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NEXUS Gains
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Water resources Using hydro economic models for decisions in Water, Energy, Food and Environment (WEFE)

Examples from Pakistan

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Introduction

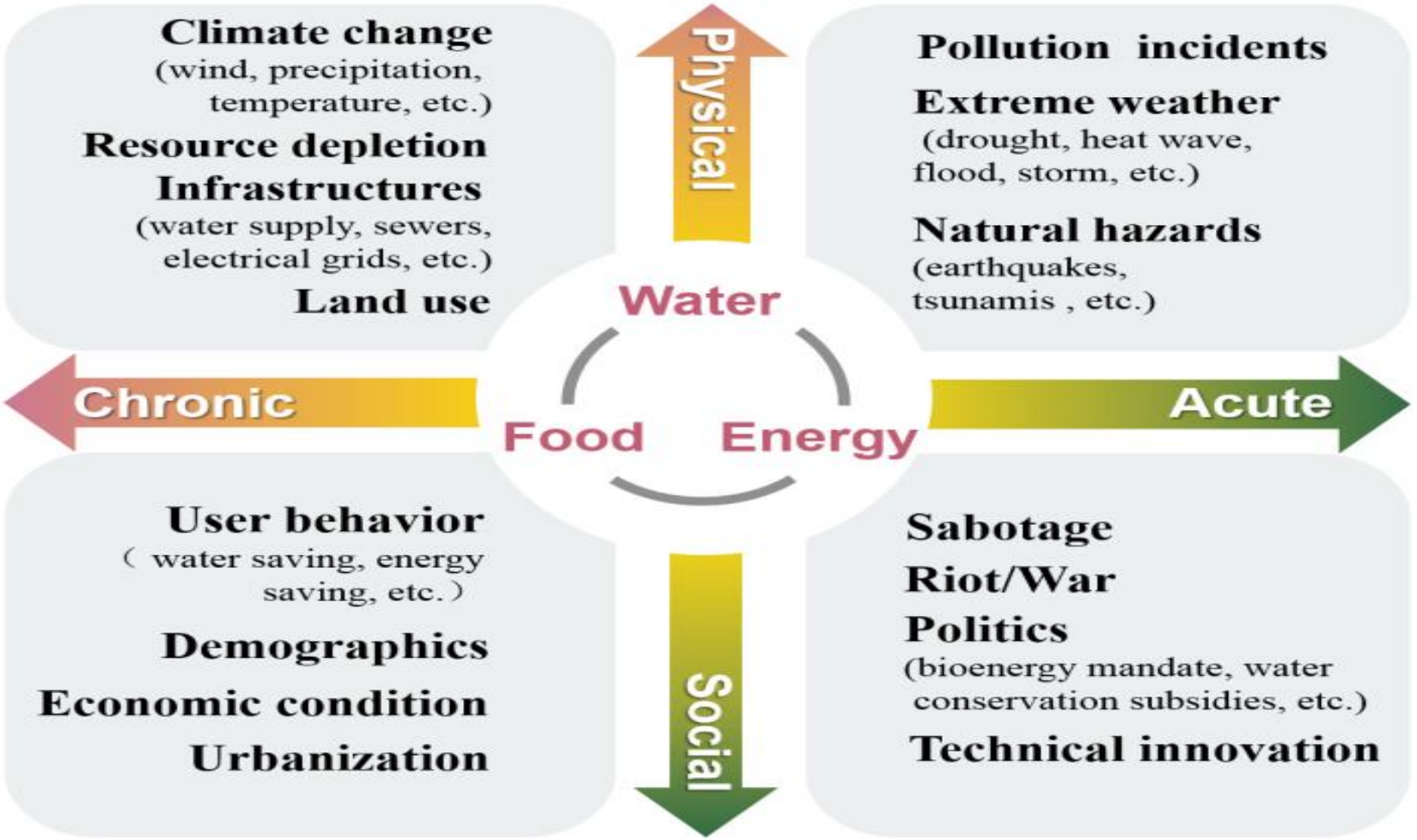
This session will show how hydro economic can address issues in the Water Energy Food Environment (WEFE) NEXUS to assess their use in policy and stakeholder deliberations.

The focus is on the Computable General Equilibrium model Water (CGE-W) which is a national model developed by the International Food Policy Research Institute

- It incorporates the full Indus basin within Pakistan and has been used in Pakistan for over a decade.

CGE models are built on a system of equations that tie markets together via price and quantity changes.

