NEXUS Gains:
Realizing Multiple Benefits
Across Water, Energy, Food
and Ecosystems

Trade-offs and Foresight Analyses of Water-Energy-Food-Ecosystems (WEFE) Interventions in the Indus Basin

Dr Mohsin Hafeez
IWMI Director – Water, Food and Ecosystems
IWMI Country Representative (Pakistan)

Water Issues and Challenges

- Rapid population growth and increasing water demand for multiple sectors
- 8th most climate vulnerable country
- Managing extreme water risks – floods and droughts
- Inadequate water storage (30 days) & rainwater harvesting facilities
- Largest contiguous irrigation system of world – 35% WUE
- GW supplement 60% to irrigation & GW >90% urban water
- Lack of water marketing, pricing and trading concept
- **Poor understanding of Water-Food-Energy-Ecosystems Nexus**
- Water quality, sanitation and related health concerns-One health
- Weak water institutes, poor governance and policy incoherence
- Transboundary water conflicts
- Social conflicts due to water scarcity
- Building water resilience and adaptation to climate change

Source (NASA)

SWAT+ Model setup

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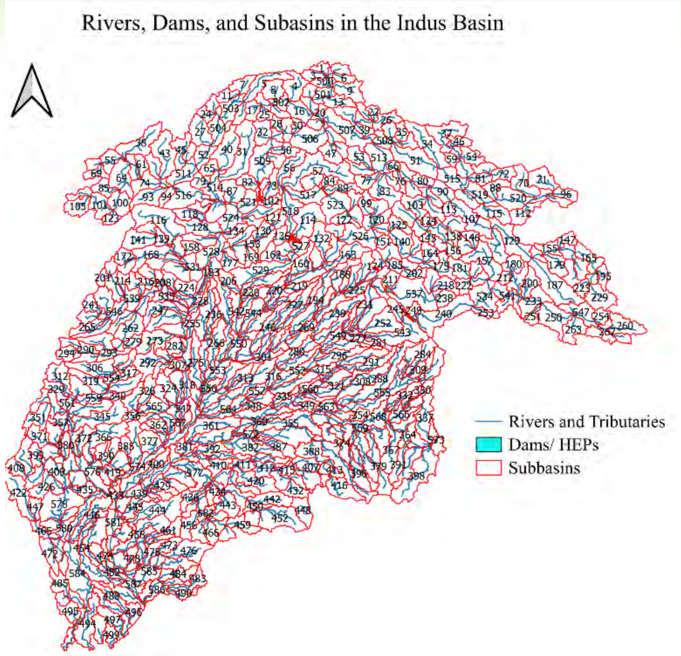
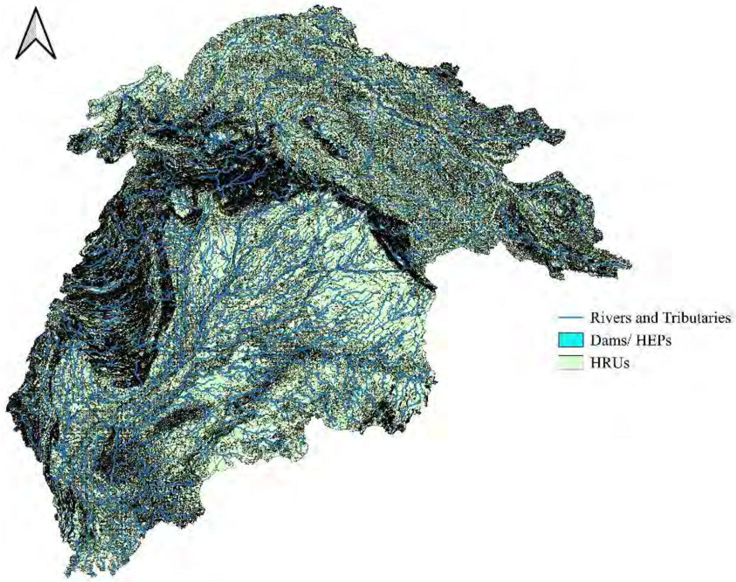
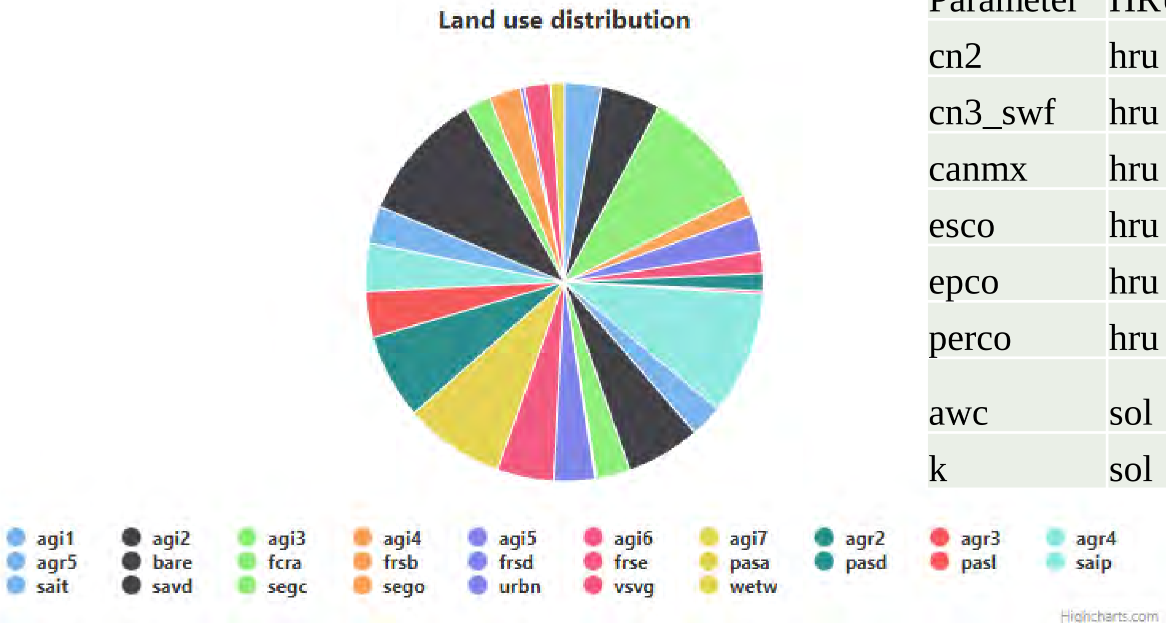




- Total Area : 1135580 km^2
- Total Sub Basins : 589
- LSUs : 3016
- HRUs : 3016
- Channels : 1488

- Warmup period : 2000 – 2002
- Modelling period : 2003 – 2023
- Calibration period : 2003 – 2013
- Validation period : 2014 – 2023



Optimized Parameters

Parameter	HRU/Soil	Optimized Value	Unit
cn2	hru	72	null
cn3_swf	hru	0.28	null
canmx	hru	8	mm/H20
esco	hru	0.2	null
epco	hru	0.13	null
perco	hru	0.19	fraction
awc	sol	0.06	mm_H20/mm
k	sol	4	mm/hr

