consumptive use of water

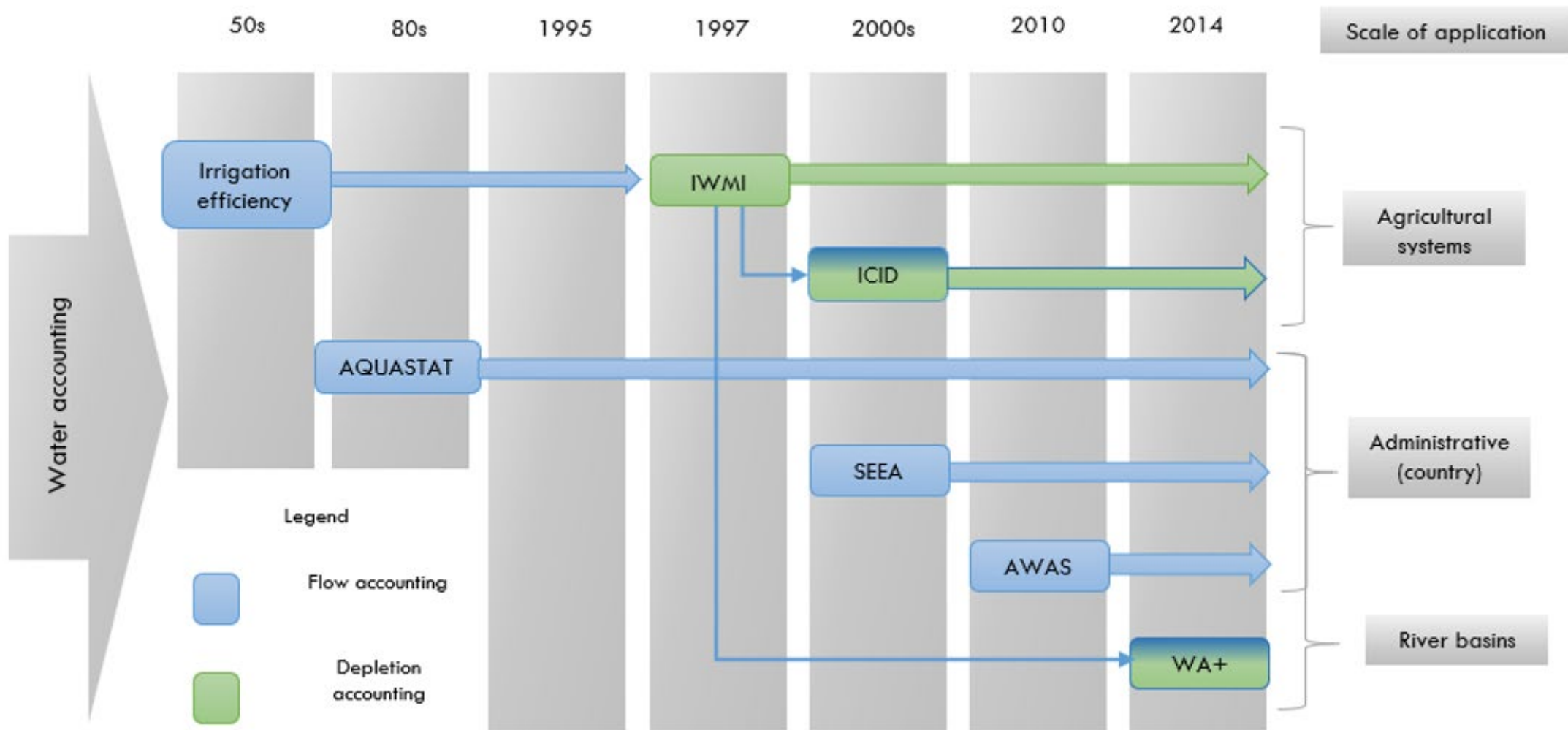
Depletion accounting can also include the concept of **non-recoverable** or **non-utilizable** water



Examples of consumptive use of water



History of Water Accounting Frameworks



Overcoming data issues

Use of remote sensing data, open source models and global datasets

Advantage for us:

data is available near-globally

data is available in a predictable manner

Advantage for stakeholders:

accounts are reproducible, based on open source code and data

 Transparency



Opportunities and limitations for using RS data for WRM&P

- In last decade reliability of RS data for WRM has improved significantly
- Continuous data set for various water resources related data sets (P, ET) for 10+ years
- Provides estimation of water consumption of largest water user (agriculture)
- Provides spatial information

But

- Need for adjusting hydrological models for incorporating water consumption data
- Requires ground validation data
- Long time series missing (>30 year) needed for trend analyses
- Methodology for scenario assessments (eg climate change etc) to be developed
- Water quality not well presented

Water Accounting Plus (WA+)

Hydrol. Earth Syst. Sci., 17, 2459–2472, 2013
www.hydrol-earth-syst-sci.net/17/2459/2013/
doi:10.5194/hess-17-2459-2013
© Author(s) 2013. CC Attribution 3.0 License.



Hydrology and
Earth System
Sciences



Water Accounting Plus (WA+) – a water accounting procedure for complex river basins based on satellite measurements

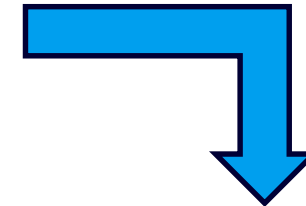
P. Karimi^{1,2}, W. G. M. Bastiaanssen^{2,3}, and D. Molden⁴

¹International Water Management Institute, Battaramulla, Sri Lanka

²Faculty of Civil Engineering and Geosciences, Water Management Department, Delft University of Technology, Delft, The Netherlands

³eLEAF Competence Centre, Wageningen, The Netherlands

⁴International Centre for Integrated Mountain Development, Kathmandu, Nepal



Water Accounting Plus (WA+)

Developed by IHE Delft in partnership with IWMI and FAO

- Geographical domain: river basin
- Combination of flow and depletion accounting
- Data acquisition
 - Open access spatial data bases and remote sensing data
 - Other open access data and information
 - Validated using ground observations and literature values
- Data analyses
 - Standardized analyses
 - Using open access programming tools and scripts (python, QGIS)
- Reporting
 - Standardized sheets, maps, tables and graphs

Data collection
gaps identification



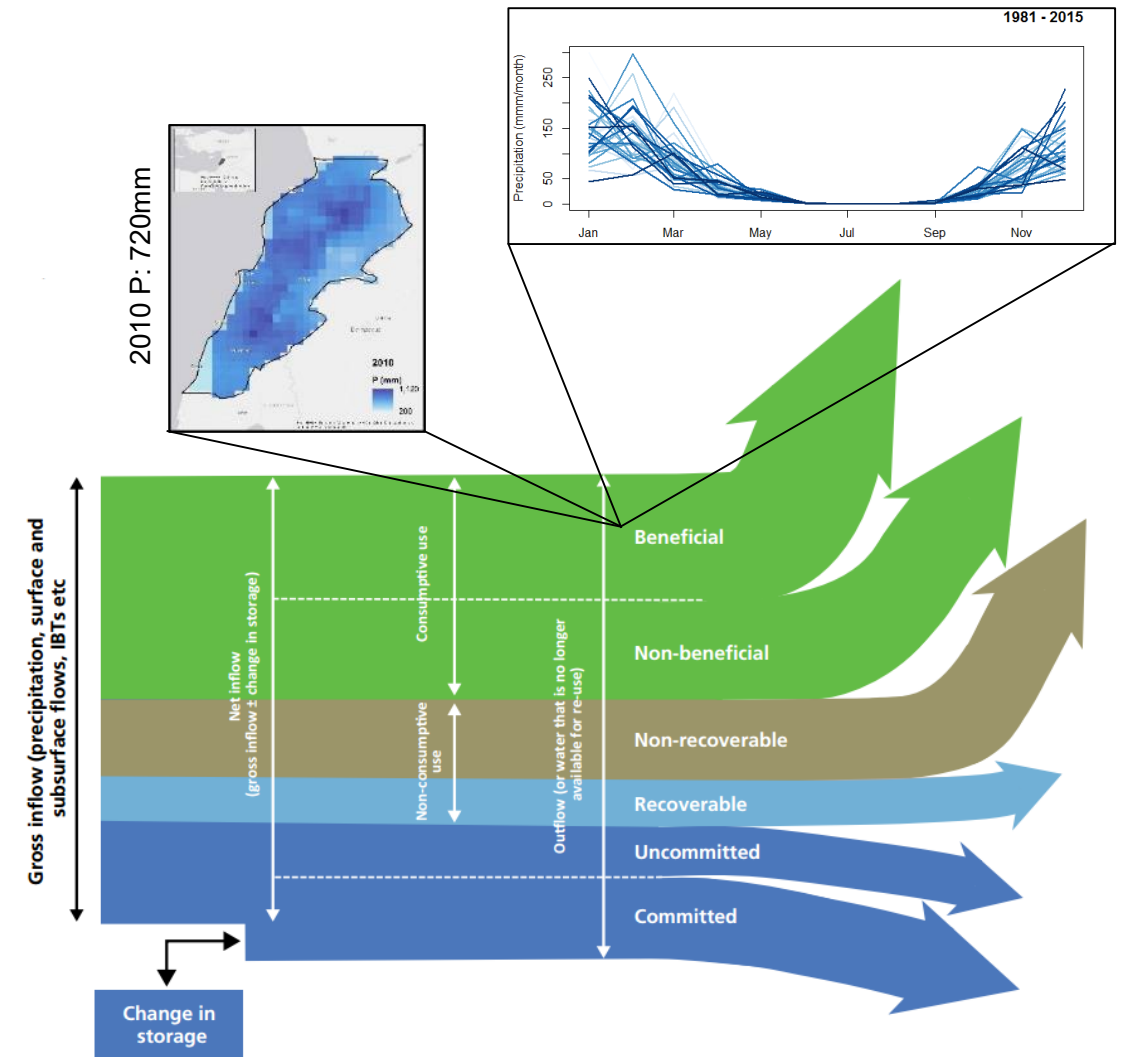
Data analysis
from data to
information



Communication
making information
available to stakeholders

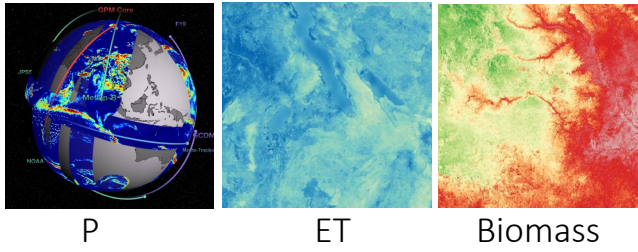
Water Accounting Plus (WA+)

WA+ attempts to make WA
scalable
spatially explicit
temporally detailed

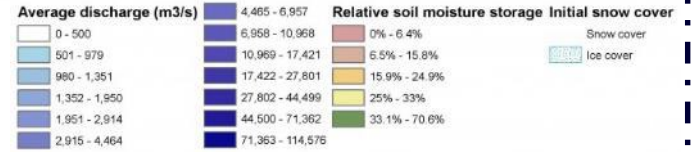
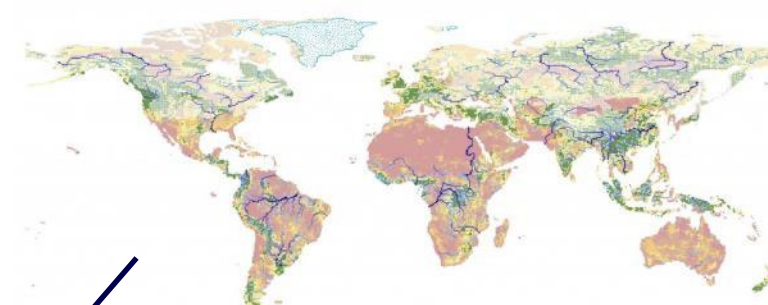


Remote Sensing

Global Datasets



P ET Biomass



Ground measurements



Sheets

Sheet 8: Agricultural services
Part 1: Agricultural water consumption (km³/yr)
Basin: Nile basin
Period: 2005

Crop										Agricultural water consumption	
Cereals	Non-cereals	Fruit & vegetables	Oil seeds	Feed crops	Reverend crops	Other crops					
7.9		53.9	46.7	2.0		26.3	61.9	0	ET	value	223.0
ET from rainfall: irrigated											
2.3		3.8	0.4	0.6		7.2		0	ET from rainfall: irrigated	value	14.2
Incremental ET: irrigated											
15.6		11.0	1.7	3.3		8.3		0	Incremental ET: irrigated	value	31.0
Total ET: irrigated											
12.9		14.9	2.1	3.9		15.9		0	Total ET: irrigated	value	61.0

Non-crop		Agricultural water consumption	
Forestry	2.5		0.0
Urban			0.0
Other			0.0
Total	2.5		0.0