An extended view of WEFE Dimensions and Context

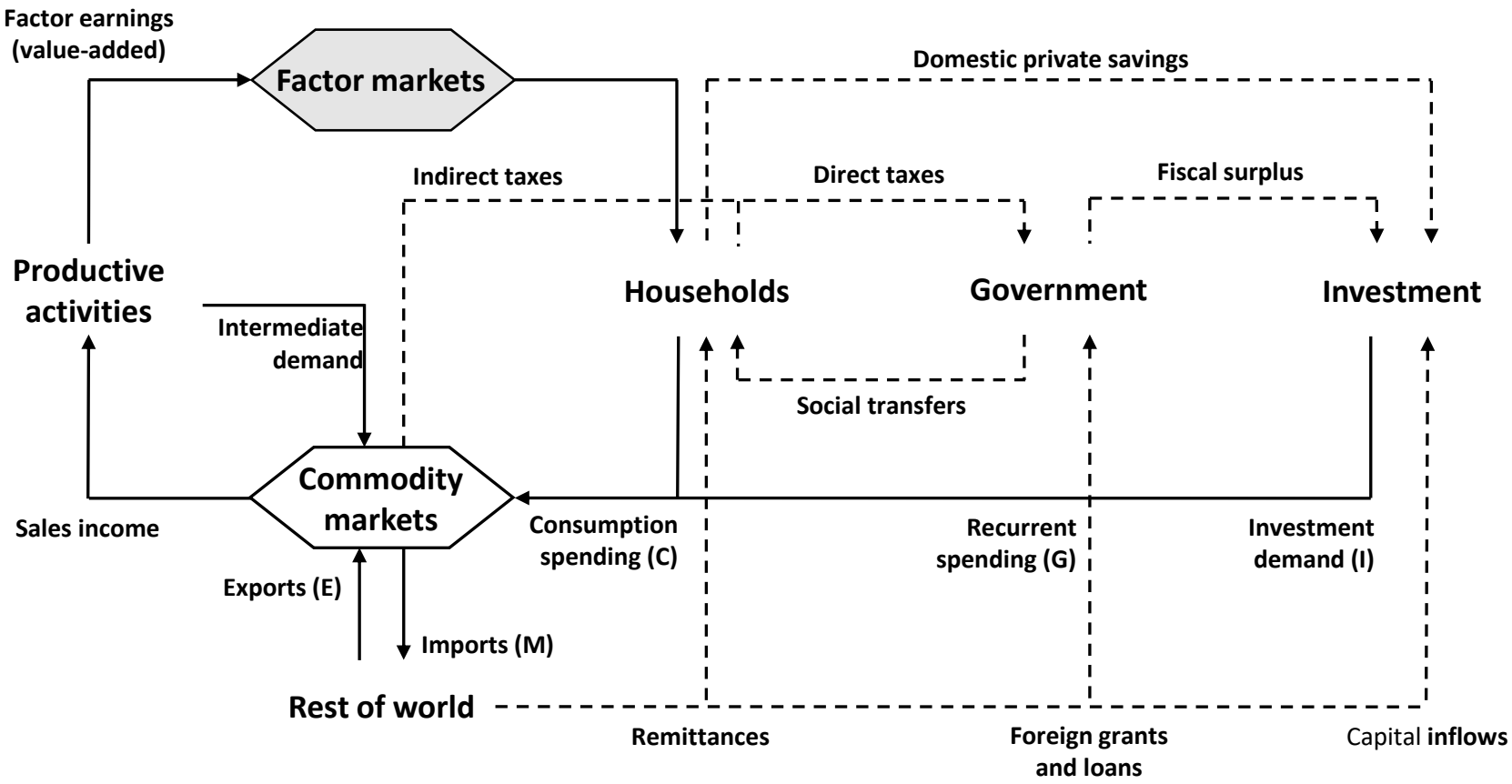


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What is included in the CGE-W Model??

IFPRI's CGE-W model = Computable General Equilibrium Model - Water

Circular flow diagram of the economy



Source: Breisinger, Thomas, and Thurlow (2009)

Basic Structure of SAM

		Expenditure columns							
		Activities C1	Commod's C2	Factors C3	Households C4	Government C5	Investment C6	Rest of world C7	Total
Income rows	Activities R1		Domestic supply						Activity income
	Commodities R2	Intermediate demand			Consumption spending (C)	Recurrent spending (G)	Investment demand (I)	Export earnings (E)	Total demand
	Factors R3	Value-added							Total factor income
	Households R4			Factor payments to households		Social transfers		Foreign remittances	Total household income
	Government R5		Sales taxes and import tariffs		Direct taxes			Foreign grants and loans	Government income
	Savings R6				Private savings	Fiscal surplus		Current account balance	Total savings
	Rest of world R7		Import payments (M)						Foreign exchange outflow
	Total	Gross output	Total supply	Total factor spending	Total household spending	Government expenditure	Total investment spending	Foreign exchange inflow	

Table 10: Macro SAM for Pakistan in 2023 (Billions of Pakistani Rupee (Rs)

	Activities	Commodities	Factors	Enterprises	Households	Government	Taxes	Investment	Rest of the World	Total
Activities		141,910			10,989					152,899
Commodities	73,256	39,265			59,375	8,500		11,495	8,597	200,489
Factors	79,642								191	79,833
Enterprises			31,722			5,057			458	37,236
Households			45,852	28,718		668			7,547	82,785
Government				669			9,009		115	9,792
Taxes		4,394	171	2,040	2,404					9,009
Savings				5,784	9,938	-4,437			210	11,495
Rest of the World		14,920	2,089	26	80	4				17,117
Total	152,899	200,489	79,833	37,236	82,785	9,792	9,009	11,495	17,117	

Source: 2023 Pakistan SAM.