SWAT+ Model Calibration/Validation

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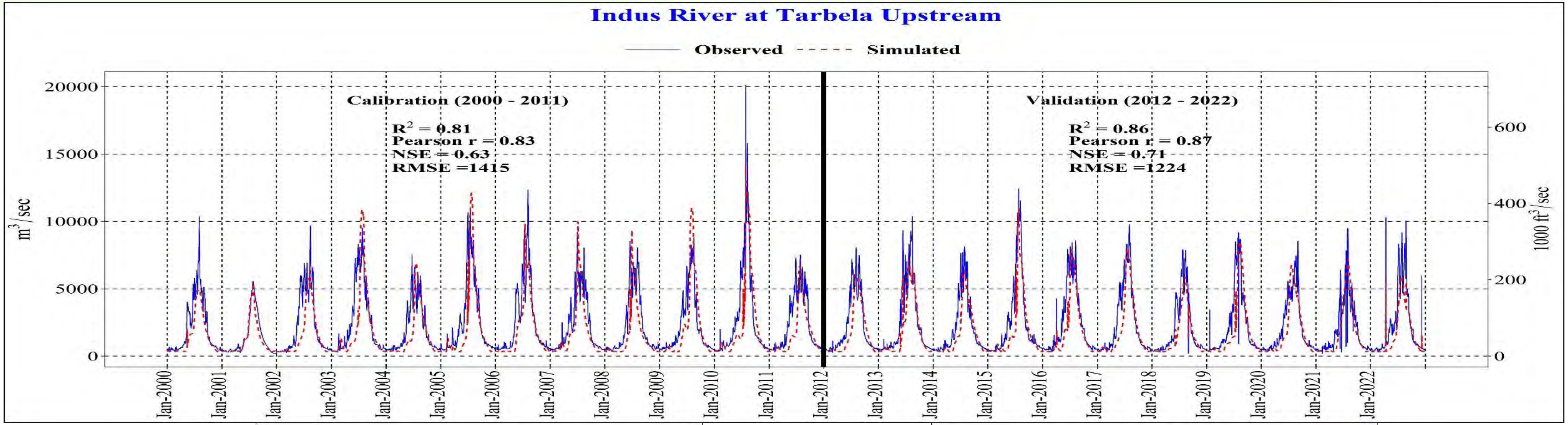
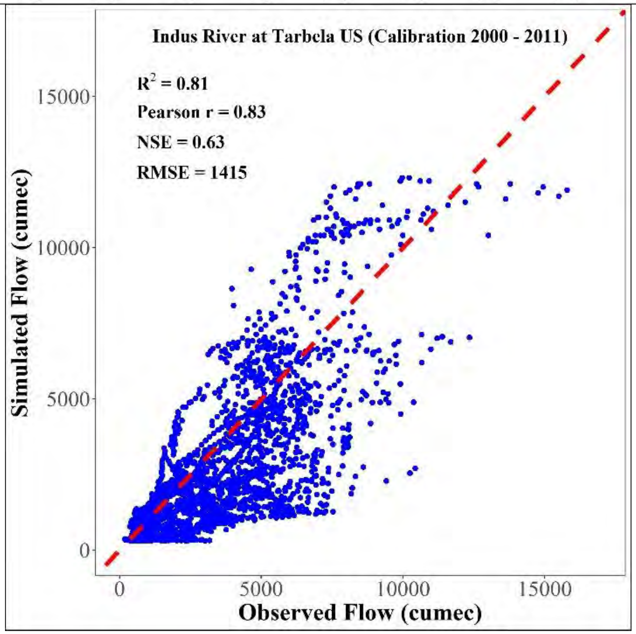
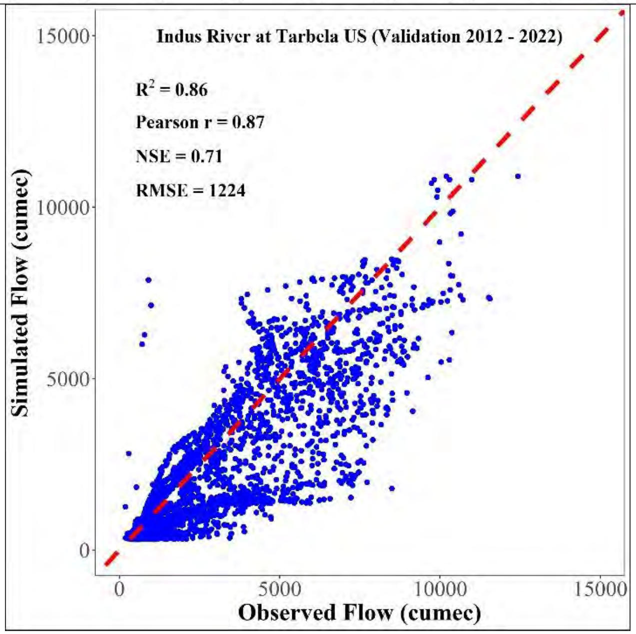
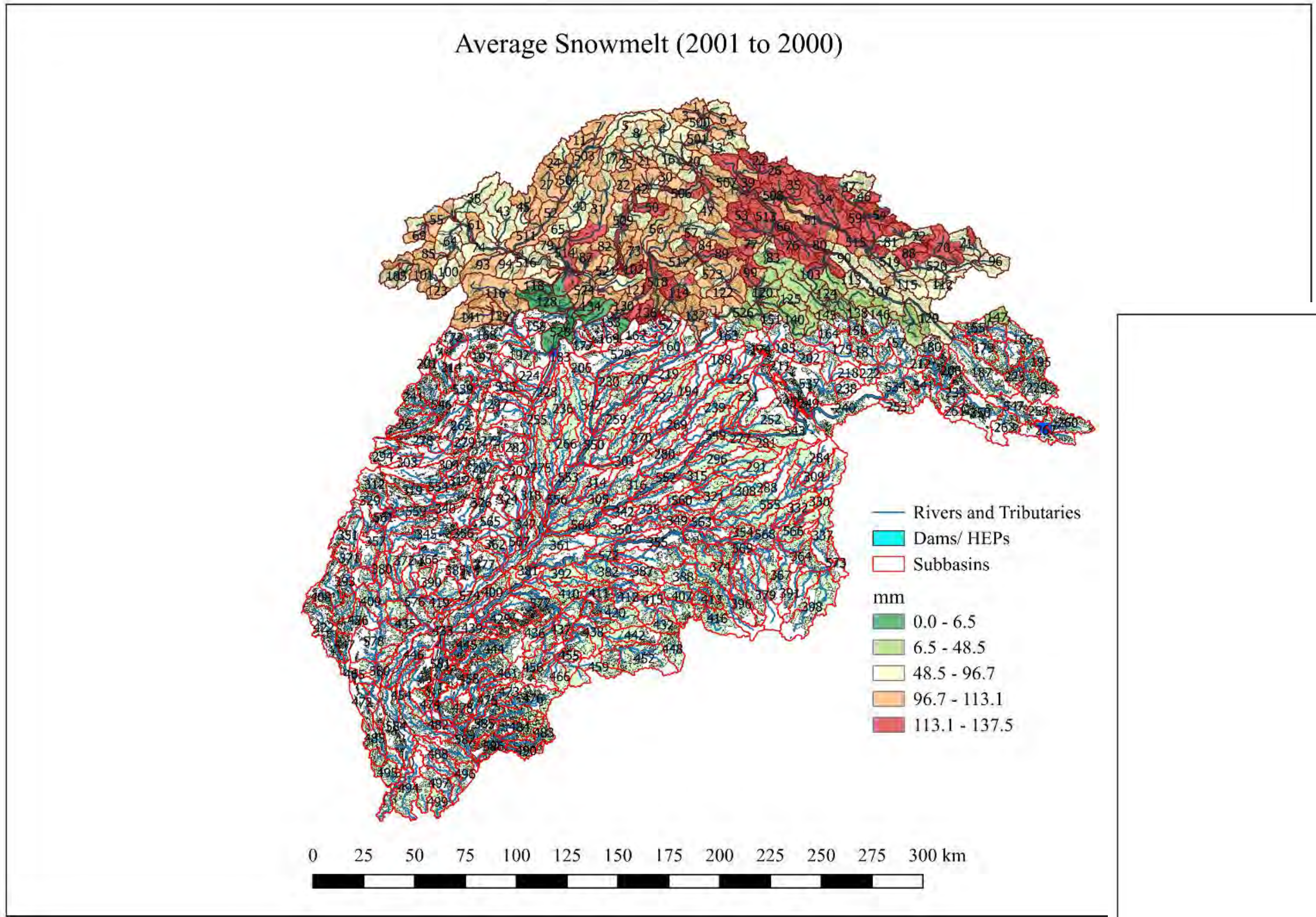
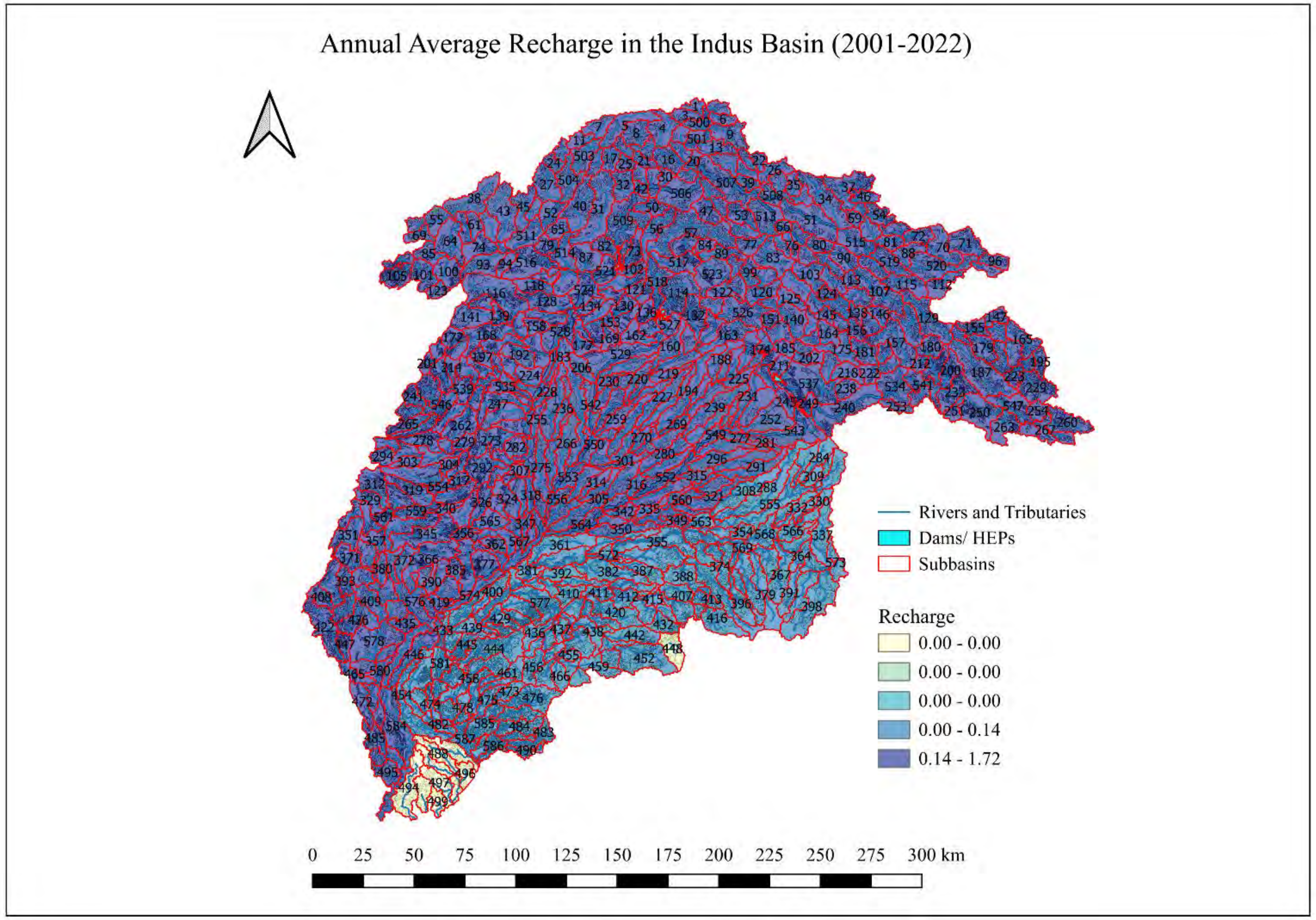