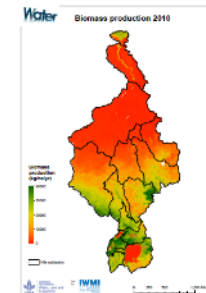
Tables

ET Sheet
Basin: Nile basin
Period: 2005

Table 1: Distribution of evaporation by land use class

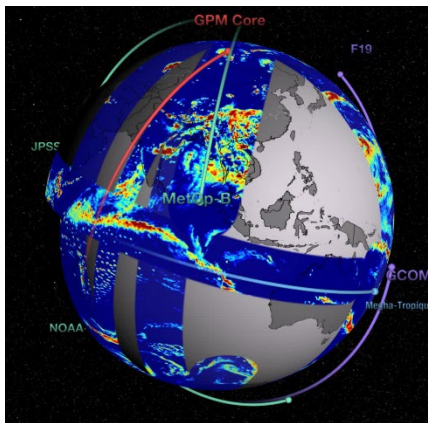
Land use class	Area	Transpiration	Evaporation	Transpiration	Evaporation	Total ET	Total ET		Transpiration	Evaporation	
							mm/day	mm/day			
Production (m³/yr)											
Produced in basin	487381	22812	14228	8822	0	47978	2	3072	10328	0	85328
Produced in other	250231	10710	6221	3279	0	17790	8	807	2876	0	21573
Consumption (m³/yr)											
Consumption in basin	72836	2162	1827	108	0	2322	0.8	107	180	0	1488
Consumption in other	12780	76	162	33	0	258	0.3	147	211	0	183
Production (m³/yr)											
Produced in basin	572828	1472	1812	173	0	6747	2	1268	3291	0	15292
Produced in other	0	0	0	0	0	0	0	0	0	0	0
Consumption (m³/yr)											
Consumption in basin	84266	1476	1176	115	0	1689	0.6	539	910	0	1648
Consumption in other	889588	18988	18193	1715	0	97766	18	1815	18518	0	11776

Maps

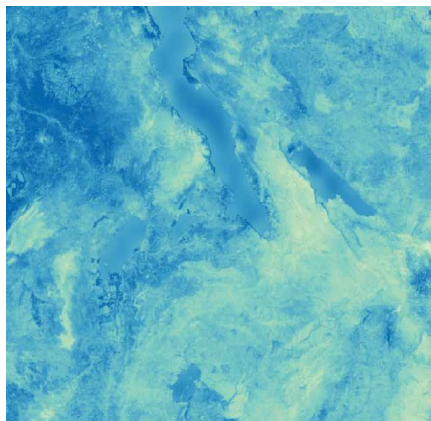


Water Accounting Plus (WA+): using RS for water resources management

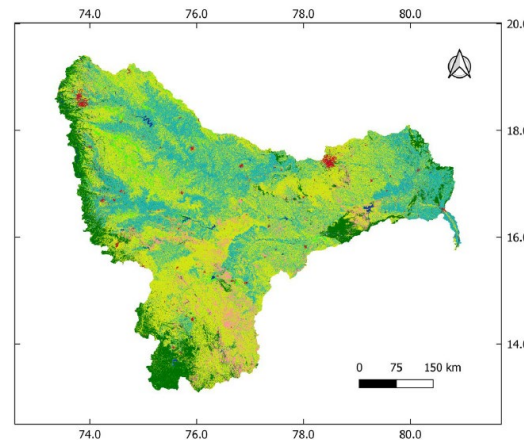
Rainfall



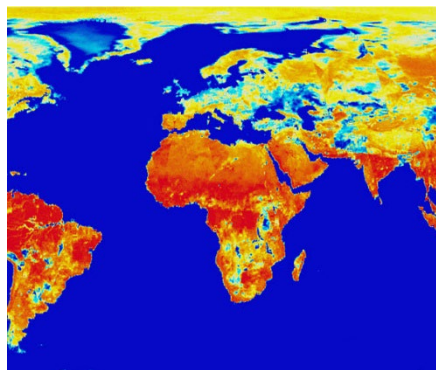
Evapotranspiration



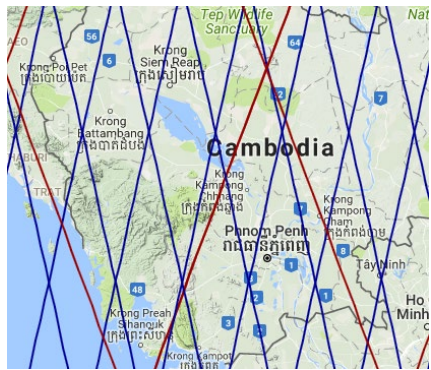
Land use



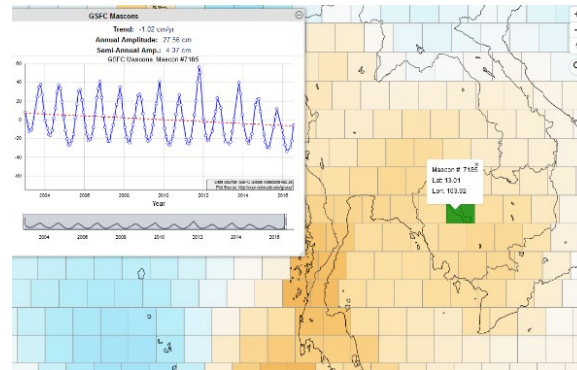
Soil Moisture



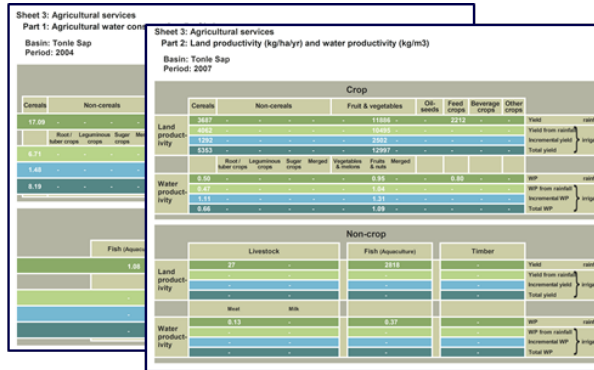
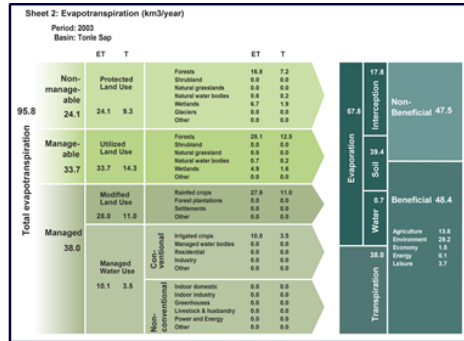
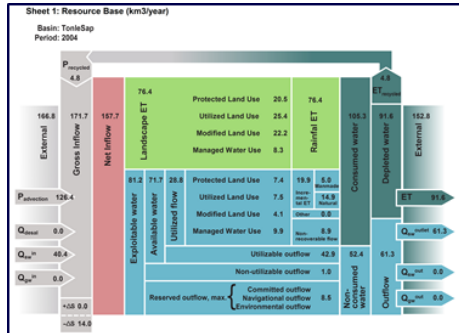
Water Levels



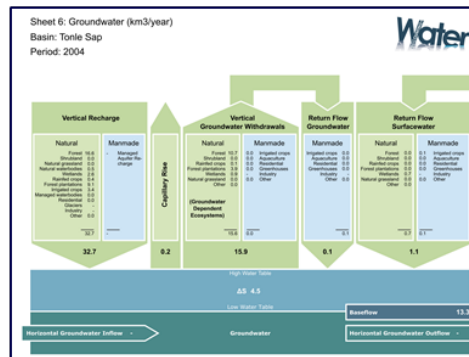
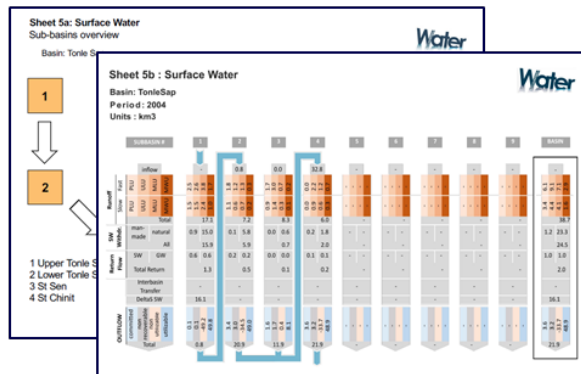
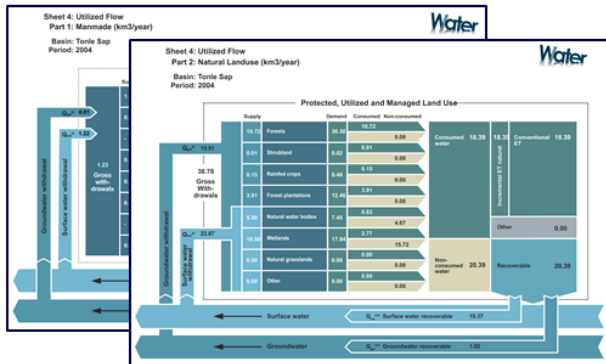
Groundwater



Water Accounting Plus (WA+)



Finger diagram → thematic accounting sheets



Water Accounting Plus (WA+): river basin management options

- Modify water flows
 - Diversions
 - Retentions
 -
- Modify land use practices
 - Cropland
 - Urban
 - Forests
 -