Pak Indus Water Balance

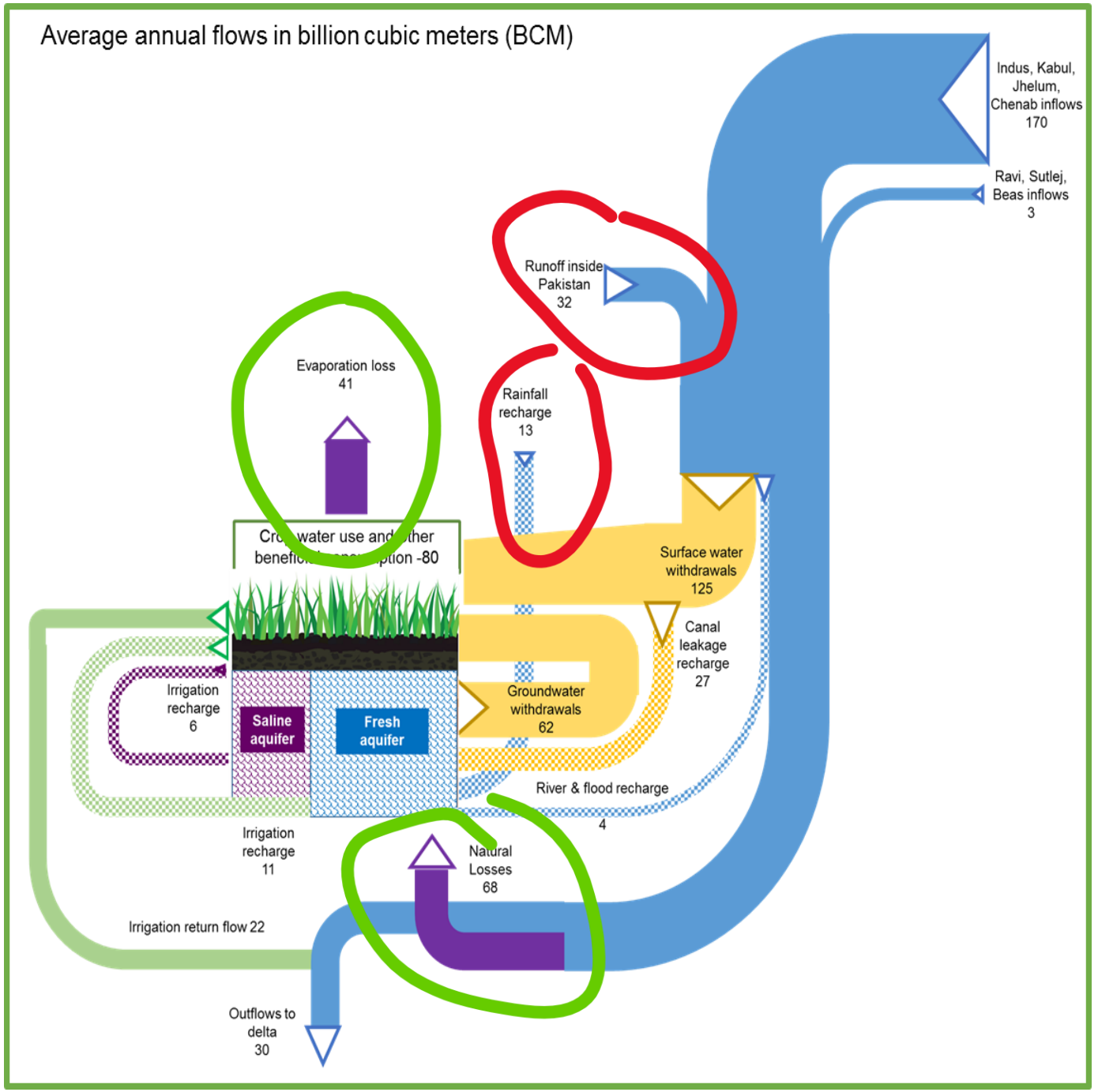