SWAT+ Results





SWAT+ Results

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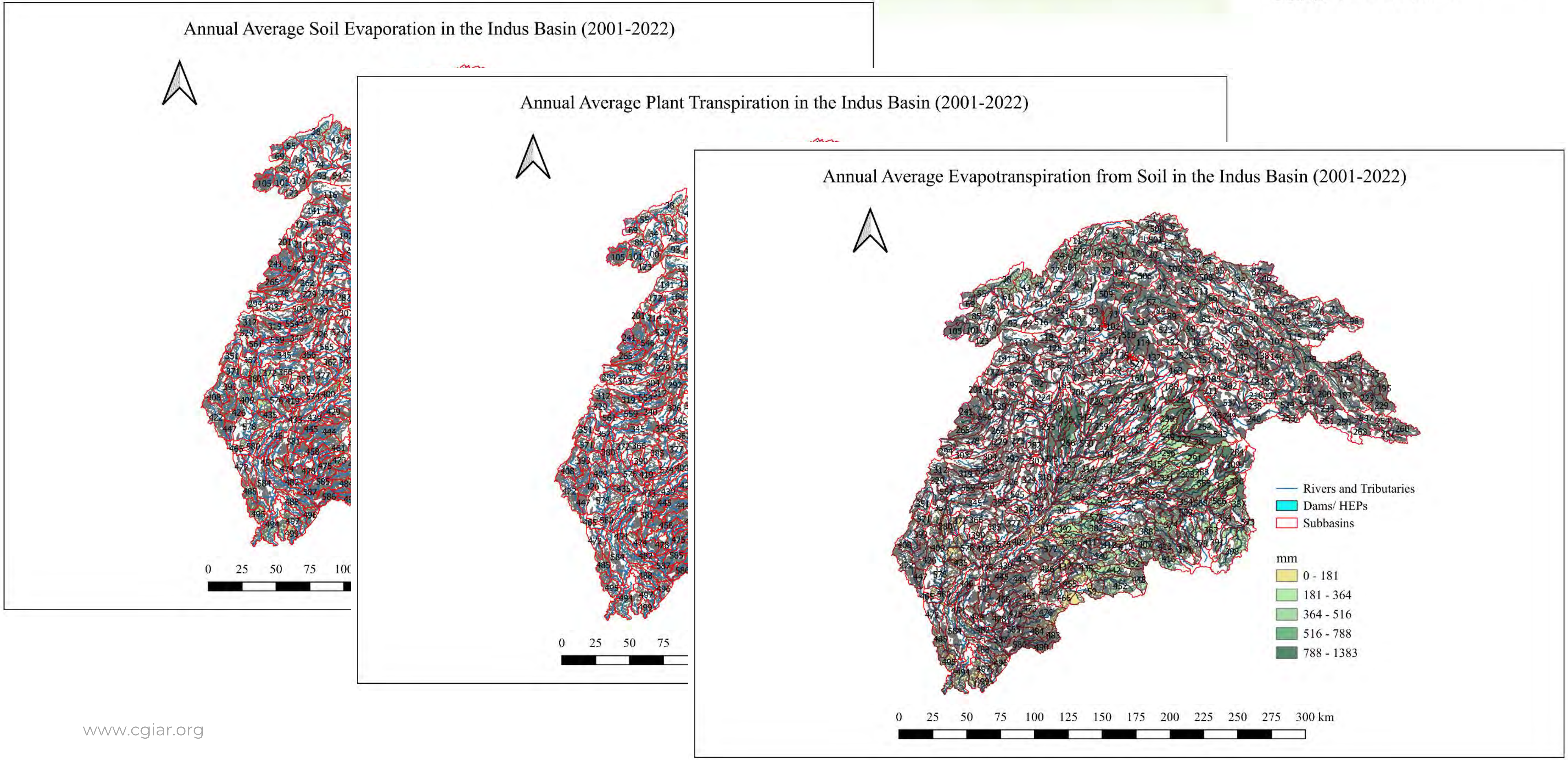
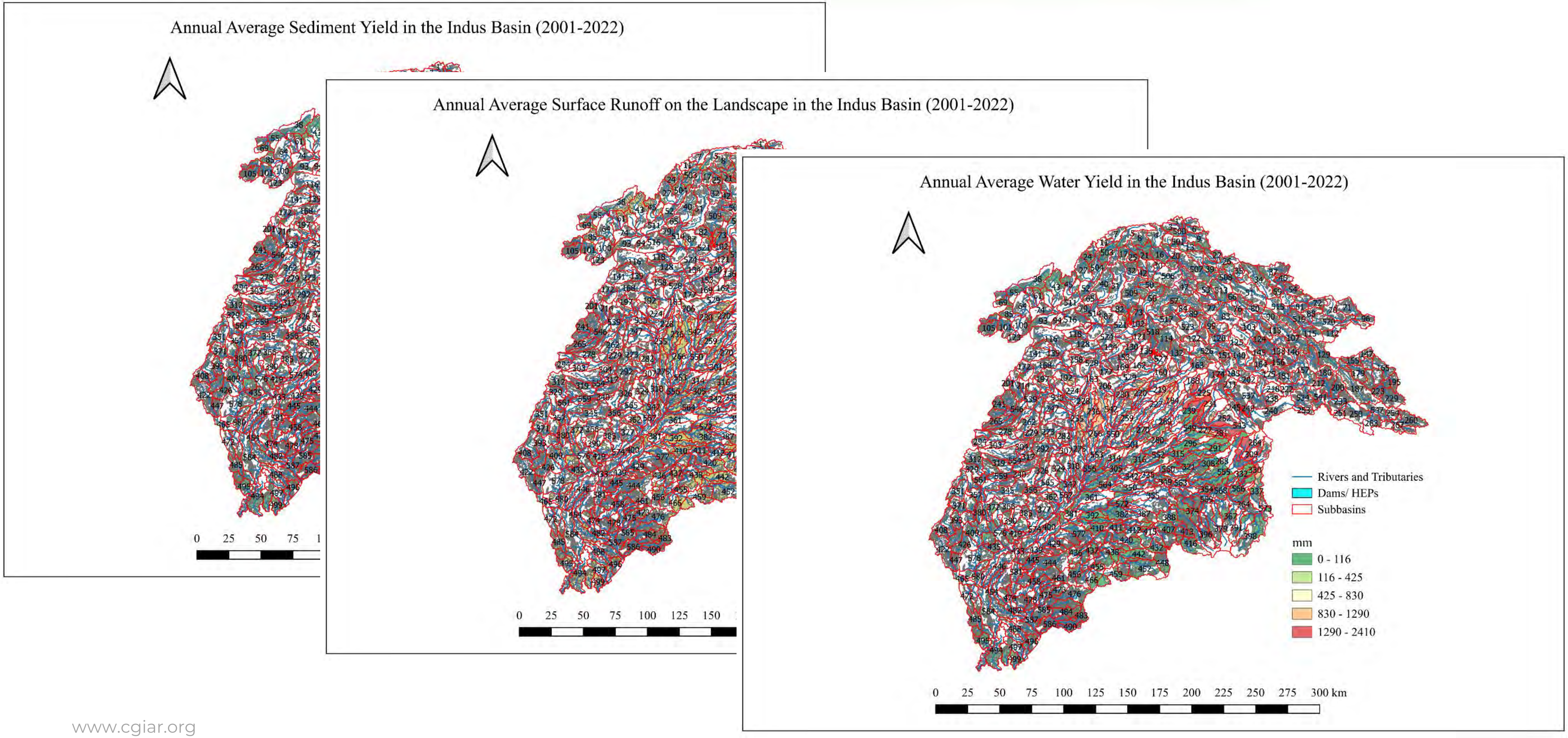


SWAT+ Results



SWAT+ Results

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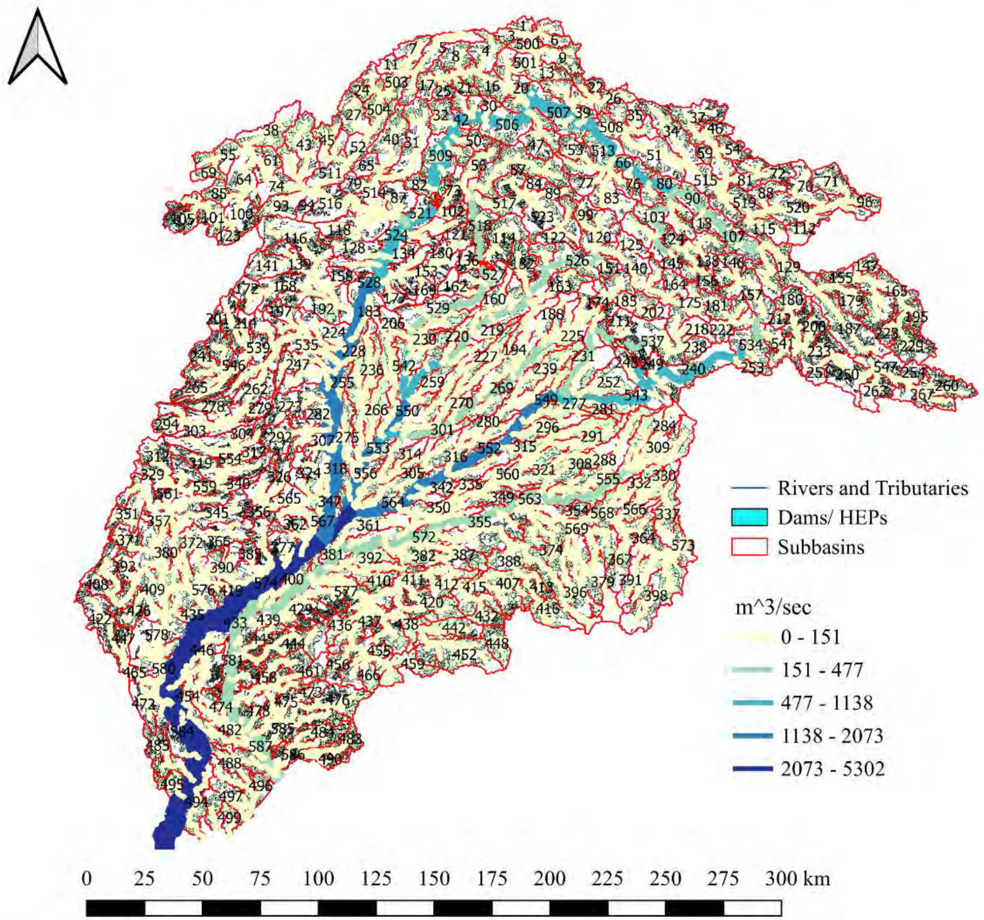
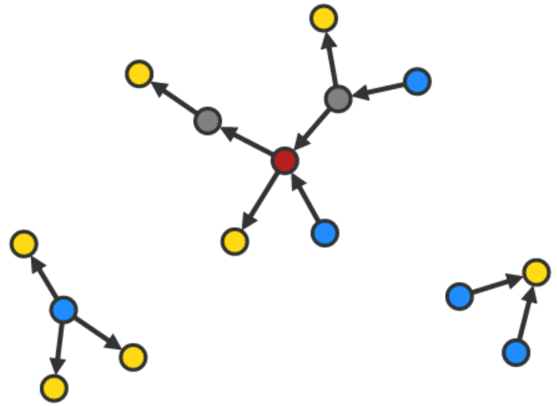
Annual Average Daily Outflow from the Indus Basin (2001-2022)