Protected Land Use



Utilized Land Use

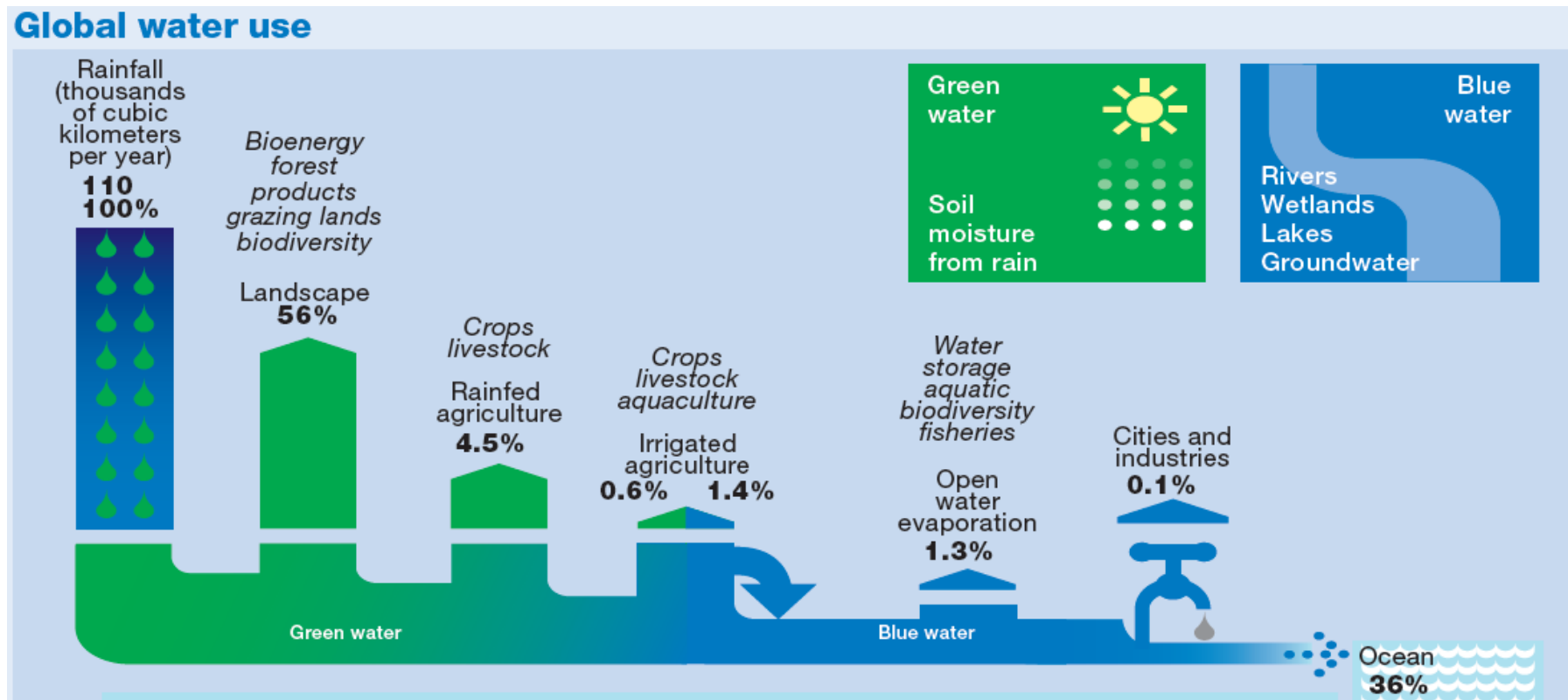


Modified Land Use



Managed Water Use

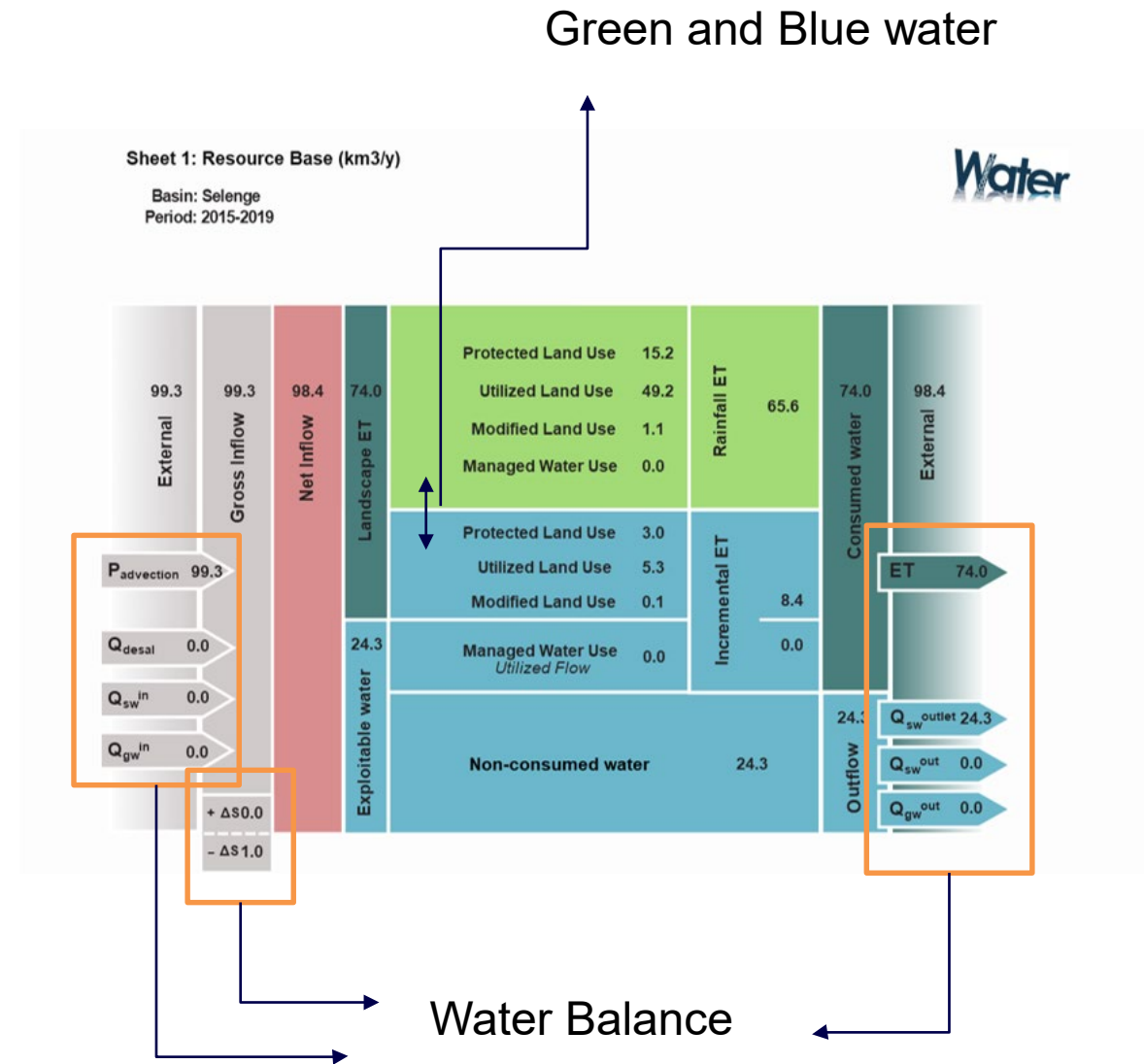
Water Accounting Plus (WA+): concepts of green and blue water



WA+: Sheet 1 Resource base

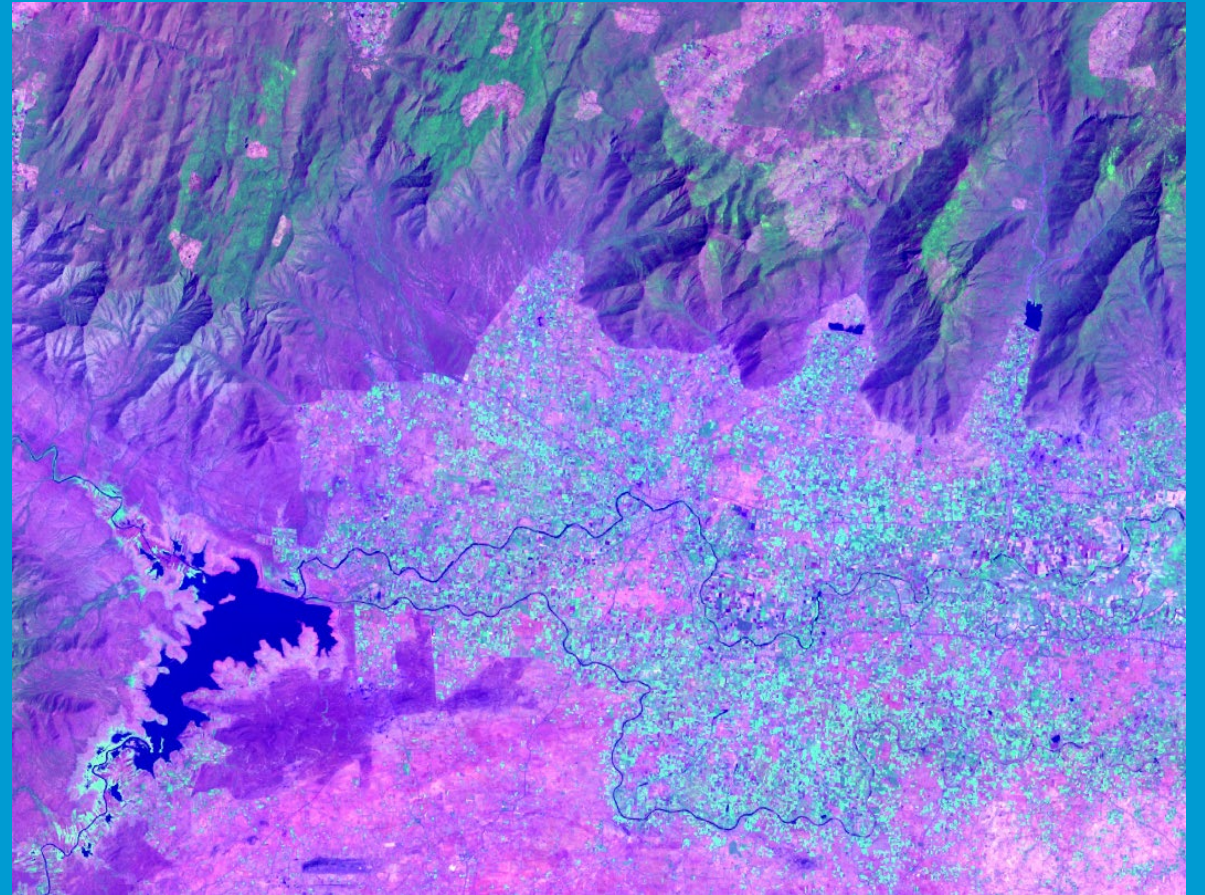
General overview at river basin scale of

- water availability vs water consumption
- exploitable flows
- manageable vs unmanageable flows
- over-exploitation
- green and blue water

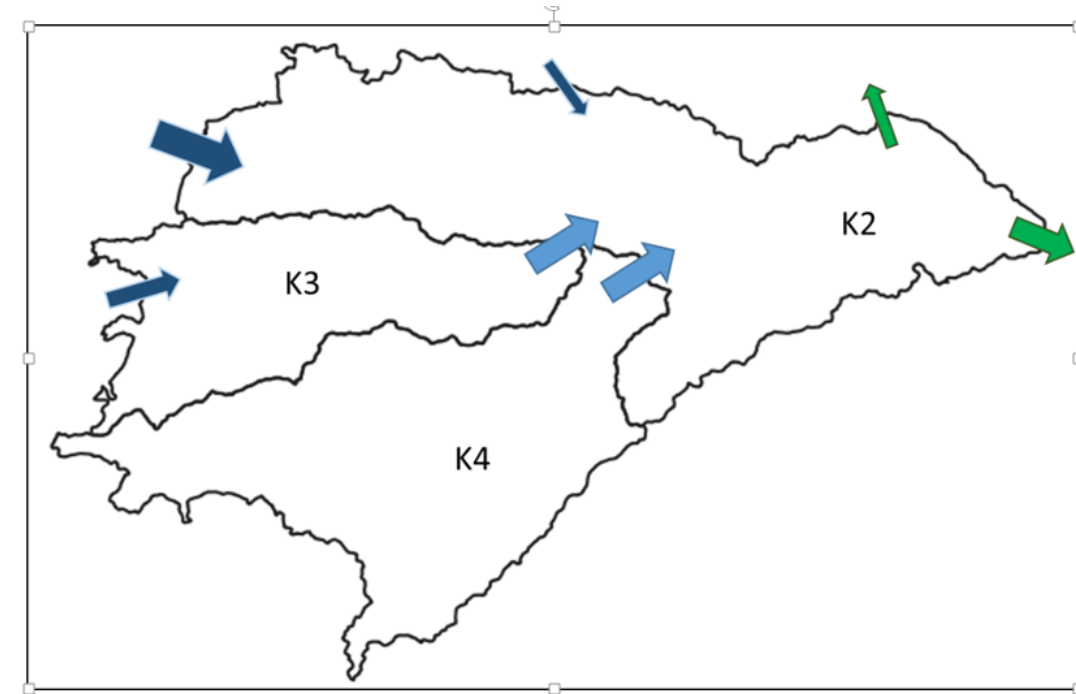
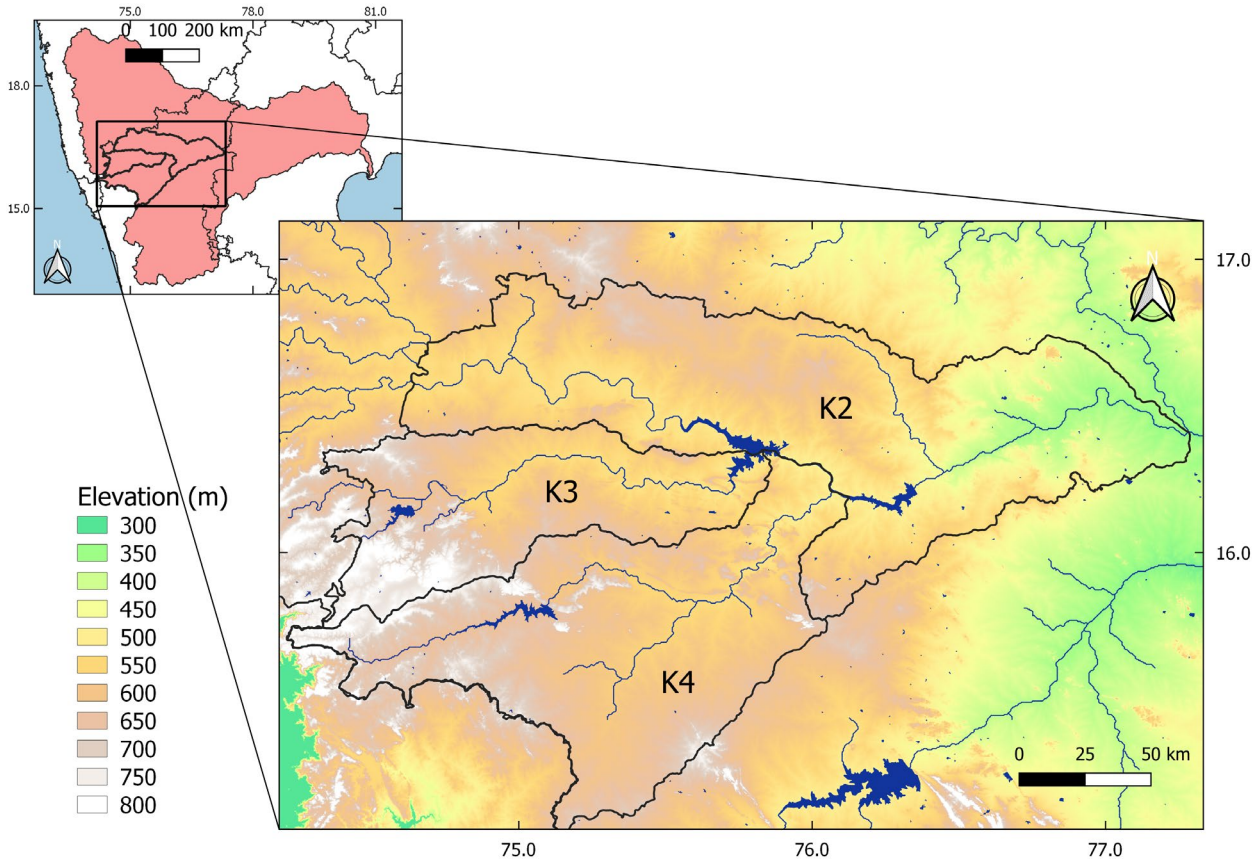