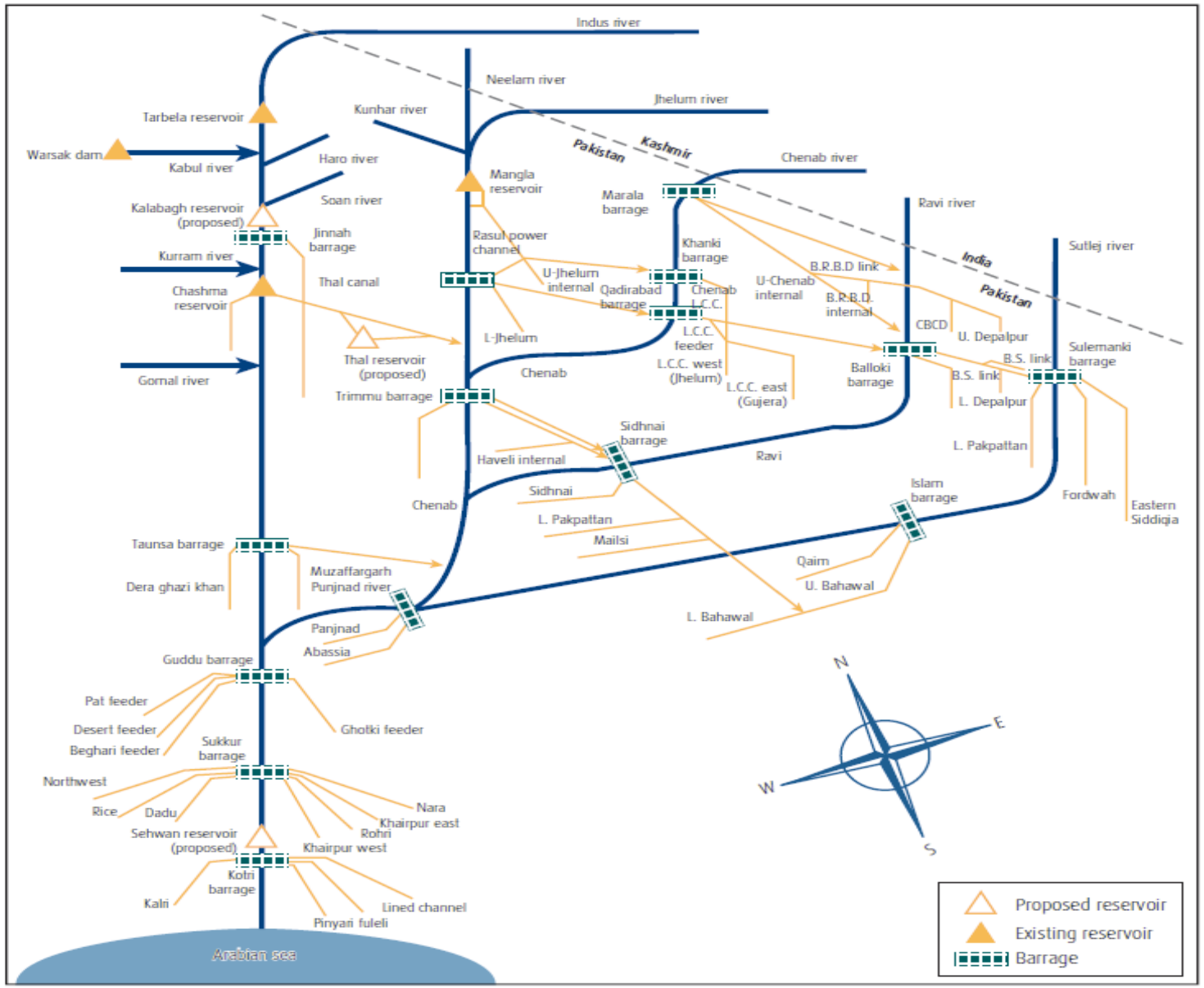