PyWR: Water Resource Allocation Model for Indus Basin

Pywr is a tool for solving network resource allocation problems at discrete timesteps using a linear programming approach.

IWMI Pakistan is developing a **Digital tool** for the Indus Basin Irrigation System under the Nexus Gains Initiative especially to address the Water Resource Allocation and Optimization



MANCHESTER 1824 The University of Manchester

IWMI International Water Management Institute

CGIAR INITIATIVE ON NEXUS Gains

PyWR is an open-source Python library for building water resource models.
It can be an effective tool for water allocation under the Indus River System Authority (IRSA) in several ways

Indus PyWR Model : Model Structure and Creation

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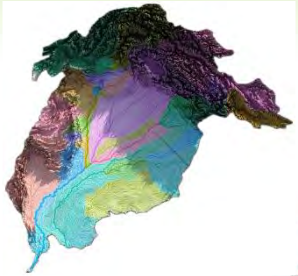
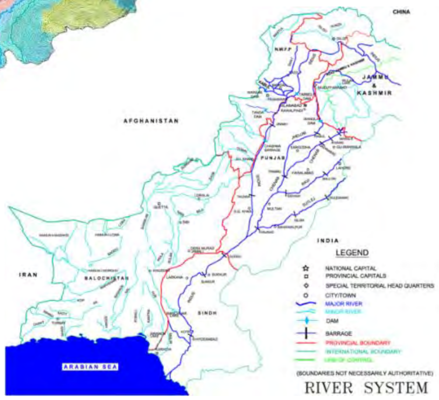
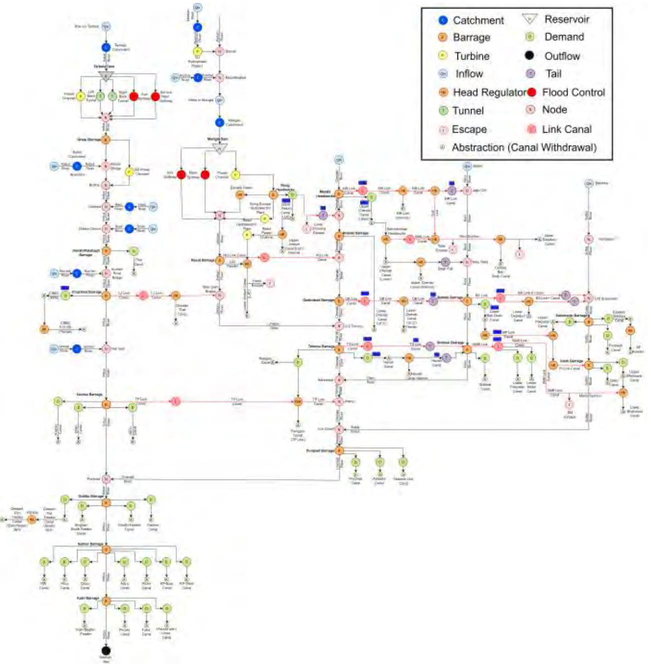
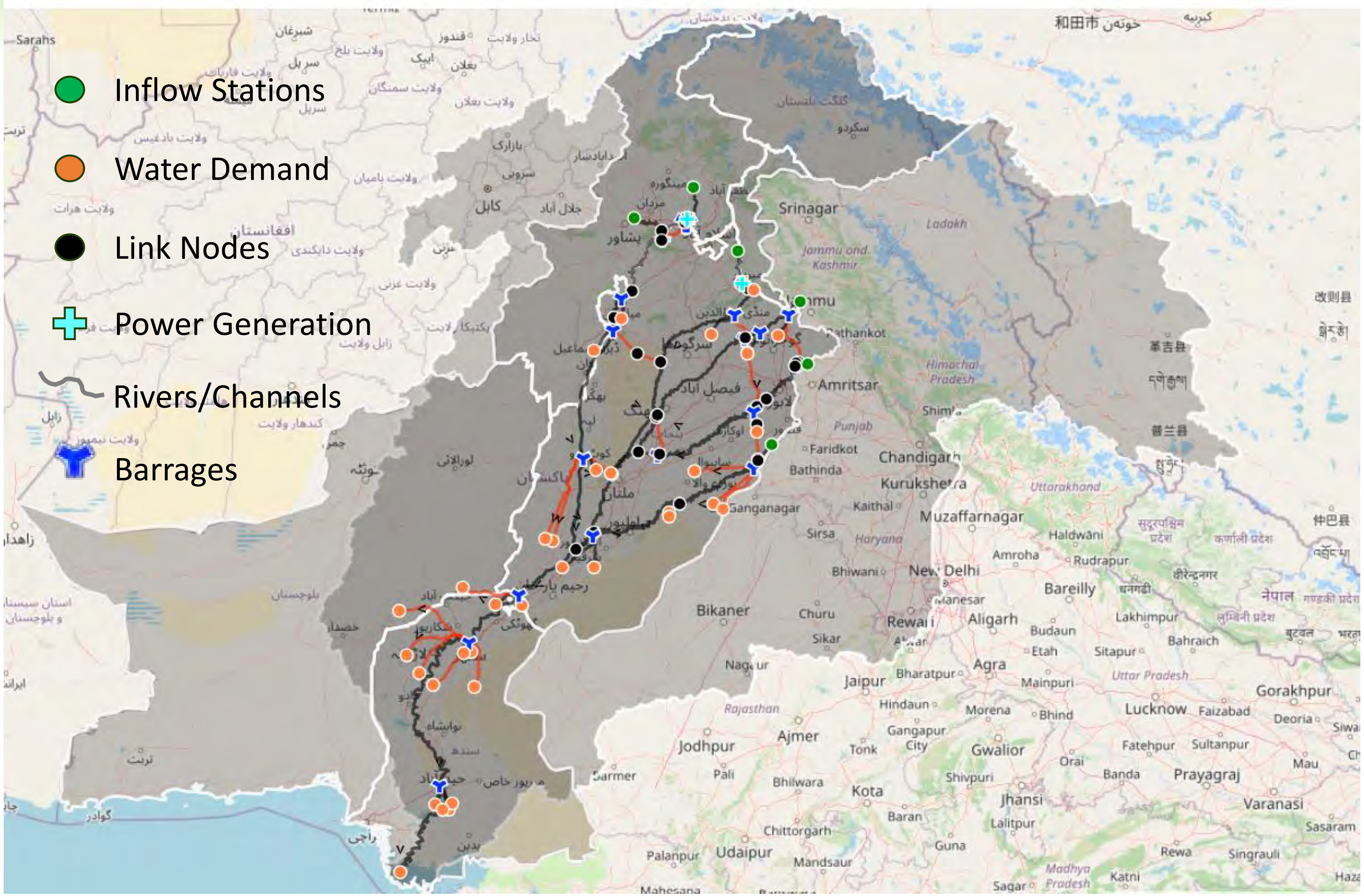
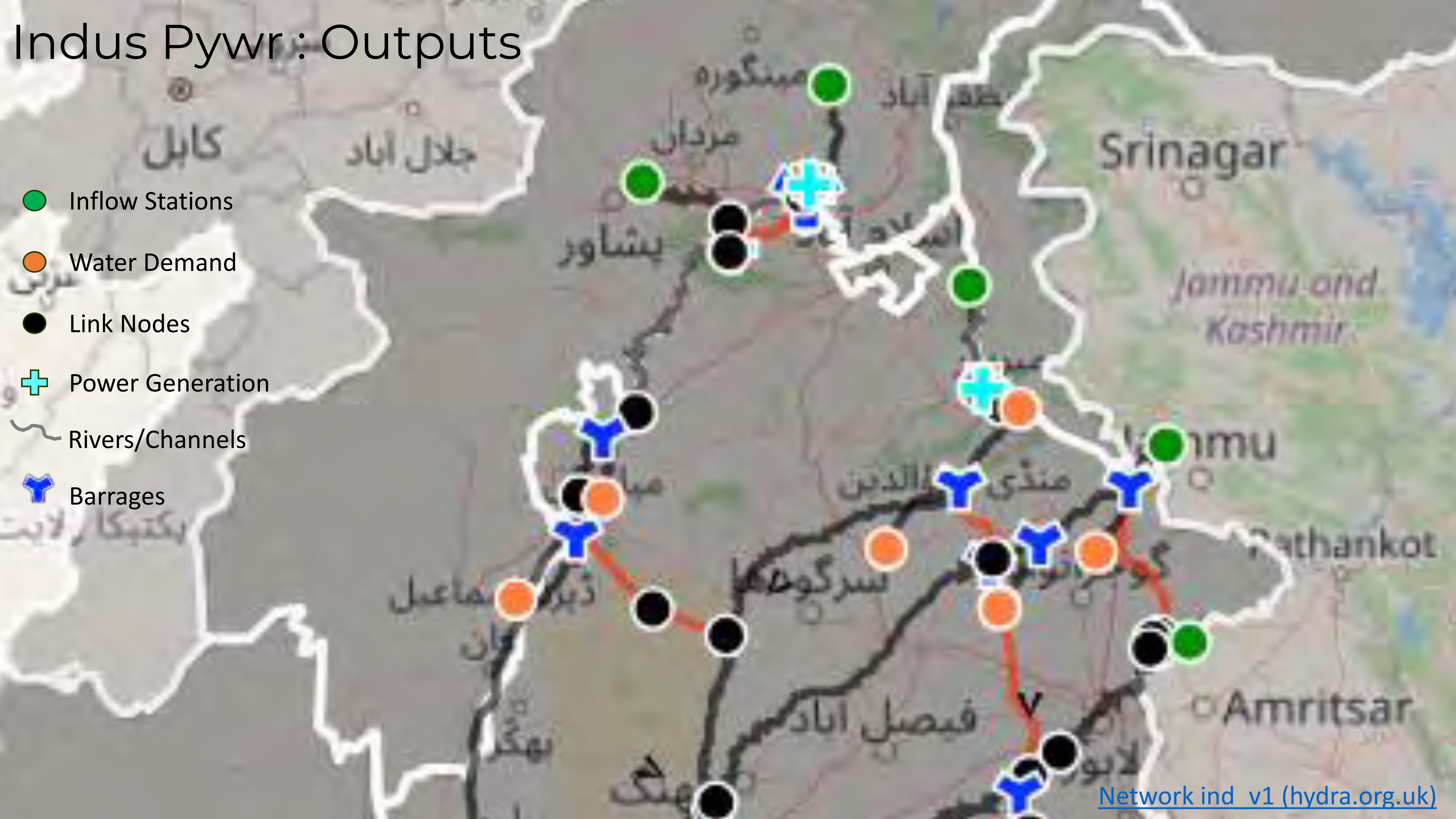