Examples of the application of WA+ in India

*Results from a recent
ADB funded project*



Case Study: 3 Krishna sub-basins in Karnataka

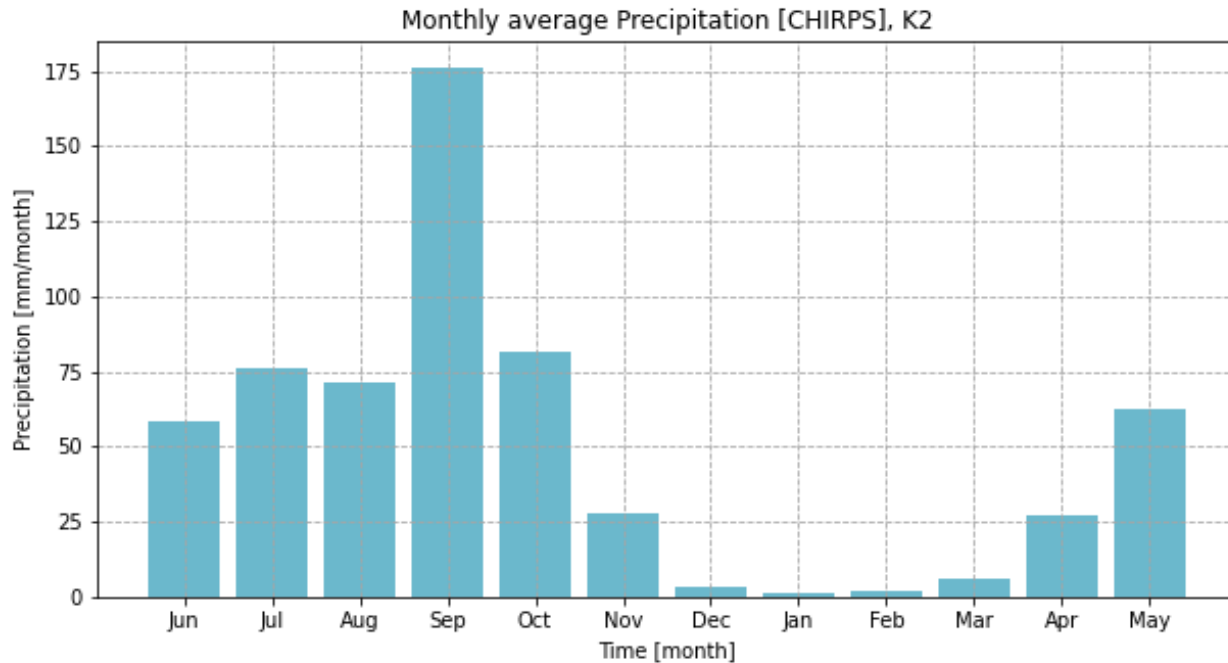


Sub-basin	Area in Karnataka (km ²)	% area of Krishna basin in Karnataka	Average elevation (m) (min and max)	Average yearly rainfall (mm/yr), CHIRPS (2006-2018)
K2: Middle Krishna	15,829	13.93%	530 (308-796)	594
K3: Gatprabha	6,833	6.02%	633 (484-1024)	714
K4: Malprabha	11,780	10.38%	627 (167-1022)	671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

Data Collection

Dataset	Start	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	Temporal resolution	Used
Precipitation																
CHIRPS	1981														monthly	X
CHIRPS	2007														daily	X
GPM v5	2014														monthly	
GPM v6	2007														monthly	
GPM v6	2007														daily	
TRMM	1998														monthly	
Evapotranspiration																
<u>SSEBop</u>	2003														monthly	X
ALEXI	2003														monthly	
CMRSET	2003														monthly	
<u>ETens</u>	2003														monthly	
SEBS	2000														monthly	
Other data																
ASCAT (SWI)	2007														daily	
LAI	2007														8-daily	X
GPP	2007														8-daily	
NPP	2007				Data is currently unavailable due to unexpected errors in the input data										yearly	
DMP	2014														decadal	X
GDMP	2014														decadal	X
ET reference	2007														monthly	X
ET reference	2007														daily	
GRACE	2003														monthly	
GLDAS <u>gs</u>	2007														monthly	
GLDAS <u>gbs</u>	2007														monthly	

Data Validation and Analysis

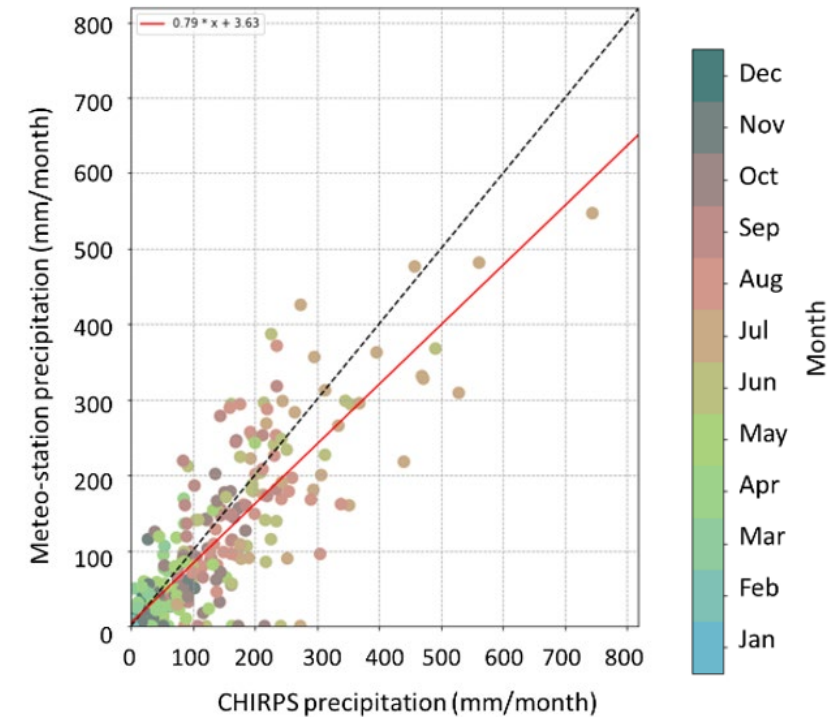


Monthly average
2007-2019

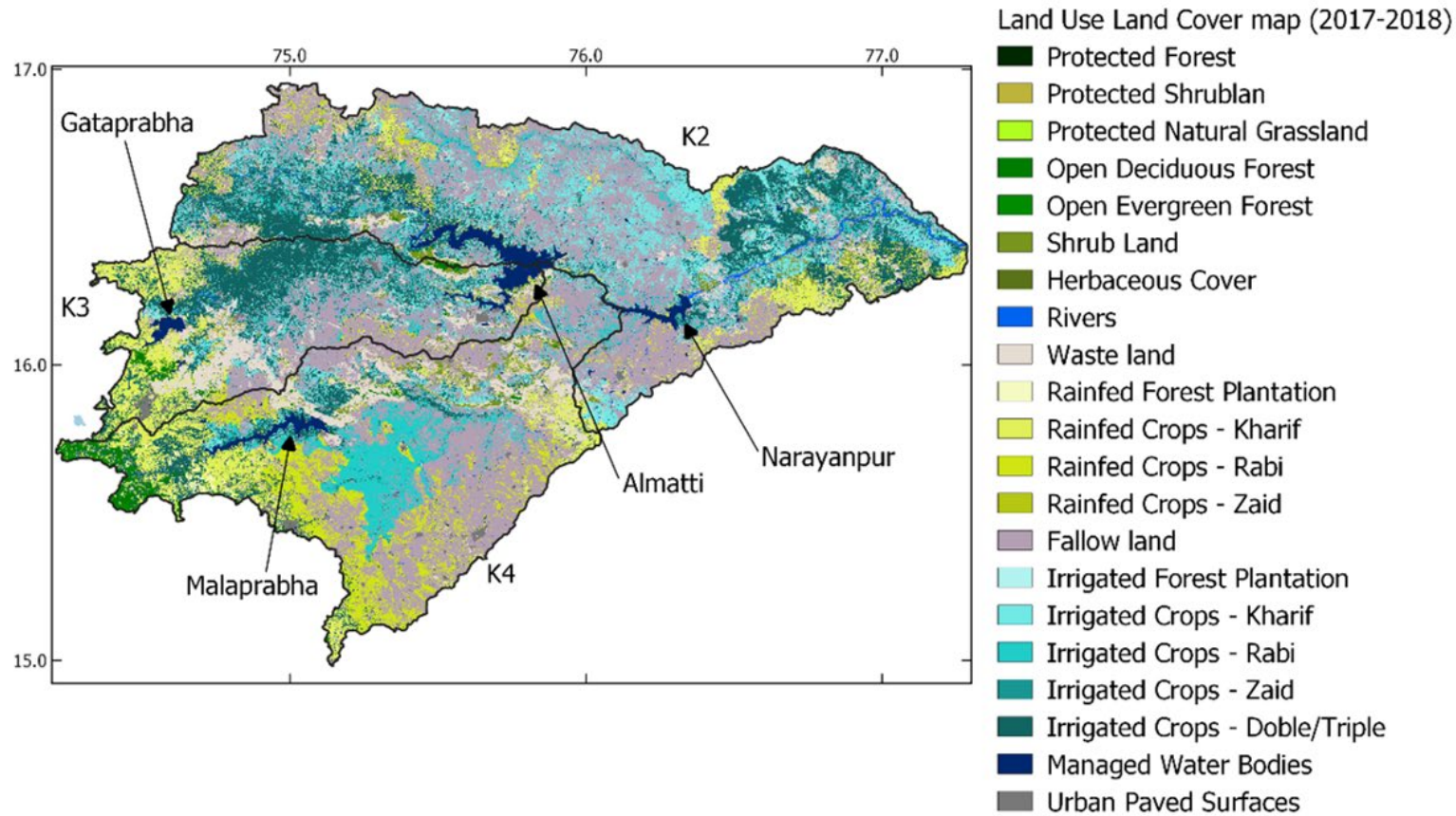
→ strong seasonal
variation

CHIRPS data validated with 139 stations

Dataset	Average NS	Average Pearson Coefficient	Average Relative Bias	Average RMSE
CHIRPS	0.32	0.73	0.93	52.67
TRMM	0.45	0.77	0.68	71.12
GPM	0.48	0.78	0.71	62.88



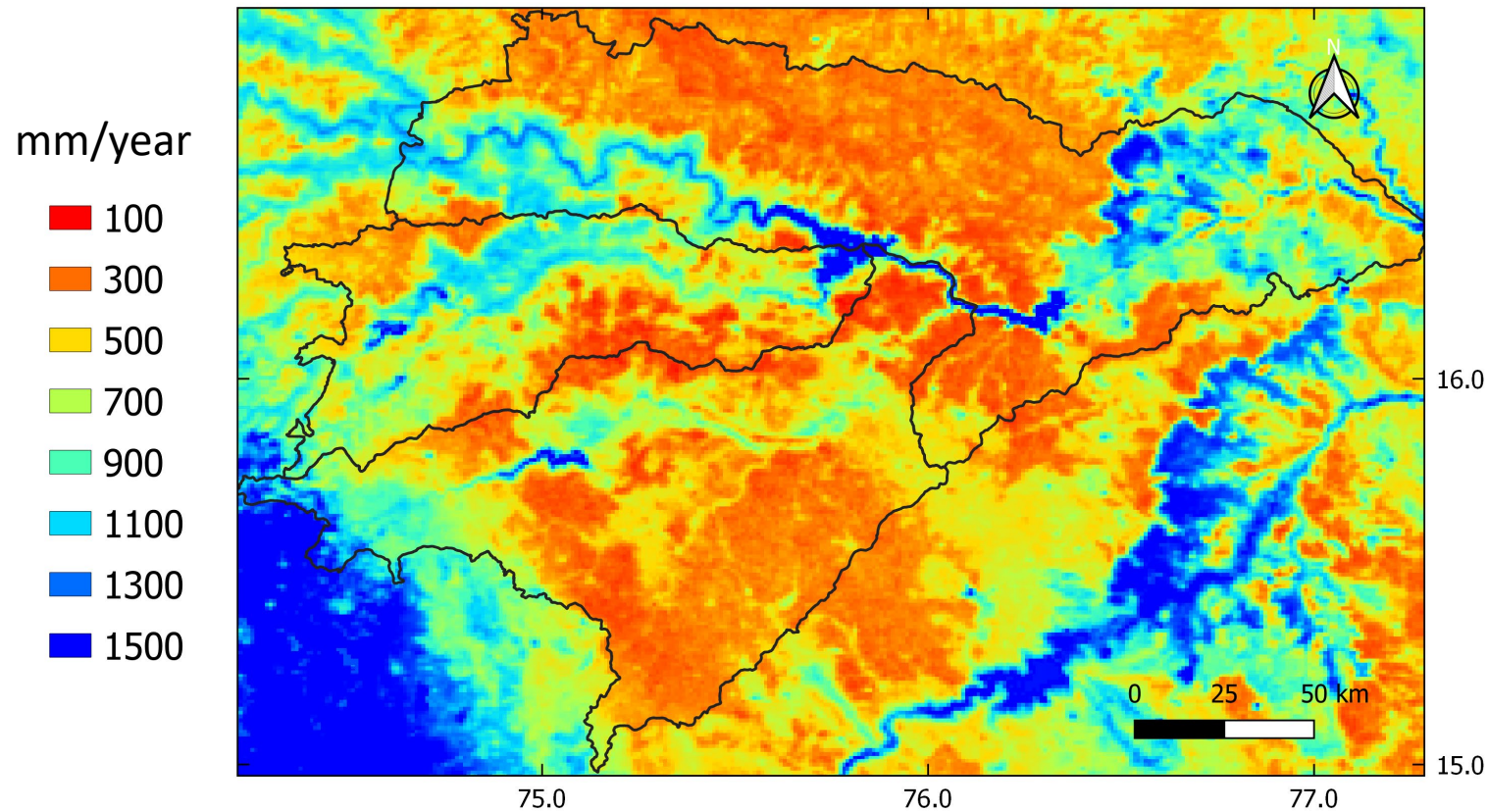
The 3 sub-basins are highly modified by human activity