Figure 4.1 Indus Basin Irrigation System of Pakistan



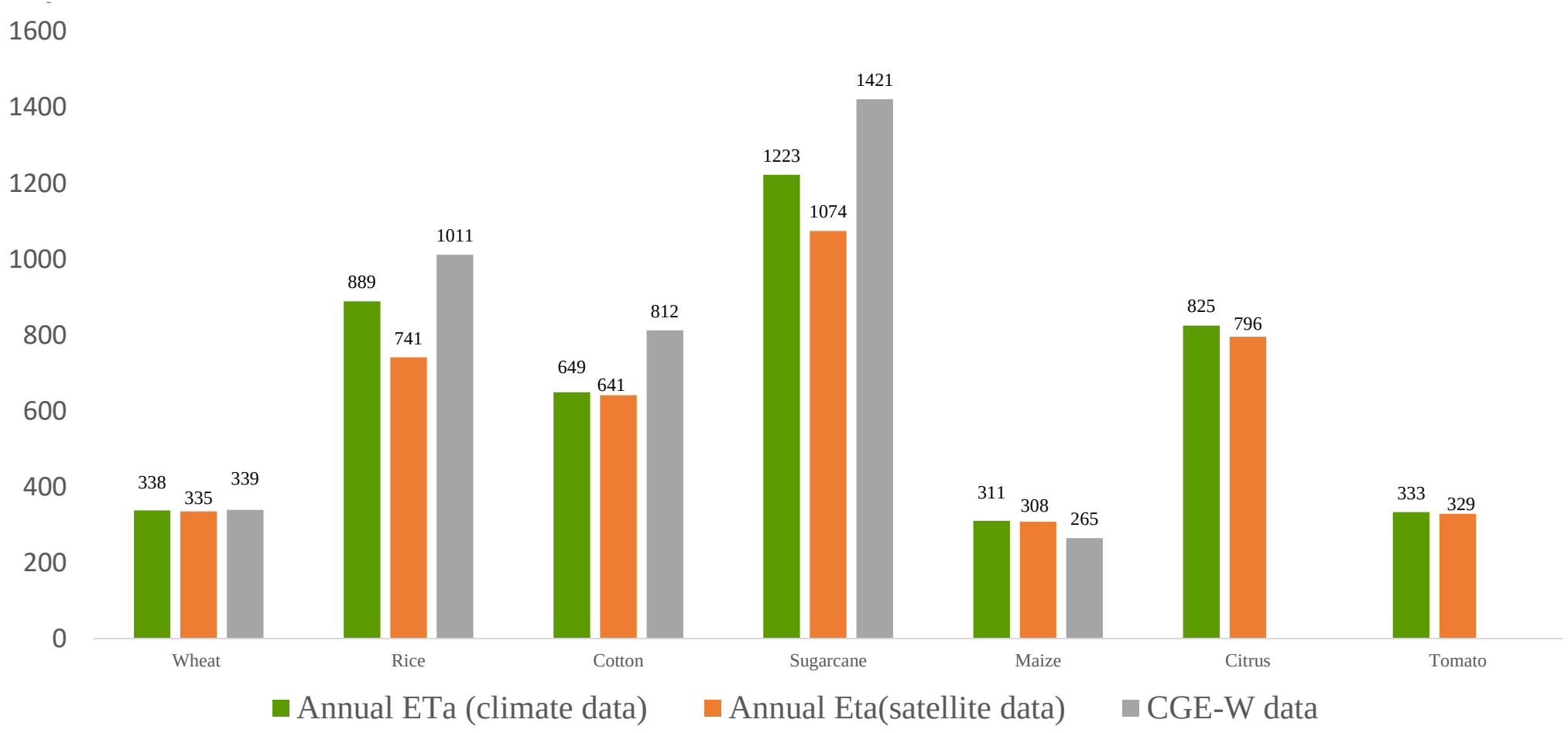
The Indus basin has **49 canal command areas, 9 tributaries, 4 major reservoirs, and 16 crops** with spatially disaggregated crop water requirements.

These are all linked **via a nodal system** that permits tracking of all water flows and losses.

Hydro Side

Components
Monthly Averaged River flow data
Rim station flow data
Inflows - Per month (SWAT,HARO SOAN)
Committed annual outflows from Pakistani rivers – Monthly
Storage Capacity of Reservoirs - Latest (For all reservoirs)
Groundwater type as per canal command area (Fresh/Saline) – Overall Data Required for all canals
Mapping Canals to nodes
Proportion of the previous month’s flow lagging - Latest available numbers
Loss coefficient for river routing - Latest available numbers
Loss coefficient for tributaries - Latest available numbers
Public tubewells pumping across ACZ* (Fresh/Saline) - Per Month Data required for all zones
Depth of Water Table Zone-wise (Fresh/Saline) - Per Month

Crop Water Requirements



Source. Authos' estimation

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What can the CGE-W Model do??

IFPRI's CGE-W model = Computable General Equilibrium Model - Water

Drivers of Change in the CGE-W model

Simulate the economy and water resources across time with changes such as the following:

Expansion of resources:

- Labor, Land and Capital
- Population Growth

Productivity of inputs and production

- Total Factor Productivity (TFP)
- Efficiencies of Individual Factors of Production

Prices and Taxes

- International Prices
- Indirect and direct tax rates

Per Annum Growth in Output by Crop in Punjab, 2014-30, with Associated Water and Land Use

	% Output Chg. (p.a.)		Punjab Water Use (MAF)		Punjab Land Use (mm Acres)	
	10-year Growth in Okara	16 years of Simulated Punjab Output Growth	Base	LFPHE	Base	LFPHE
Wheat	-3.7	0.61	-0.4	0.5	-2.2	-1.8
Rice B	5.9	5.59	1.9	-1.1	2.6	-0.7
Rice I	--	5.84	4.7	-2.4	1.5	-0.4
Cotton	-18.3	0.03	-2.1	1.8	-1.1	0.7
Sugarcane	1.5	0.86	-0.6	-0.3	-0.2	-0.1
Maize	3.5	1.65	-0.1	0.0	-0.1	0.1
Potato	5.8	5.65	0.1	0.4	0.6	0.9
Other	--	3.02	-1.8	2.2	0.8	4.3
Net Effect			1.8	1.1	2.0	3.0

CGE-W Simulations changing growth rates of rice and potatoes

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Elasticities based on Growth rates*, 2014-2030