Indus Pywr : Outputs



[Network ind_v1 (hydra.org.uk)](hydra.org.uk)

Indus PyWR Model : Model Results – Barrages

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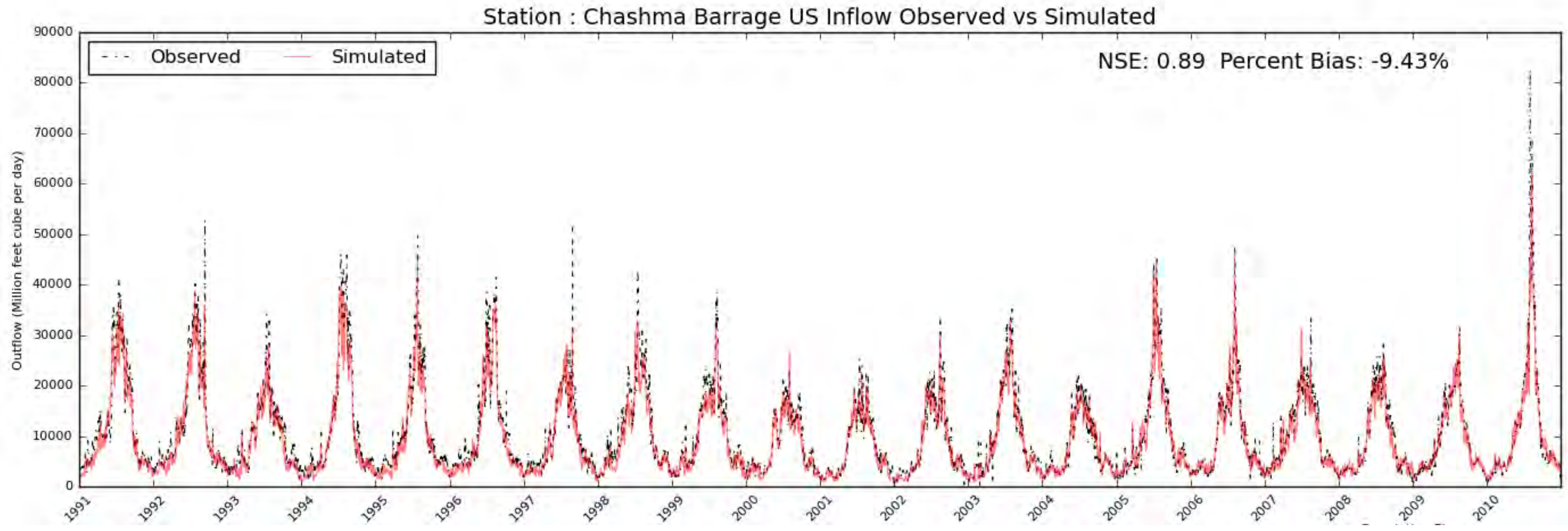

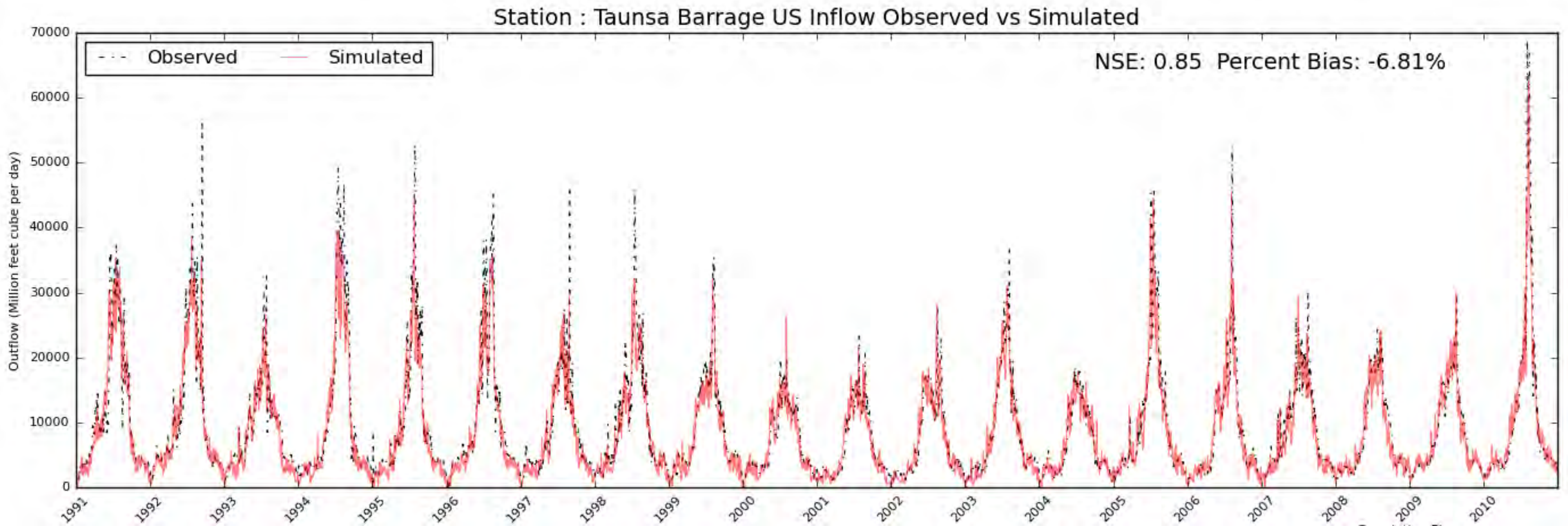

Indus PyWR Model : Utilities and Prospects

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Flexible Model for Indus Basin: PyWR allows the creation of tailored models reflecting the unique features of the Indus Basin.

Integration of 10-Daily Flow Data: Incorporates IRSA's 10-daily flow data for precise water allocation.

Dynamic Allocation Adjustments: Adjusts allocations based on real-time data, ensuring accurate and responsive water distribution.

Optimization Capabilities: PyWR can optimize water distribution based on various criteria, such as maximizing agricultural output or minimizing shortages, which aligns with IRSA's goal of equitable water distribution

Scenario Analysis: The tool supports scenario analysis, helping IRSA evaluate the impacts of different water management strategies under varying climatic and demand conditions.

Transparency and Collaboration: Being open-source, PyWR encourages transparency in modeling and facilitates collaboration among different stakeholders, including provincial authorities and researchers.

Trades-off Analysis Provision

Indus PyWR : User Case Studies

No. IWT&R/24/ 112 /
GOVERNMENT OF THE PUNJAB
IRRIGATION DEPARTMENT

Dated 16/02/2024

To,

The Chief Engineer,
Water Resource Zone,
Irrigation Department,
Punjab, Lahore.

Subject: **REQUEST FOR COLLABORATION: TAILORING PyWR MODEL FOR PUNJAB IRRIGATION DEPARTMENT UNDER CGIAR NEXUS Gains INITIATIVE:**

It is informed that the Directorate of Indus Water Treaty & Regulation is responsible for water regulation and distribution in the province. To distribute the available supply more efficiently, this office not only use past proved experience, but also try its best to use modern tools and technology.

2. During recent consultative sessions, we were introduced to the PyWR Model, a development by **International Water Management Institute (IWMI) under CGIAR NEXUS Gains Initiative.** We acknowledge the model's capabilities and its direct relevance to our department's specific needs. The PyWR Model, with its flexible and robust framework for simulating and optimizing water resource systems, appears to be an essential tool for our decision support information system.