2010 → 2018

Cultivated area –16.5% (especially double and triple crops)

Spatial Distribution of Water Consumption



RS-based evapotranspiration:
SSEBop (global ET product)

SSEBop was the only RS open access product available in recent years in India at the time of this study
Low values of ET (100-300 mm/yr) seems too low for this climatic zone (up to 600 mm/yr rainfall)

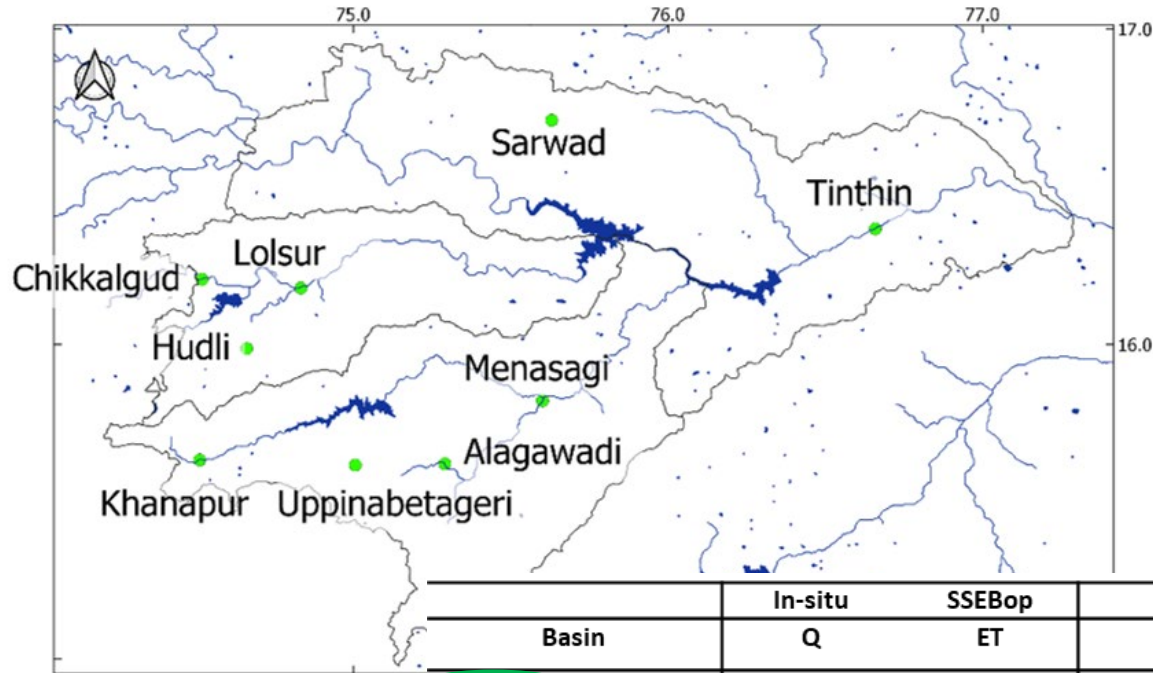
→ **Additional validation required!**

Data Selection: RS yearly water balance v.s. in-situ measurements

We need to know the physical boundaries of the watersheds, and inflows and outflows

Nine stations:

$$\frac{\Delta S}{\Delta t} = P - ET - Q_{out} + Q_{in}$$

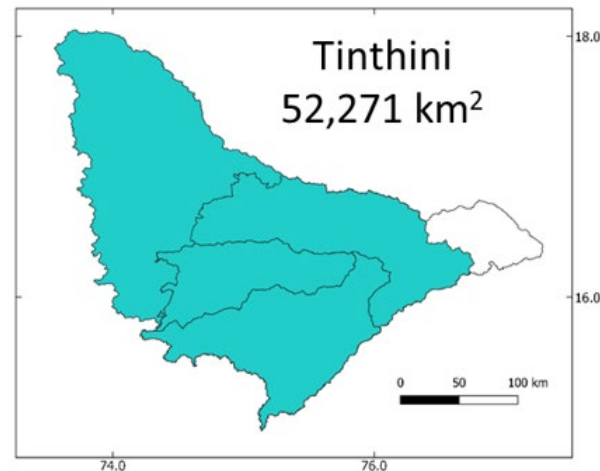


10 year period

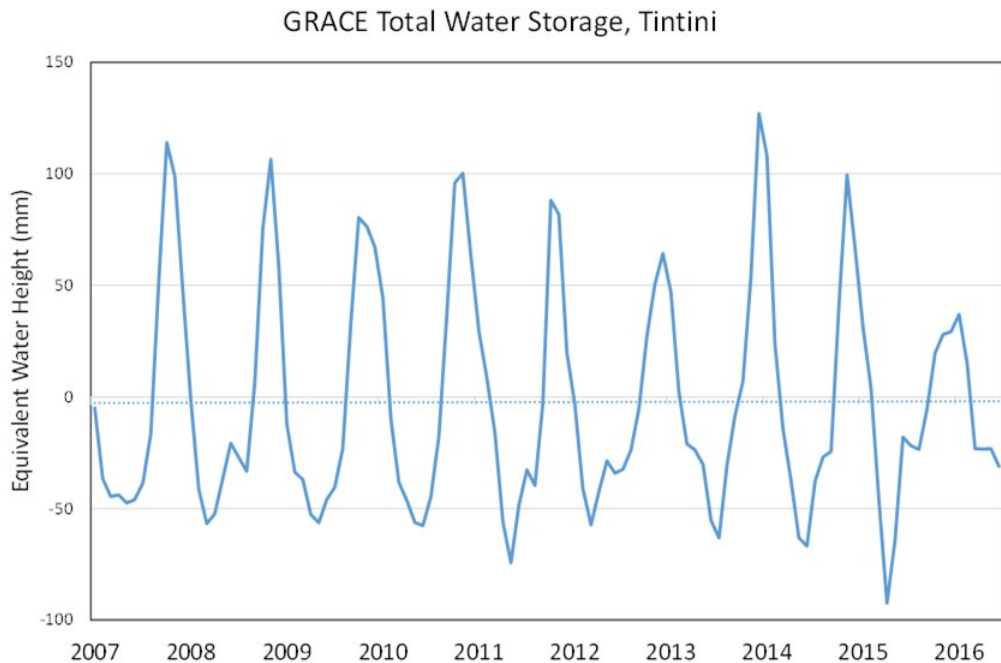
Basin	In-situ		SSEBop				GPM				CHIRPS			
	Q	ET	P	P-ET- $\frac{\Delta S}{\Delta t}$	Diff	% Diff	P	P-ET- $\frac{\Delta S}{\Delta t}$	Diff	% Diff	P	P-ET- $\frac{\Delta S}{\Delta t}$	Diff	% Diff
Thintini	13,076	33,106	59,092	26,421	13,345	102	46,620	13,950	873	7	46,620	13,950	873	7
Menasagi	418	1,823	4,489	2,667	2,249	538	2,791	969	551	132	2,791	969	551	132
Lolsur	1,633	3,183	6,320	3,137	1,505	92	5,126	1,943	311	19	5,126	1,943	311	19
Alagawadi	122	578	1,502	924	802	656	807	230	108	88	807	230	108	88
Khanapur	1,348	581	1,061	480	-868	-64	876	295	-1,053	-78	876	295	-1,053	-78
Chikkalgud	1,990	864	1,841	977	-1,014	-51	1,543	678	-1,312	-66	1,543	678	-1,312	-66
Sarwad	80	191	387	196	116	144	391	200	120	149	391	200	120	149
Hudli	115	190	406	215	100	87	288	98	-17	-15	288	98	-17	-15
Uppinabetageri	25	160	367	207	183	741	218	57	33	133	218	57	33	133

More in-depth analysis at Tinthini station

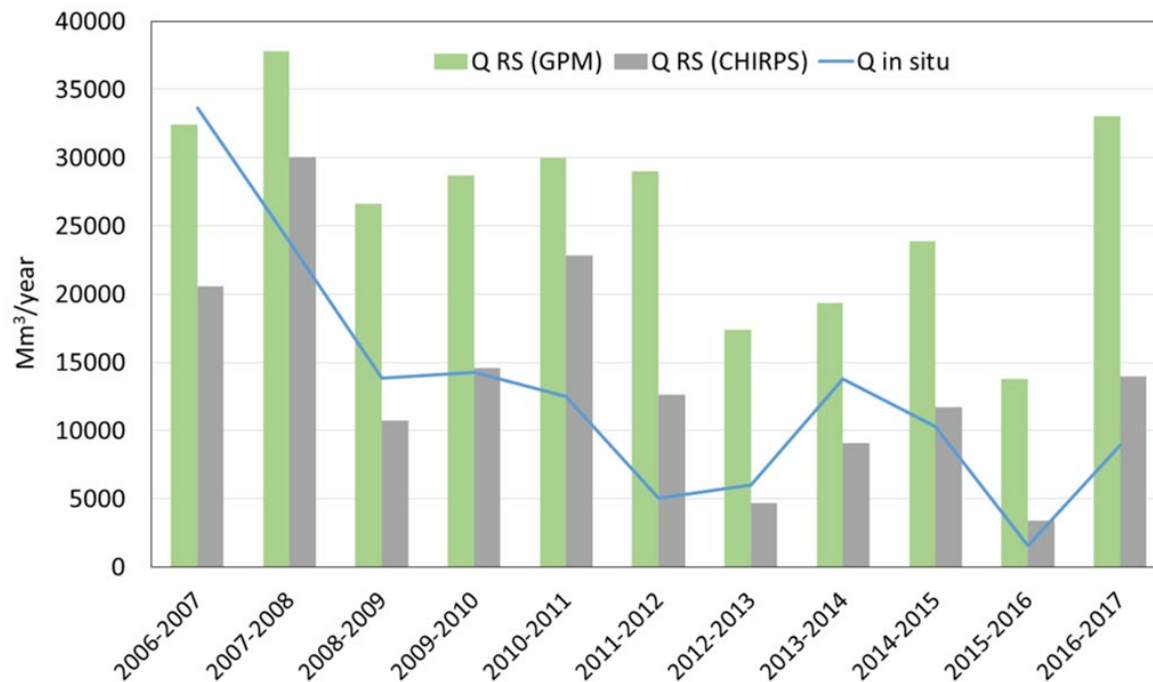
Largest watershed



No significant long-term trend in storage change was observed by GRACE (slightly negative)



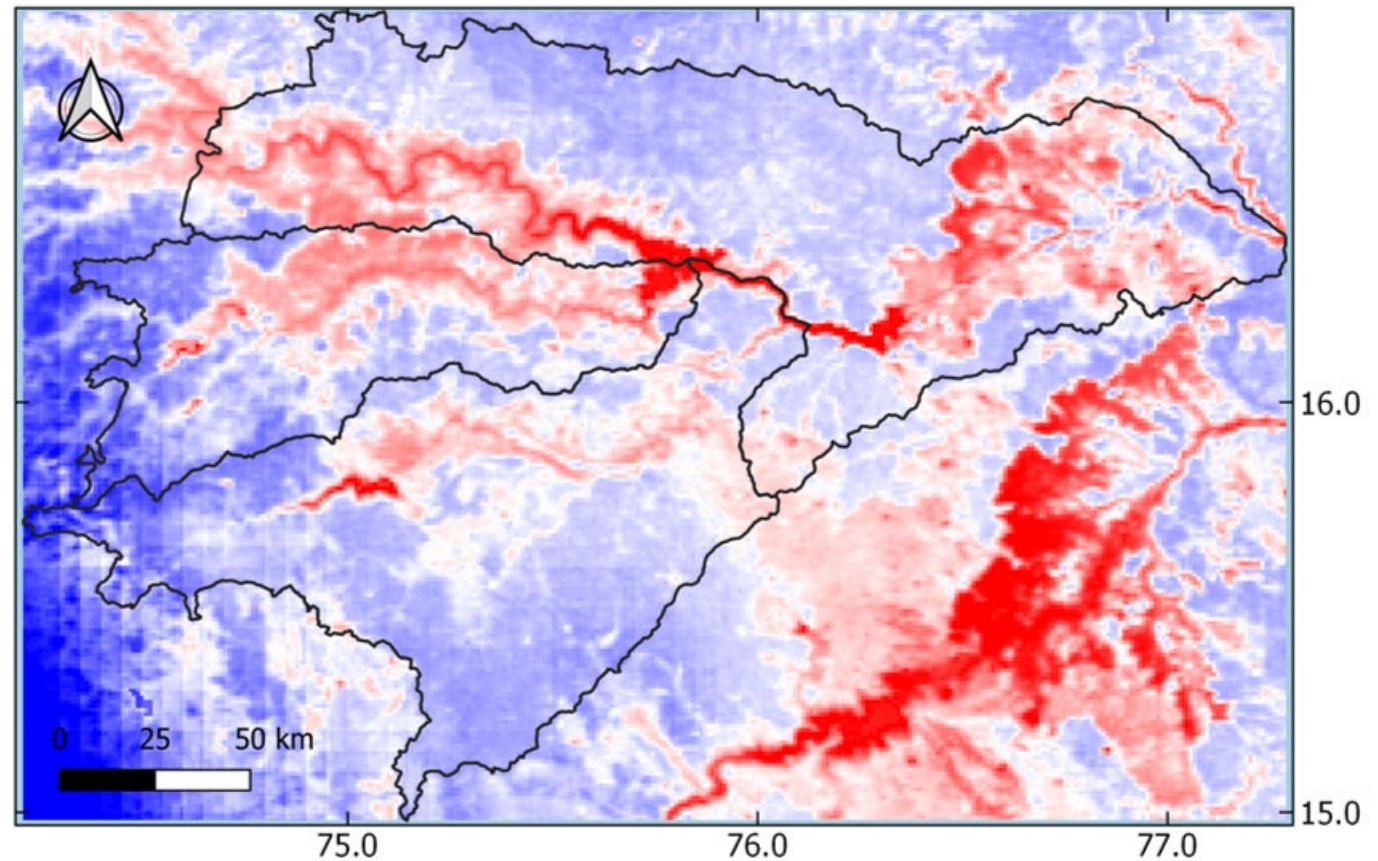
The water balance computed with CHIRPS data has a closer match to the observations