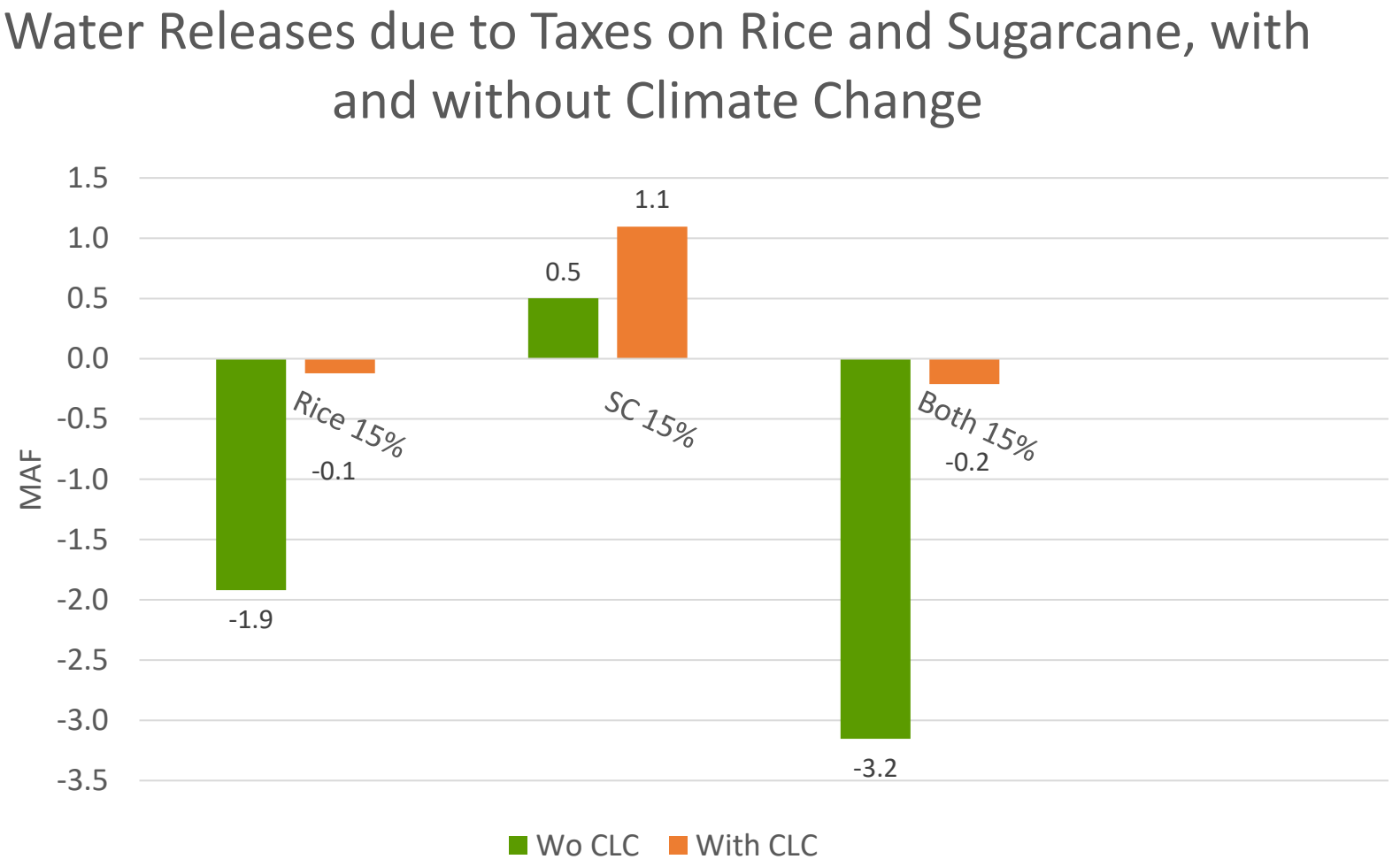
	Low Rice	High Rice	Low Potato	High Potato
Wheat	0.56	-0.01	0.26	0.57
Basmati Rice*	**-1.00**	**1.00**	1.00	-0.93
IRRI Rice			-0.01	-1.28
Sugarcane	0.00	-1.18	-0.06	0.15
Maize	0.67	-0.93	0.13	1.25
Potato	0.49	-0.31	**-1.00**	**1.00**
Other	0.45	-0.58	0.12	0.46

Changes in Water Use in Punjab to 2030 for a Base and Three Scenarios (MAF)

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	Base			15% decrease in Rice		15% decrease in Sugarcane		15% decrease 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**

Annual Water Releases from Tax policy, with and without climate change



Note: SC- Sugarcane, CLC- Climate Change, Wo- Without

Okara district multiplier results

	Effects of PKR 1.0 Billion Expansion in Okara Commodities				
	Wheat	Basmati	Maize	Potato	Milk
Output (w bill PKR shock	933.0	1,015.9	1,139.1	1,091.9	1,127.9
Change in electric cost	23.3	58.4	32.1	14.2	17.4
Diesel cost	26.2	78.5	38.9	13.3	10.7
Surface Water Cost	1.2	1.2	1.7	0.4	0.2
Payments to labor	119.9	70.9	99.2	106.2	137.3
Rural hh income	317.6	236.7	304.8	304.8	485.0
Urban hh income	362.7	327.0	384.0	347.9	498.0
Implied subsidy	26.2	28.2	37.7	8.1	3.6