3. Given the escalating stress on our water resources due to factors like climate change and increasing agricultural demands, we are eager to leverage the PyWR Model to enhance our decision-making processes related to water allocation and distribution. As currently, the Punjab Irrigation department is in the process of implementing the Punjab Water Act, aiming for a more integrated and sustainable framework for water resource management, the PyWR Model aligns seamlessly with our objectives.

16/02/24
DIRECTOR
Indus Waters Treaty & Regulation,
Irrigation Department Punjab Lahore.

(Link to full Document)

Ministry of Water Resources

WAPDA

PCRWR

NDRMF

IRSA
INDUS RIVER SYSTEM AUTHO

Federal Flood Commission

PAKISTAN
National Disaster Management Authority
NDMA

Irrigation Department

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Groundwater Management Information System (GMIS)

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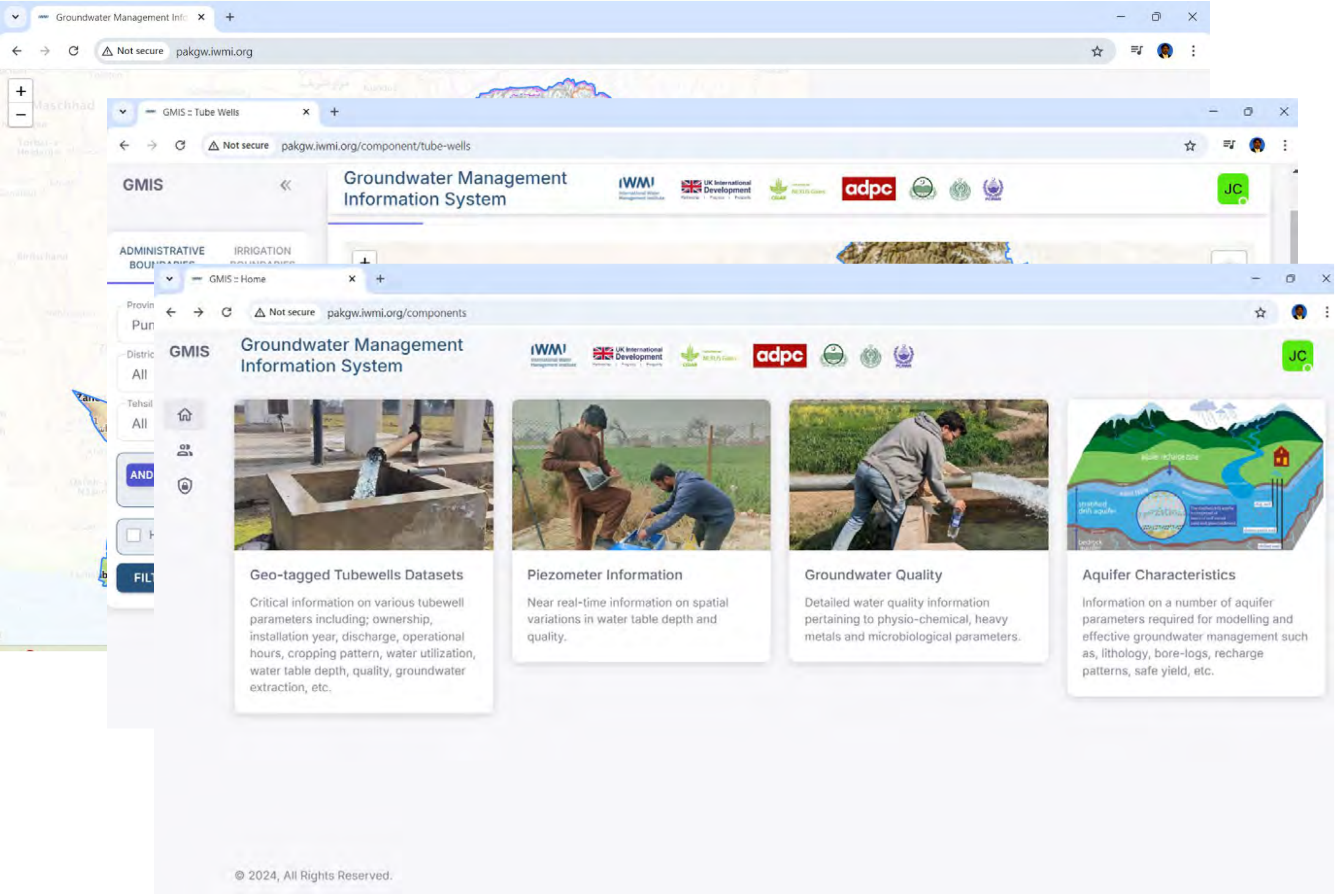
Interface of GMIS

- **Tubewell information**
- **Piezometer information**
- **Groundwater Quality**
- **Aquifer Characteristics**



Groundwater Management Information System (GMIS)

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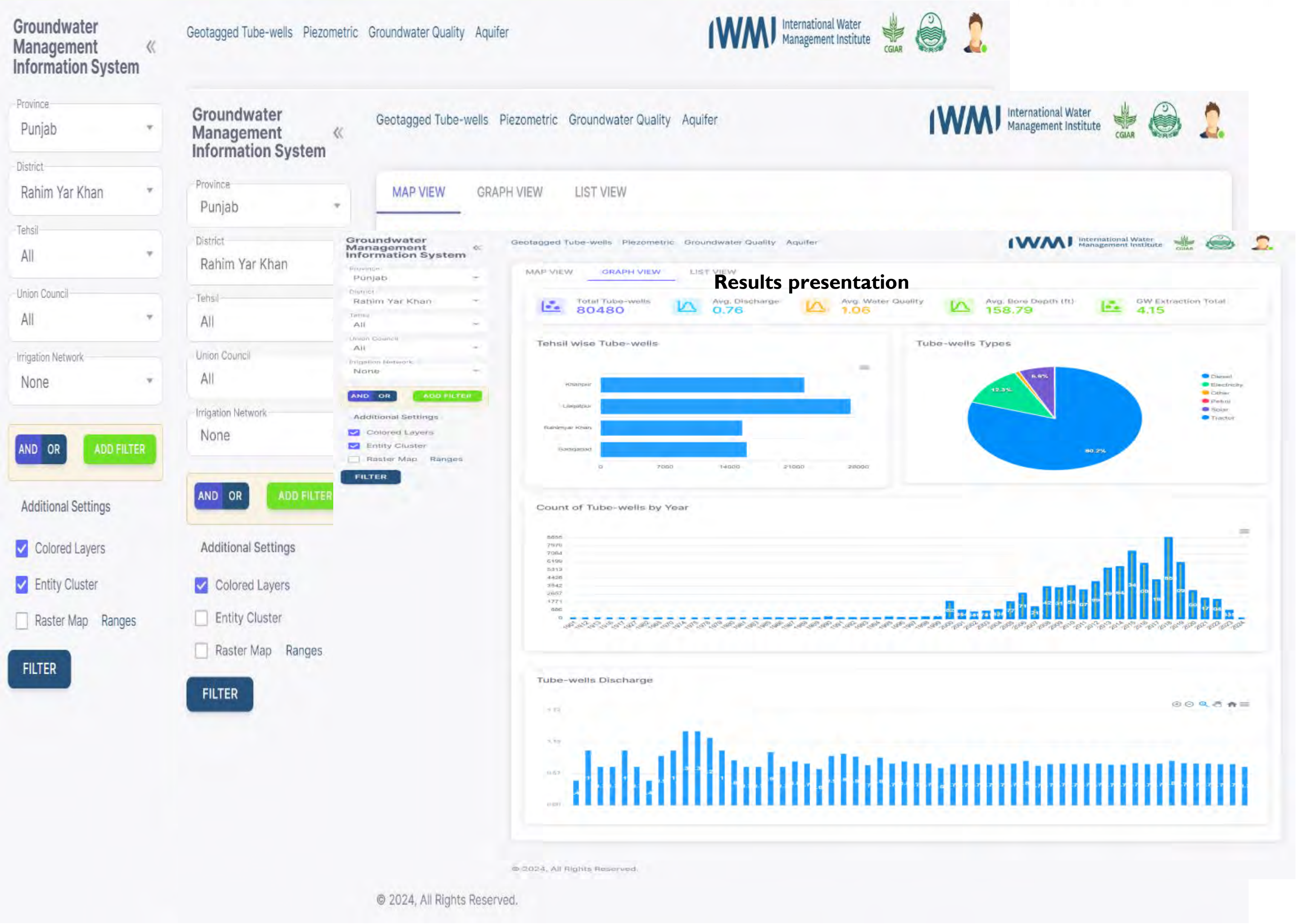
Main Feature

- A robust tool for data base management, analysis and reporting.
- Quantification of seasonal and annual extraction, depletion patterns, qualitative demarcation, aquifer vulnerability assessment, etc.
- Provides interactive mapping to facilitate identification of hotspots and critical areas.
- Supports WRZ for enabling informed decision for implementing sustainable management practices.
- Facilitates WRC for the compliance of Punjab Water Act by setting appropriate caps on resource extraction in vulnerable areas, thereby safeguarding groundwater resources for future generations.