Water Yield (P-ET)

$P > ET \rightarrow$ runoff generation (blue)

$P < ET \rightarrow$ net consumption (red)



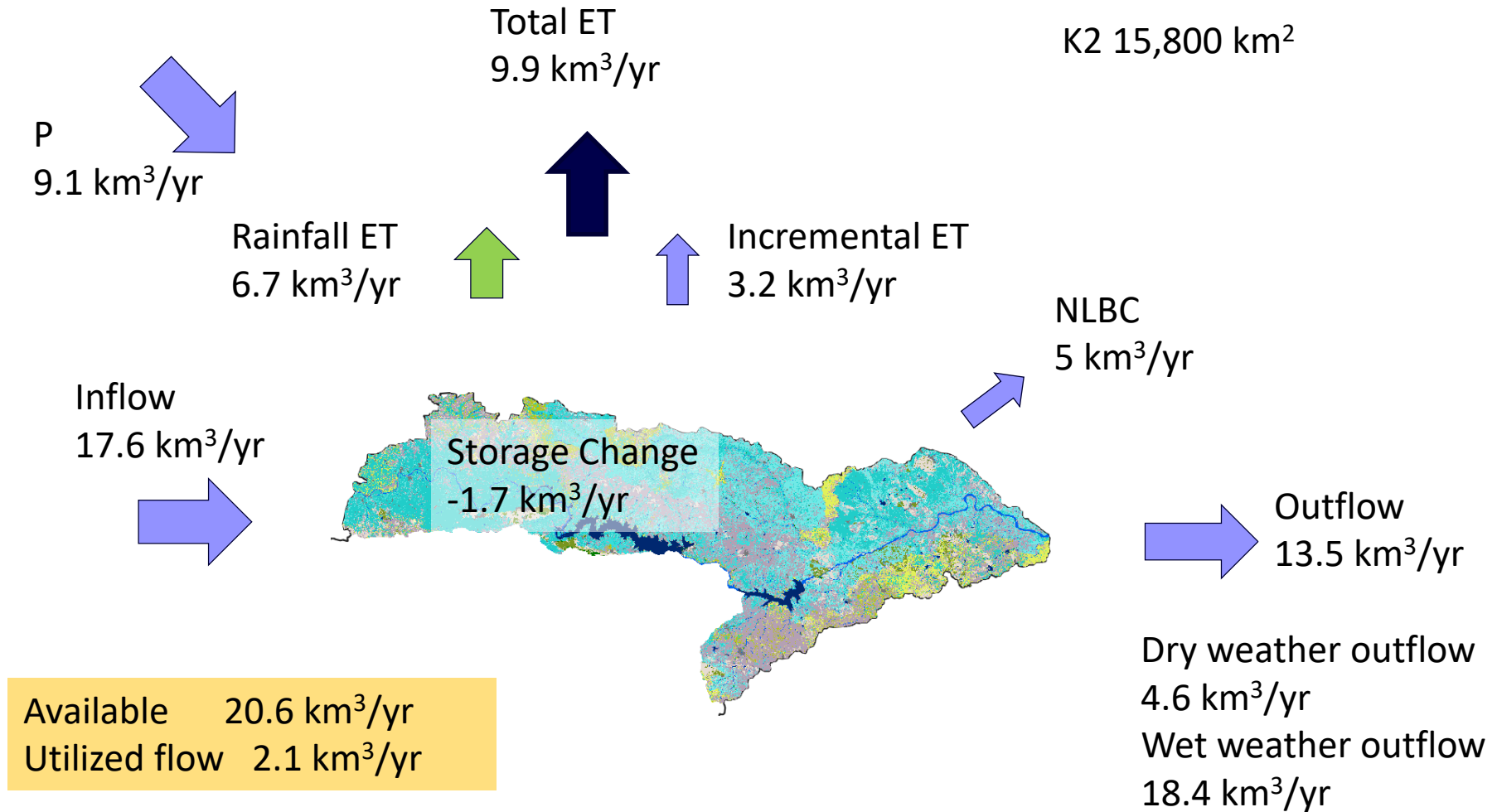
Most of the **runoff** is generated in the **upstream mountainous areas**

Agricultural areas and reservoirs are net consumers

The long-term average of $P-ET < 0$ in K2 and $P-ET > 0$ in K3 and K4

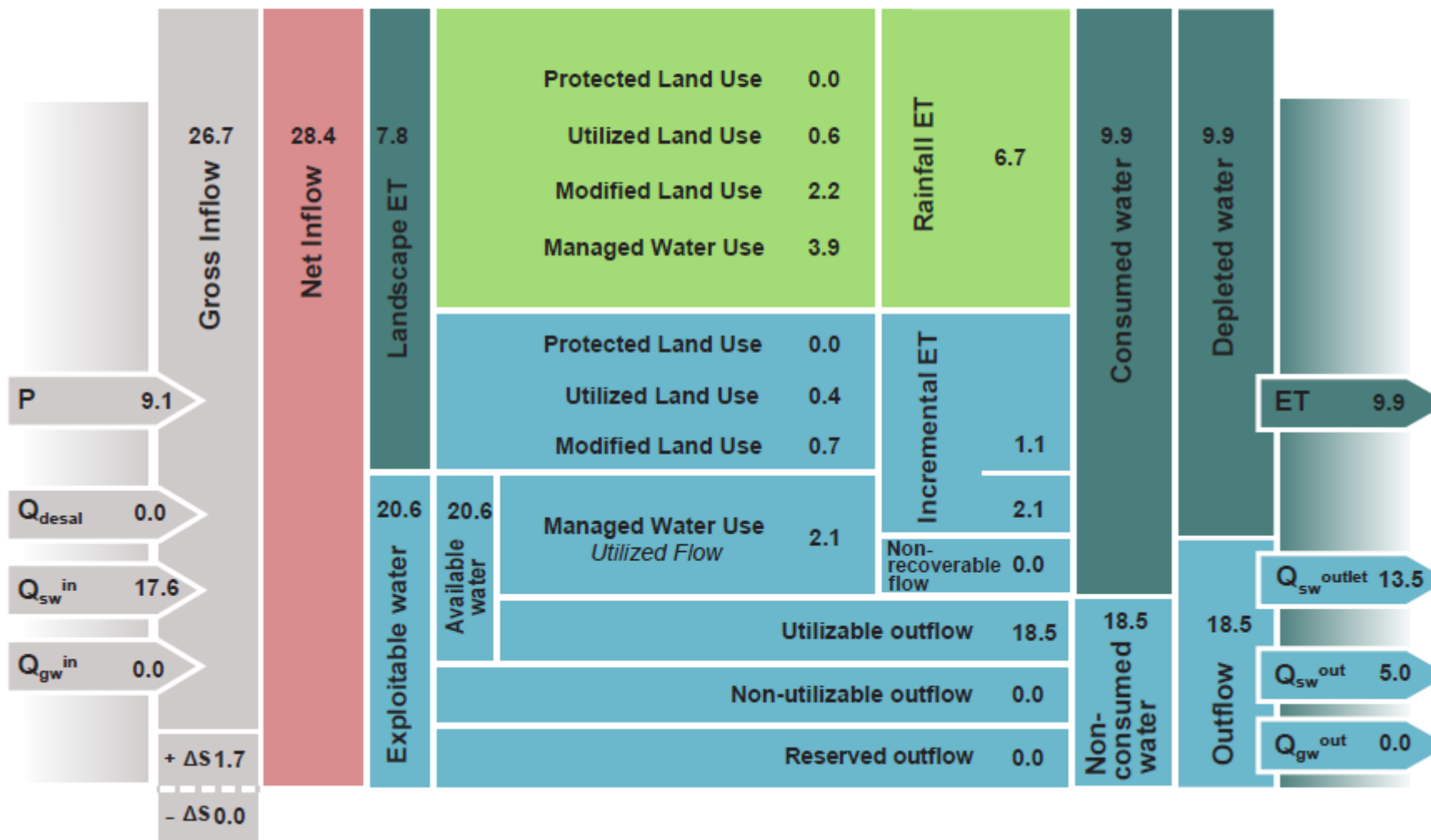
\rightarrow K3 and K4 are generating water, part of which is then consumed in K2

Annual Average Water Balance in K2 2010/2011 – 2017/2018

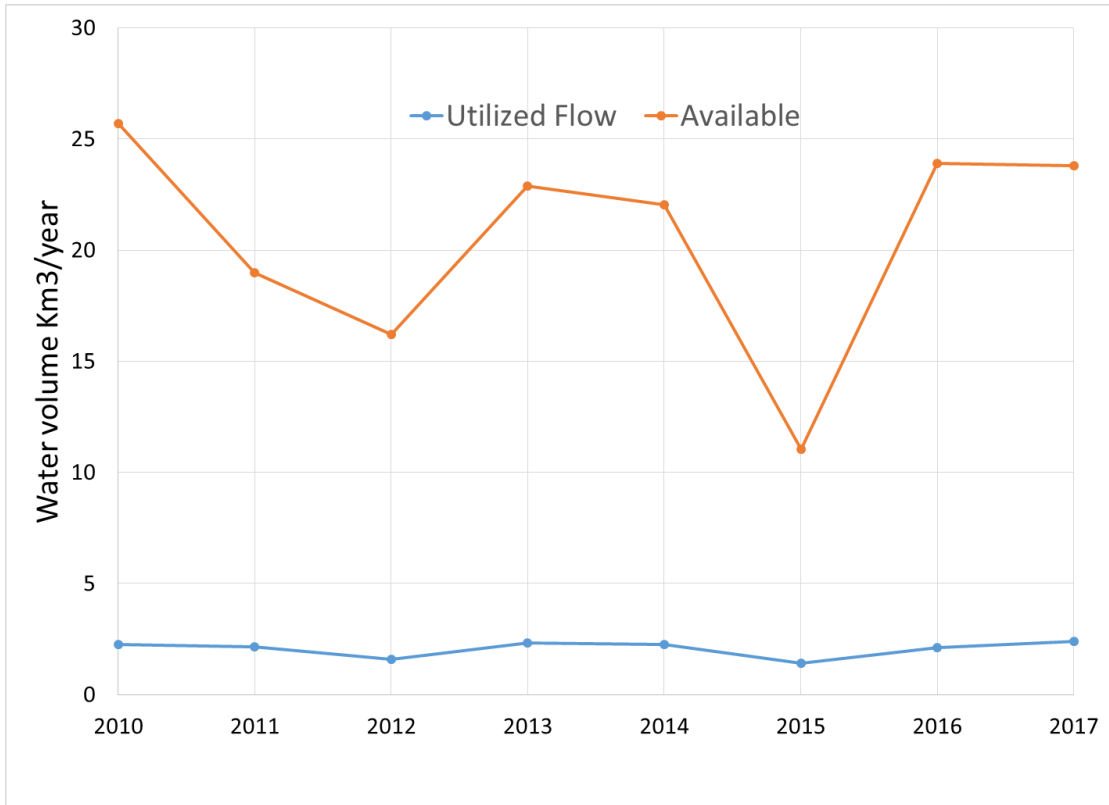


Sheet 1: Resource Base (km³/year)

Basin: K2
Period: 2010-2017



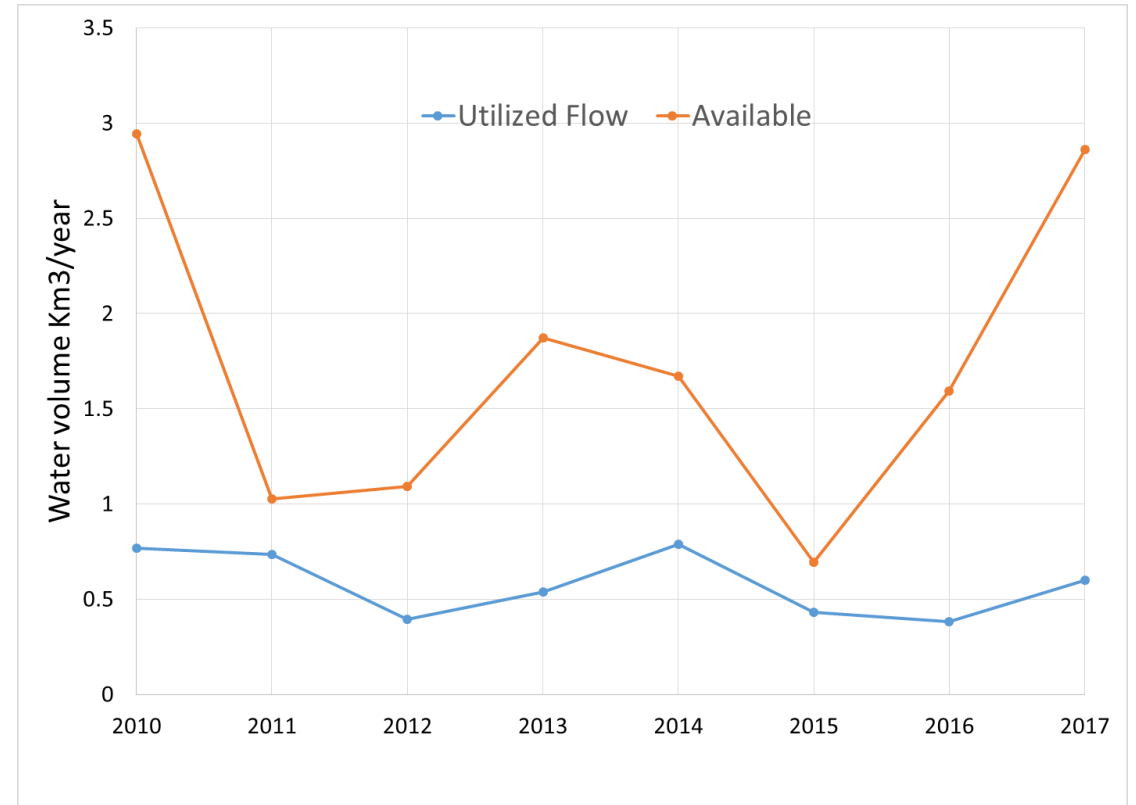
K2: the available water in the basin is 8-10 times the utilized flow



High water availability because of inflows.