Effects of Alternative Policies

Crop	Combined SC and Rice	SC Rice Cotton - 30 30 30	Diff. (Col. 3 – 2)	Fertil-izer (35%)	Diff. (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**

*This scenario yields a reduction of 3.15 MAF relative to the Base

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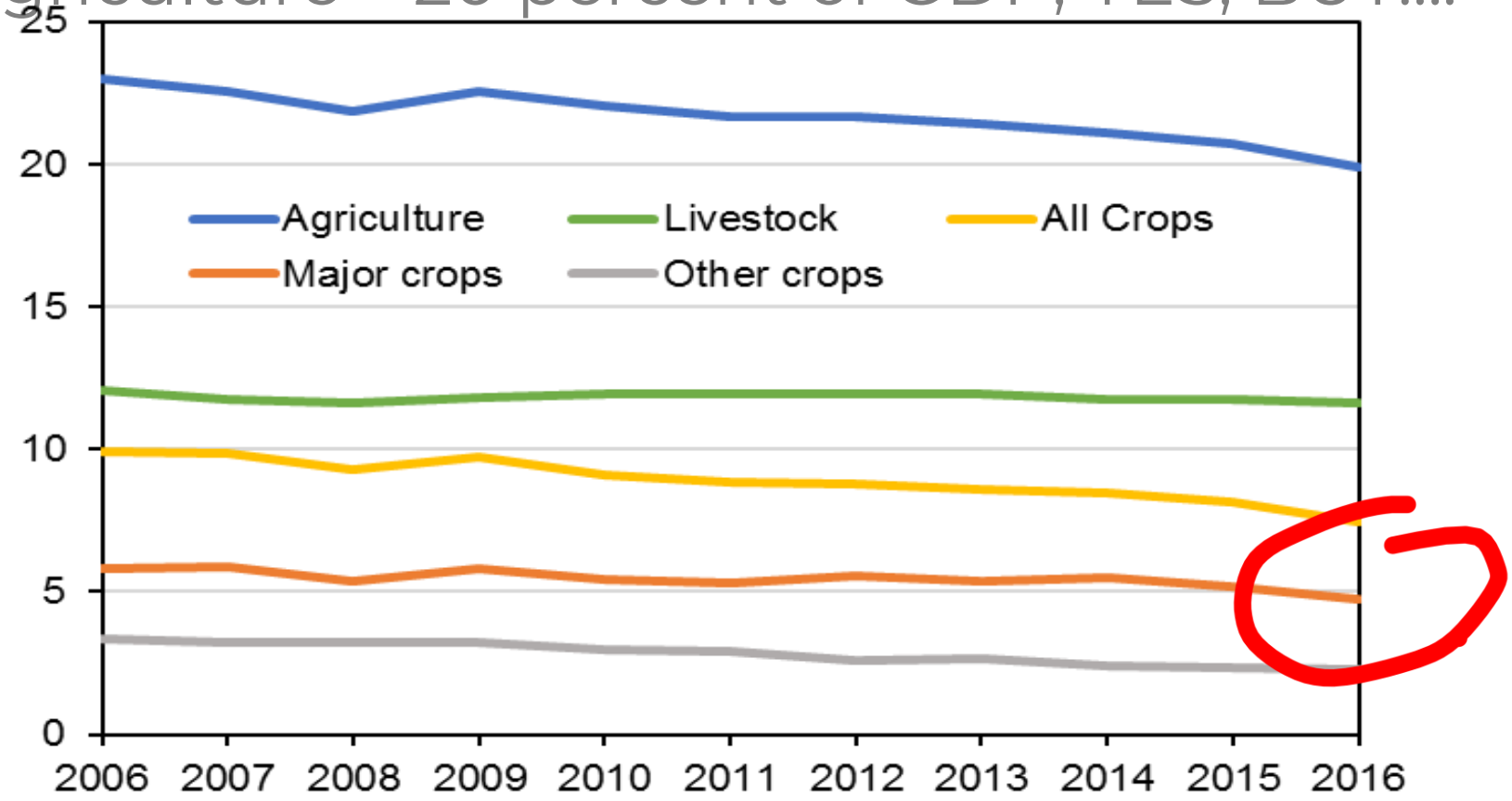
Challenges and Limitations of the CGE-W Model