Impact on Environment

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Carbon credit while replacing 5, 10 and 15% of the non-solar electric and diesel tube wells with solar tube wells

Carbon credit by replacing 5, 10 and 15% of electric pumps with solar pumps

District	GHG Emission Rate (tons)				Carbon Credit (tons)		
	Total	5% scenario	10% scenario	15% scenario	5% scenario	10% scenario	15% scenario
Chakwal	299.62	284.60	269.64	254.68	-15.02	-29.98	-44.94
Jhang	503.80	478.60	453.40	428.20	-25.20	-50.40	-75.60
Rahim Yar Khan	261.32	248.27	235.21	222.10	-13.06	-26.11	-39.22
Punjab	17470.90	16597.37	15723.84	14850.32	-873.53	-1747.06	-2620.59

Carbon credit by replacing 5, 10 and 15% of diesel pumps with solar pumps

District	GHG Emission Rate (tons)				Carbon Credit (tons)		
	Total	5% scenario	10% scenario	15% scenario	5% scenario	10% scenario	15% scenario
Chakwal	577.73	548.76	519.96	490.99	-28.97	-57.77	-86.74
Jhang	3745.81	3558.55	3371.20	3183.94	-187.26	-374.61	-561.87
Rahim Yar Khan	5430.22	5158.74	4887.14	4615.66	-271.48	-543.08	-814.56
Punjab	191648.55	182066.14	172483.73	162901.32	-9582.41	-19164.81	-28747.22

The Economywide Impacts of Increasing Water Security through Policies on Agricultural Production

Implication of Restricting Rice and Sugarcane acreage by 15% in Pakistan

Computable General Equilibrium –Water model (CGE-W) used to assess that releasing water from high delta crops for other beneficial uses

Annual Crop Water Requirement (mm/year)

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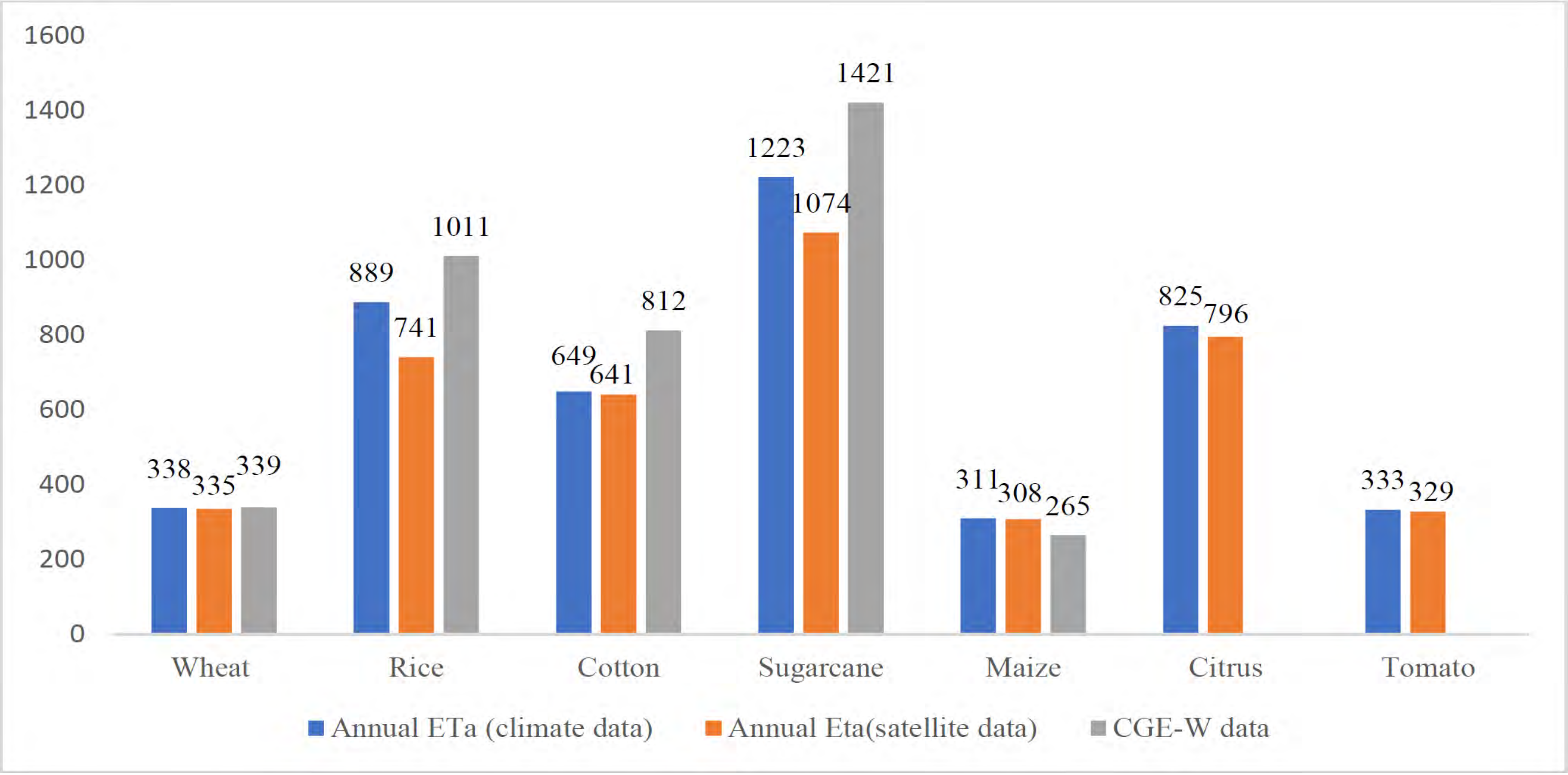

Changes in Land Use in Punjab to 2030 based on the Historical Scenario and Three Scenarios (Million Acres)

Crops	Base			15 percent ↓ in Rice		15 percent ↓ in Sugarcane		15 percent ↓ in Rice & Sugarcane	
	2014	2030	Change	2030 Level	Diff*	2030 Level	Diff	2030 Level	Diff
Wheat	17.10	15.42	-1.68	15.61	0.19	15.70	0.28	15.99	0.58
Irri Rice	1.39	1.48	0.08	1.41	-0.07	1.55	0.07	1.42	-0.06
Basmati	2.63	2.54	-0.09	2.25	-0.29	2.43	-0.11	2.22	-0.32
Cotton	5.67	5.95	0.28	6.13	0.17	6.15	0.20	6.39	0.44
Sugarcane	1.58	1.59	0.01	1.61	0.02	1.36	-0.23	1.39	-0.20
Maize	1.75	1.78	0.03	1.79	0.01	1.80	0.02	1.81	0.02
Other Crops	8.77	9.30	0.54	9.31	0.01	8.71	-0.60	8.52	-0.78
Vegetables	2.41	3.80	1.39	3.92	0.12	3.90	0.10	4.03	0.23
Fruit	1.57	2.92	1.35	2.97	0.05	3.29	0.36	3.33	0.41
Total	**42.87**	**44.80**	**1.93**	**45.00**	**0.20**	**44.88**	**0.08**	**45.10**	**0.31**

Source: Authors' estimation. IFPRI CGE-W model runs

Note: *The Diff columns show the differences in the change to 2030 in the Base versus each of the scenarios.

Changes in Water Use in Punjab to 2030 based on the Historical Scenario and Three Scenarios (MAF)