The available water has a high inter-annual variability (11-26 km³/year)

K4: the available water in the basin is 2-3 times the utilized flow

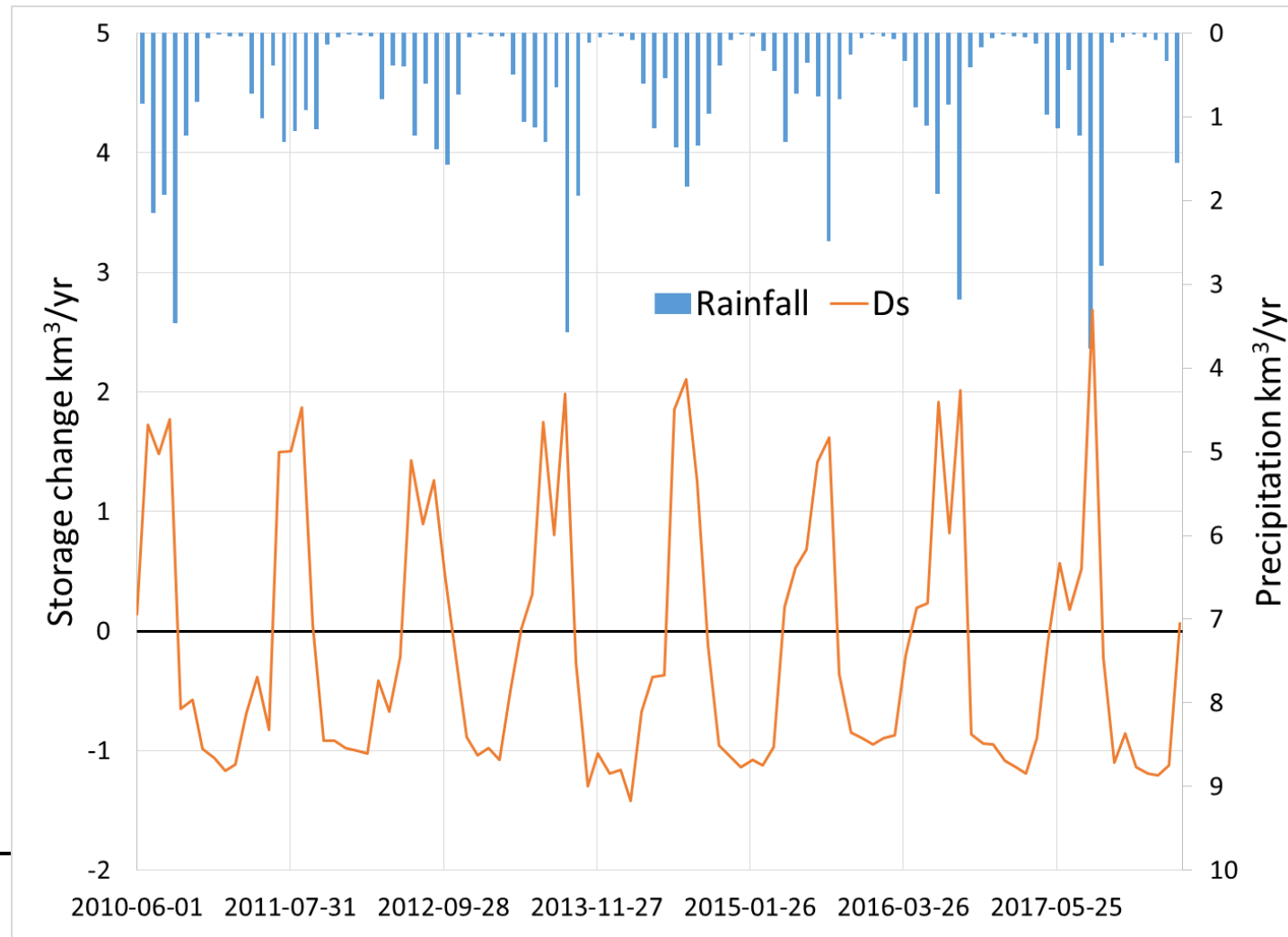


During dry years most of the available water is utilized

K2: storage change monthly scale

K2 as the other two basins has a strong seasonal variability → monsoon

Delicate
balance



Evapotranspiration

Sheet 2: Evapotranspiration (km3/year)

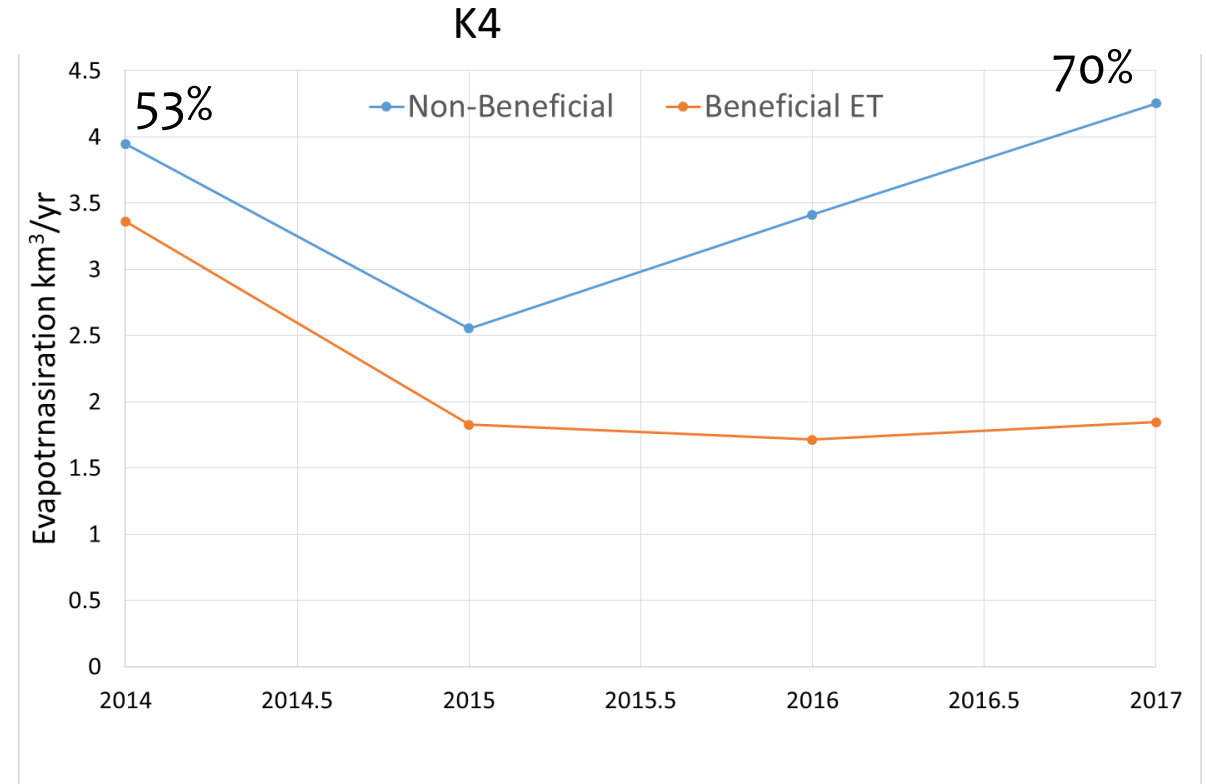
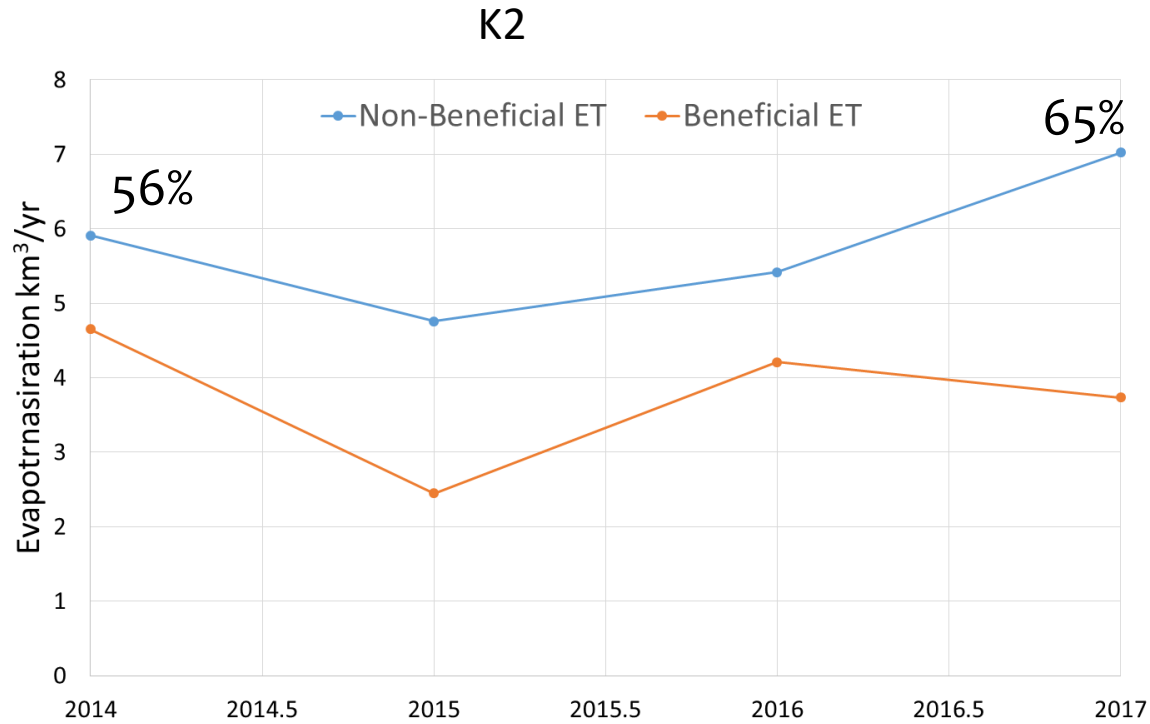
Period: 2014-2017

Basin: K2



		ET	T			ET	T		
9.5	Non-manageable	Protected Land Use	Forests	0.0	0.0	5.0	0.4	Non-Beneficial 5.8	
			Shrubland	0.0	0.0				
			Natural grasslands	0.0	0.0				
			Natural water bodies	0.0	0.0				
			Wetlands	0.0	0.0				
	0.0	0.0	0.0						
	Manageable	Utilized Land Use	Forests	0.0	0.0	4.0	0.6	Beneficial 3.8	
			Shrubland	0.2	0.1				
			Natural grassland	0.0	0.0				
			Natural water bodies	0.2	0.1				
Wetlands			0.0	0.0					
0.9	0.9	0.5							
Total evapotranspiration	Managed	Modified Land Use	Rainfed crops	0.7	0.4	4.5	4.5	Agriculture 2.9 Environment 0.2 Economy 0.5 Energy 0.1 Leisure 0.1	
			Forest plantations	0.0	0.0				
			Settlements	0.0	0.0				
	2.8	1.3	2.0	0.9					
	Conventional	Managed Water Use	Irrigated crops	5.2	2.7	5.8	2.8		
			Managed water bodies	0.5	0.0				
			Residential	0.2	0.1				
			Industry	0.0	0.0				
			Other	0.0	0.0				
			5.8	2.8					
Non-conventional			Managed Water Use	Indoor domestic	0.0			0.0	4.5
	Indoor industry	0.0		0.0					
	Greenhouses	0.0		0.0					
	Livestock & husbandry	0.0		0.0					
	Other	0.0		0.0					
0.0	0.0	0.0	0.0						