IFPRI's CGE-W model = Computable General Equilibrium Model - Water

What does Pakistan Get from its Water

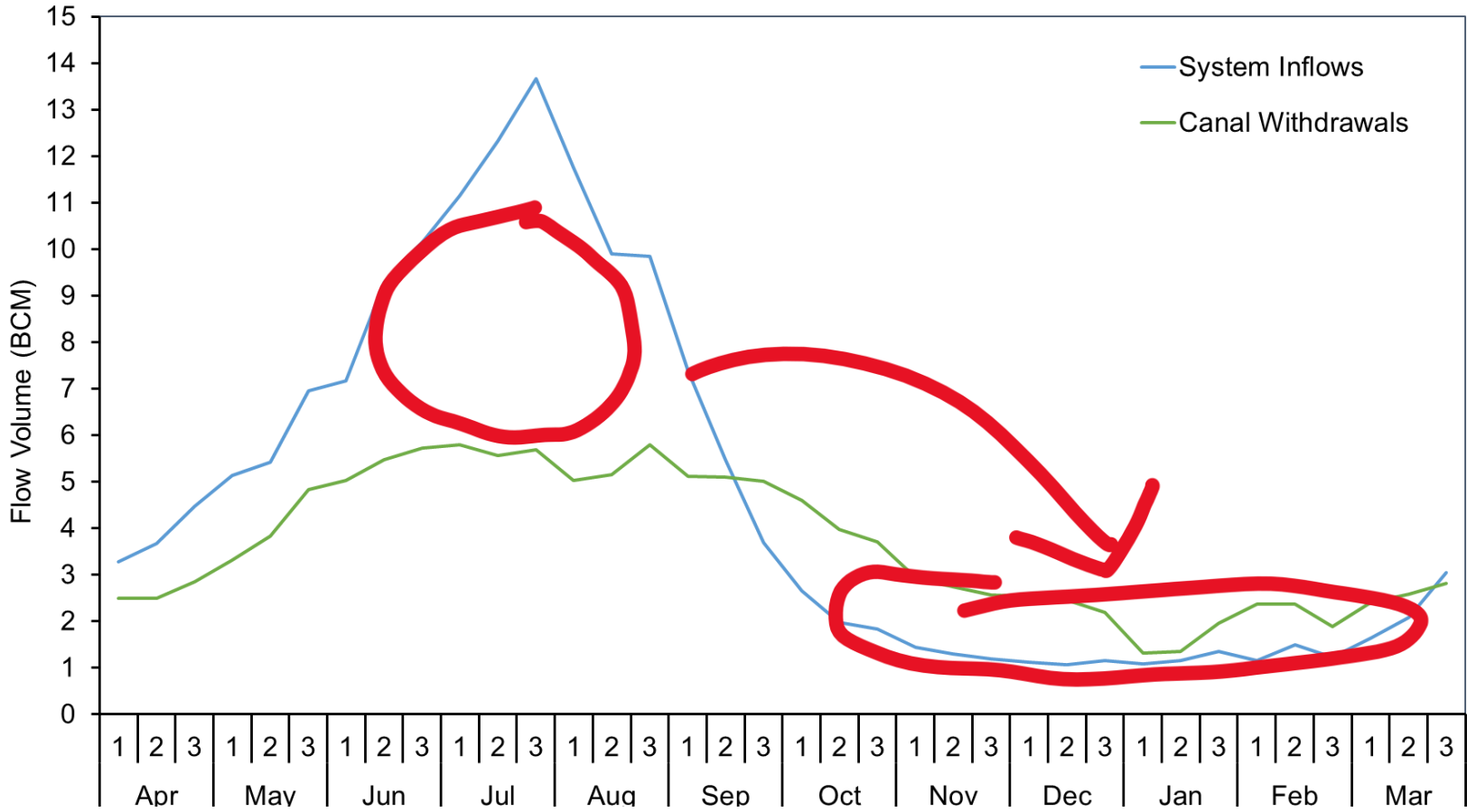
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Agriculture – 20 percent of GDP; YES, BUT….



Irrigation ~$20B per year, 4 major crops ~$15 B

The Inter-seasonal Picture



Most shortfalls are in Rabi in poor monsoon years (this will become more common)

2. Environmental Flows below Kotri Barrage

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Groundwater

	50 maf	44 maf	Enviornmental Flows below Kotri Barrage					
			TFP +10%	+10% rabi wc eff	+10% kh wc eff	both	+10% Canal Efficeny	all
hist (1960-2014 repeated)	36.9	36.2	37.4	37.2	40.1	40.3	39.1	42.8
Bhist (hist w Bhasha)	36.1	35.1	36.7	36.3	39.7	39.8	39.3	42.9
LFPHE (Low F & P, Hi Evap)	32.8	33.5	34.0	30.1	34.1	31.0	31.4	34.2
B-LFPHE (LFPHE w Bhasha)	29.4	30.6	29.8	29.0	31.4	31.6	31.3	33.2

F=flows, P= precip

Limitations

It’s a Model and replicates an equilibrium

All models are simplications of reality

- This one is more extensive than many and so more assumptions are needed
- Some are good assumptions, but others are not

It hard to capture disequilibria

- Recent wheat program issues or
- unexpected rare events
- (earthquakes floods, or protests and changes in preferences)

THANK YOU!

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