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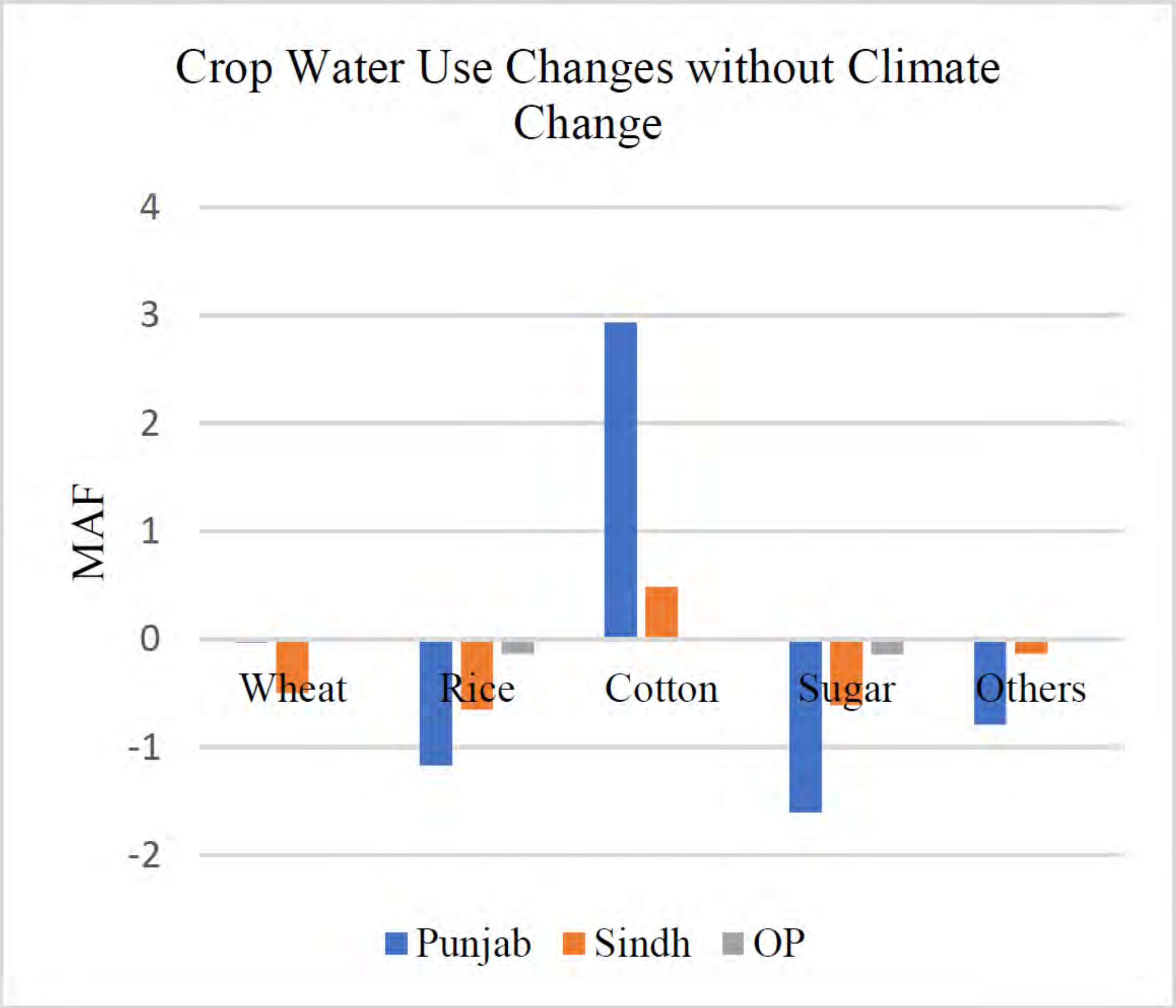
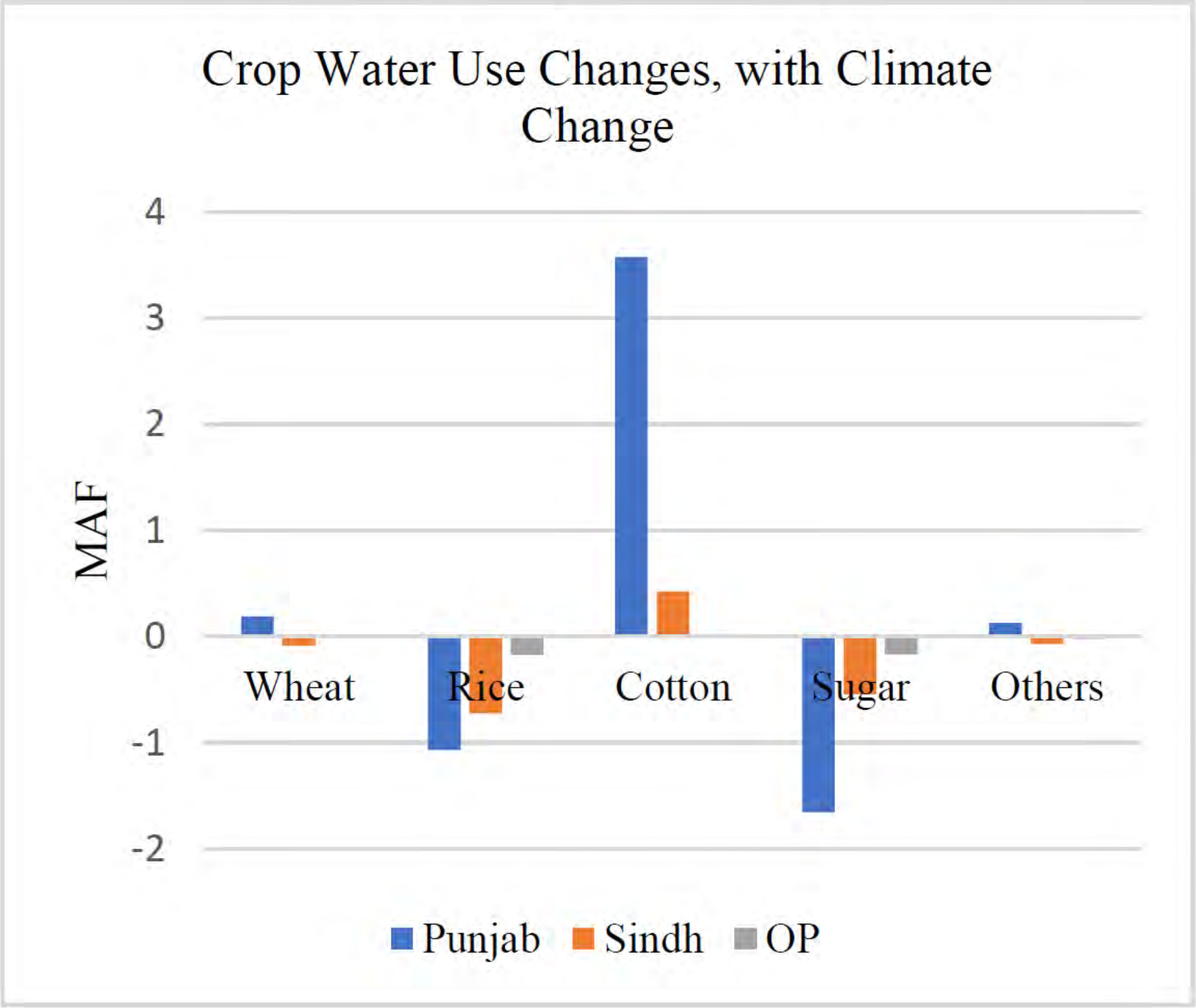
Crops	Base			15 percent ↓ in Rice		15 percent ↓ in Sugarcane		15 percent ↓ in Rice & Sugarcane	
	2014	2030	Change	2030 Level	Diff	2030 Level	Diff	2030 Level	Diff
Wheat	10.75	9.50	-1.25	9.61	0.11	9.73	0.24	9.89	0.39
Irri Rice	3.63	4.23	0.60	2.82	-1.41	4.85	0.63	2.92	-1.30
Basmati	6.44	6.67	0.23	4.88	-1.79	7.39	0.72	4.93	-1.74
Cotton	11.58	11.51	-0.07	12.39	0.88	12.55	1.04	13.93	2.42
Sugarcane	5.65	7.04	1.39	7.17	0.13	3.86	-3.18	3.93	-3.11
Maize	0.70	0.68	-0.02	0.70	0.02	0.73	0.05	0.76	0.08
Other Crops	6.19	6.34	0.15	6.59	0.25	6.87	0.52	7.21	0.86
Vegetables	3.03	3.86	0.83	4.11	0.25	4.29	0.43	4.64	0.77
Fruit	2.26	3.33	1.07	3.57	0.24	3.96	0.63	4.30	0.97
Total	**50.22**	**53.15**	**2.93**	**51.84**	**-1.31**	**54.23**	**1.08**	**52.51**	**-0.64**

Source: Authors' estimation. IFPRI CGE-W model runs

Note: *The Diff columns show the differences in the change to 2030 in the Base versus each of the scenarios.

Region wise Crop Water Use Changes with Taxes on Both Sugarcane and Rice, without and with Climate Change





National Water Use with Alternative Tax Policies (MAF)

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Applied CGE-W model to assess water release potential by reducing sugarcane and rice acreage:

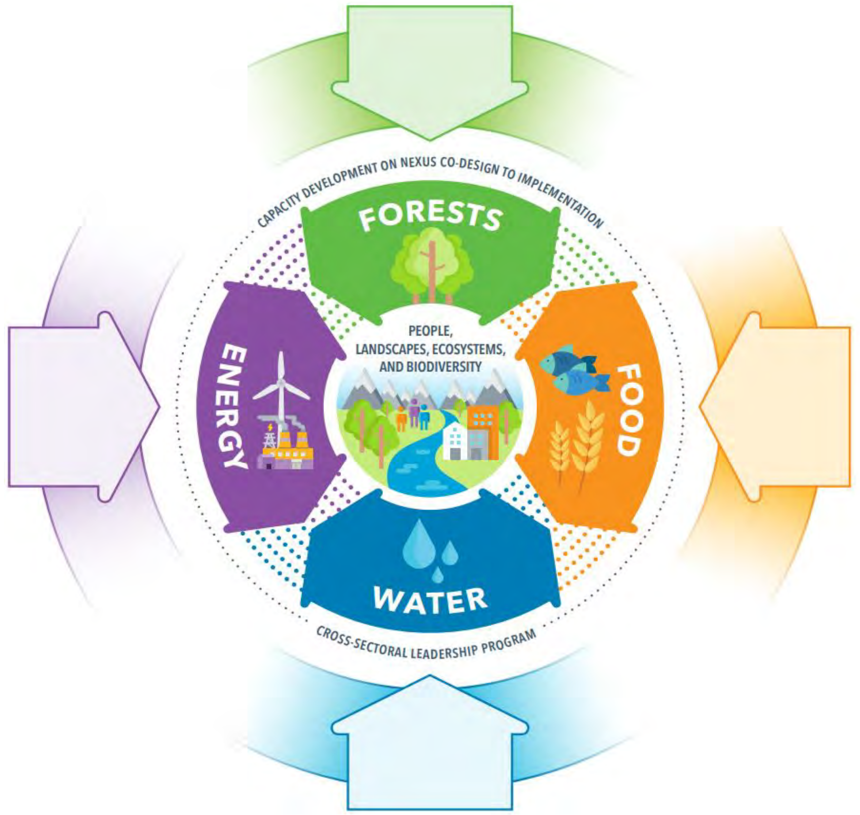
- Taxing sugarcane & rice combinedly or 30% taxing sugarcane, cotton and rice releases significant water volumes **70.1 MAF** or **68.9 MAF** respectively
- Alternatively, instead of taxing crops or reduce the acreage , Tax on the inputs such as fertilizer achieve similar results i.e. **69.5 MAF**
- Combined SC and Rice scenario released **3.2 MAF out of agriculture**.

Crop	Combined SC and Rice	SC Rice Cotton -30 30 30	Difference (Col. 3 – 2)	Fertilizer	Difference (Col. 4 – 2)	Scaled Based on CWR	Difference (Col. 5 – 2)
Wheat	12.6	12.8	0.2	12.4	-0.2	14.7	2.1
Rice	12.4	14.1	1.6	14.2	1.8	13.7	1.3
Cotton	16.5	10.2	-6.3	11.8	-4.7	11.9	-4.6
Sugarcane	8.3	9.6	1.4	9.0	0.8	7.1	-1.2
Maize	0.8	0.8	0.0	0.8	0.0	0.9	0.1
Other crops	7.9	8.2	0.3	8.2	0.3	7.7	-0.2
Vegetables	5.7	6.5	0.8	6.3	0.6	6.6	0.9
Fruit	6.0	6.8	0.8	6.7	0.7	6.8	0.8
Total	**70.1**	**68.9**	**-1.2**	**69.5**	**-0.7**	**69.4**	**-0.7**

Source: CGE-W model runs

Thank you for your attention!

Dr Mohsin Hafeez
Director, Water, Food and Ecosystems
IWMI
m.hafeez@cgiar.org



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