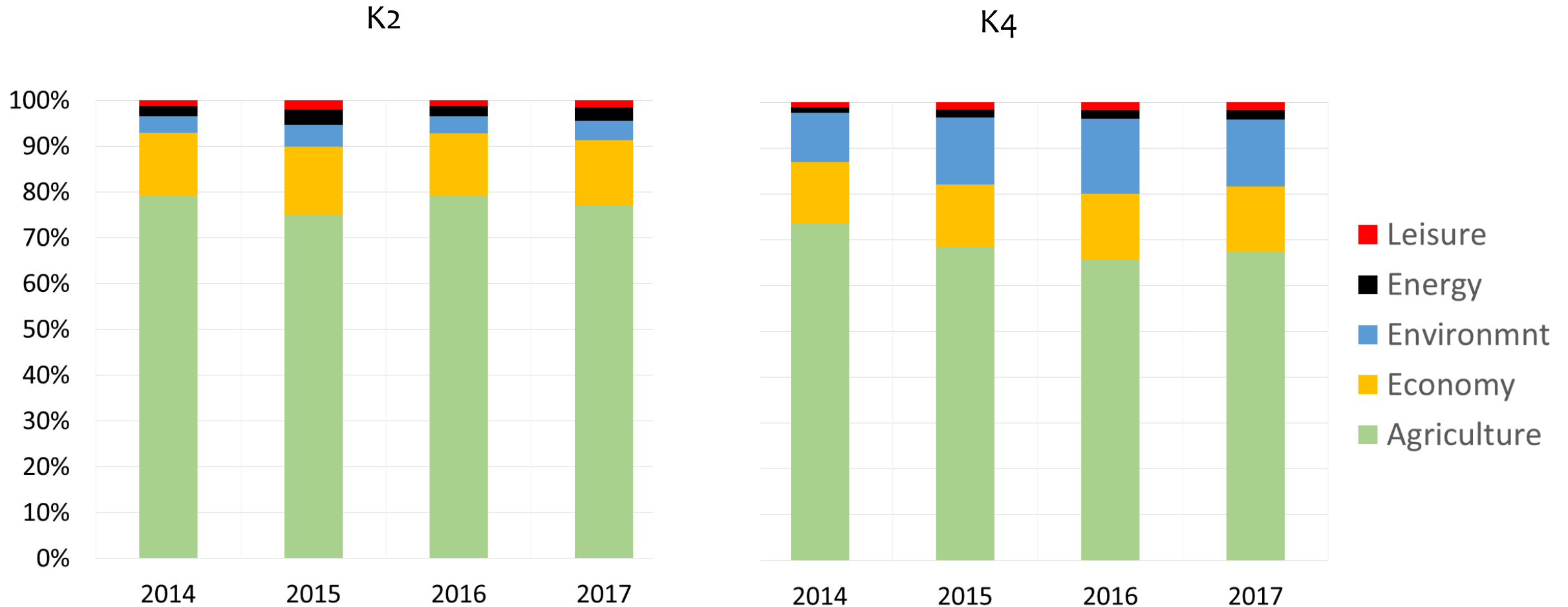
Beneficial and non-beneficial ET inter-annual variability



Non-beneficial fraction is increasing mainly due to increased soil water evaporation

→ More efficient irrigation techniques should be considered

The agricultural sector is responsible for 80% of the beneficial consumption



Biomass production and biomass water productivity

K2 2015-2016		Kharif	Rabi	Zaid	Double/Triple Crop	Forest Plantation	
ET	0.77	0.19	0	1.95	0.01	km ³ /yr	
GBP	3492	4917	569	7401	4293	kg/ha	
GBWP	1.10	5.50	0.67	1.48	1.69	kg/m ³	

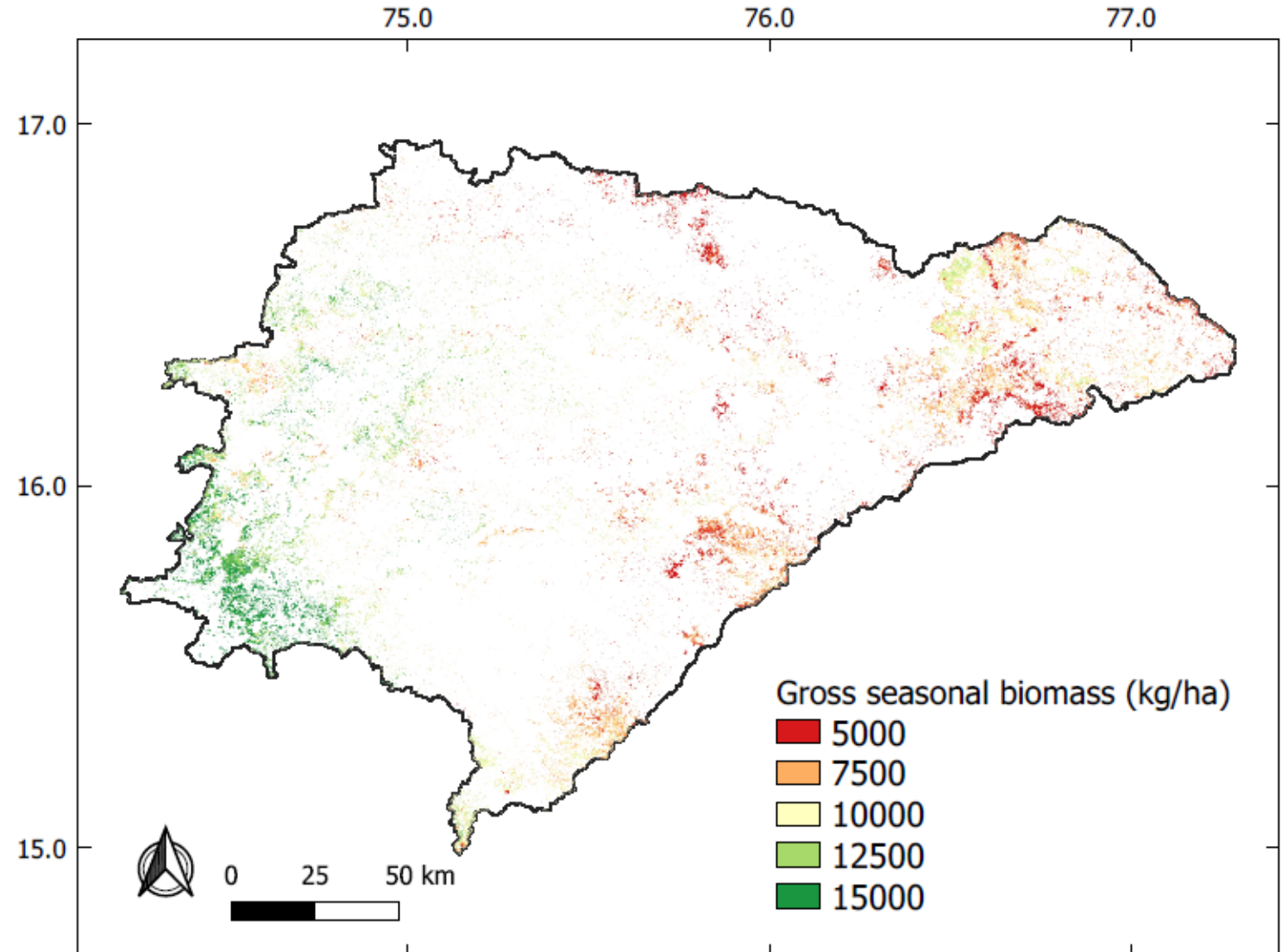
K2 2016-2017		Kharif	Rabi	Zaid	Double/Triple Crop	Forest Plantation	
ET	0.77	0.19	0	1.95	0.01	km ³ /yr	
GBP	4582	7354	334	7279	5088	kg/ha	
GBWP	1.56	3.33	0.94	1.70	2.27	kg/m ³	

K2 2017-2018		Kharif	Rabi	Zaid	Double/Triple Crop	Forest Plantation	
ET	0.77	0.19	0	1.95	0.01	km ³ /yr	
GBP	3467	7757	624	7535	4656	kg/ha	
GBWP	1.09	3.00	0.73	1.38	1.65	kg/m ³	

Biomass production and biomass water productivity

Kharif 2015-2016 (May → October)

Higher productivity zones
in the upstream areas
→ water availability



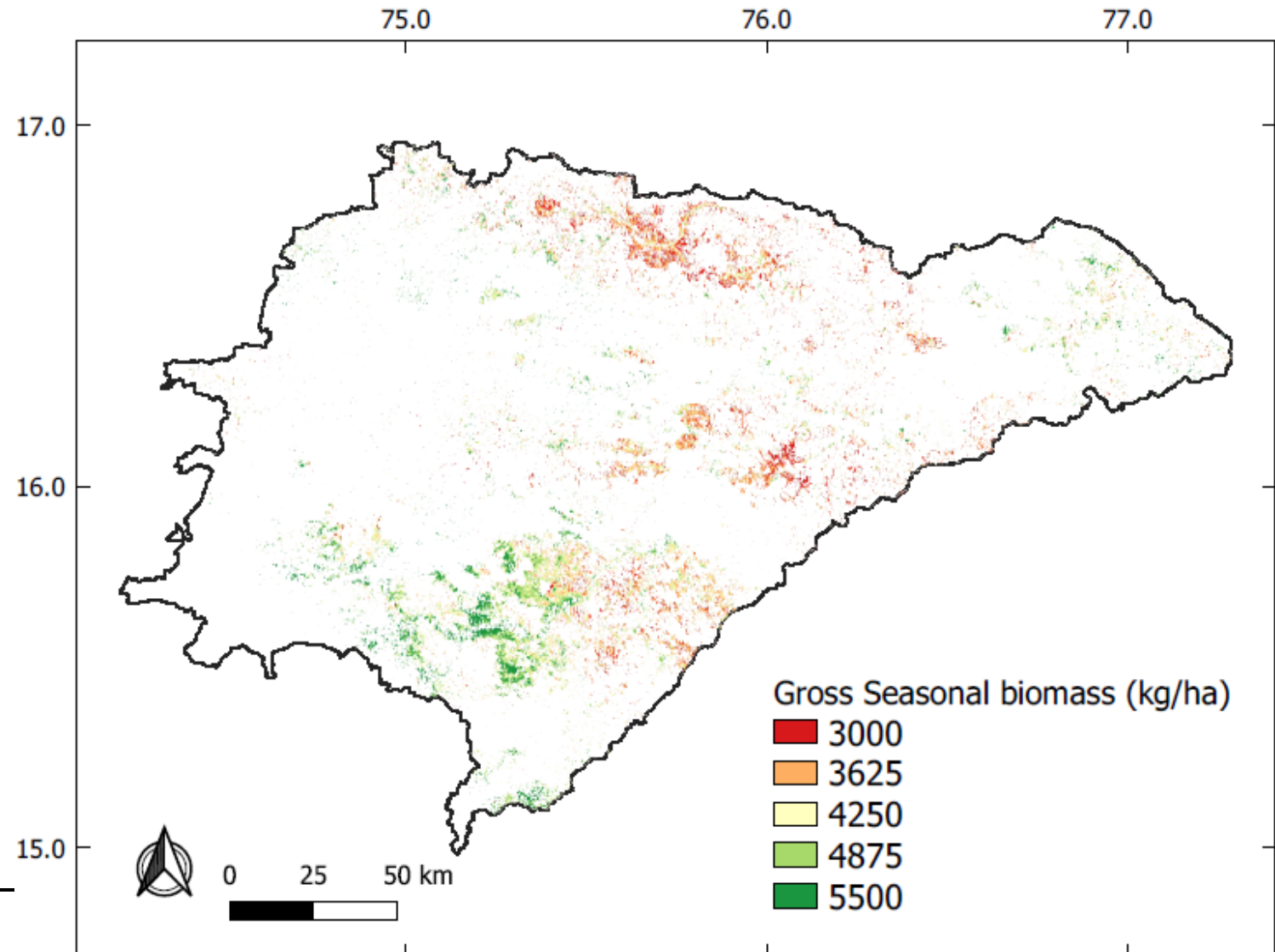
Biomass production and biomass water productivity

Rabi 2015-2016 (Nov → Apr)

Similar patterns

→ K4 is more productive

Than the other two basins



Conclusions and recommendations

- 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

- 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.

Conclusions and recommendations

- Additional validation and a field survey should be carried out for evaluating the WA+ results and for improving accuracy of the land use map.

Thank you for your attention!

Website: <https://wateraccounting.un-ihe.org/>



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 - > Symposium 2022
- > WA+ framework
- > Projects
- > Publications
- > Capacity Building
- > IHE WA+ team

Open Source software on GitHub: github.com/wateraccounting

A screenshot of the GitHub organization page for 'wateraccounting'. The page shows the organization's profile, a navigation menu with 'Repositories 14', 'Packages', 'People', and 'Projects', and a list of repositories. The first repository is 'IHEWAengine', which is a Python project using GPL-3.0 license, updated 2 days ago. The second is 'IHEWAcollect', an HTML project using GPL-3.0 license, updated 4 days ago. The third is 'WAPORWP', a Jupyter notebook project for water productivity and irrigation performance monitoring, updated 4 days ago. The page also features a 'Sign up' button, a search bar, and a 'Top languages' section showing Python, Jupyter Notebook, TeX, and HTML.

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