INITIATIVE ON
NEXUS Gains

Hydro-Economic model for decision making on water optimization in Indus Basin:

A Presentation for the NEXUS Gains Community of Practice Program

Islamabad, Pakistan

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Stephen Davies, Iqra Akram, Moh. Tahir Ali,
IFPRI and IWMI

What is water-energy-food-ecosystem nexus?

Water/Energy/Food/Ecosystems (WEFE) Nexus Challenges

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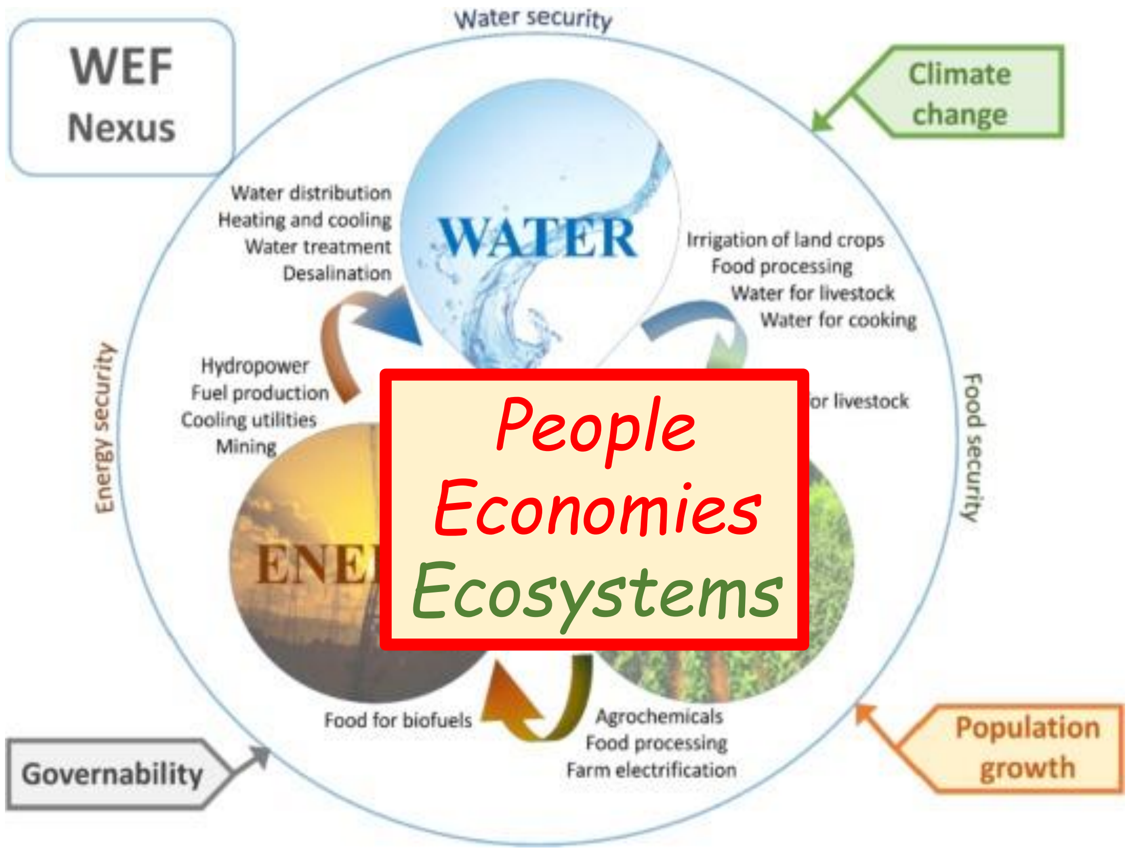

- WEFE nexus is critical to rural livelihoods, food and nutrition security & economies, and systems are **strongly interconnected**
- **National & regional institutions struggle**, particularly in transboundary basins
- Nexus goes beyond IWRM approach
- Scale dependencies of processes: Farm to landscape/watershed to basin scale
- **Women, girls, and vulnerable groups** face the greatest adverse consequences

Source: Mahlknecht et al., 2020; adapted

NEXUS Gains examines WEFE systems in internationally significant transboundary basins. The approach involves fully embracing the complexity of interconnected systems, including the additional challenges of working across national borders. The Initiative works with a broad range of stakeholders to overcome disciplinary and administrative silos and co-develops solutions that can be applied from local to transnational scales. The goal is not solely economic efficiency, but inclusive socio-economic development and environmental sustainability in the context of the climate crisis.

NEXUS Gains focuses on river basins: mosaics of ecosystems and landscape elements connected by water flows. Digital tools will help understand and quantify both upstream and downstream system interdependencies and predict future conditions. Practical innovations can then be implemented to better manage WEFE systems while strengthening capacity and governance in collaboration with partners at all levels.

WP1-Foresight and Tradeoff Analysis

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- **Target:** NEXUS gains modeling tools will be used to assess prioritized WEFE innovations
- **System Transformation:** National and sub-national government agencies use system transformation research to implement policies and programs that reduce emissions and enhance climate resilience and environmental sustainability of food, land and water systems
- **Progress:** Swat+ Model, PyWR and CGE-W models are being used to prioritized the WEFE innovations

Menti-Meter Results

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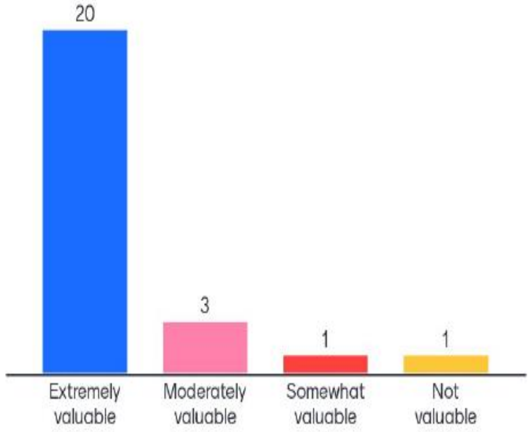
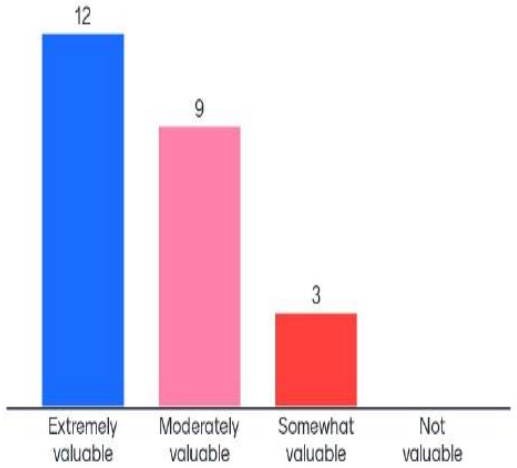
- Menti results from the workshops indicated strong support for the model, with valuable feedback from technical and policy experts, ensuring continuous refinement.

Multiple ChoiceHow do you perceive the role of stakeholder engagement in the success of policy scenarios/simulations?



How integral do you perceive policy scenarios or simulations in informing your decision-making processes?



Menti-Meter Results

What are the primary challenges you anticipate encountering when applying scenarios or simulations in policymaking?

41 responses

What are 3 top priority simulation scenarios that could aid in addressing Pakistan's water, energy, food, and ecosystem challenges?

60 responses

Workshop- CGE-W Modeling

GAMS & CGE-W Model

Layout of Session

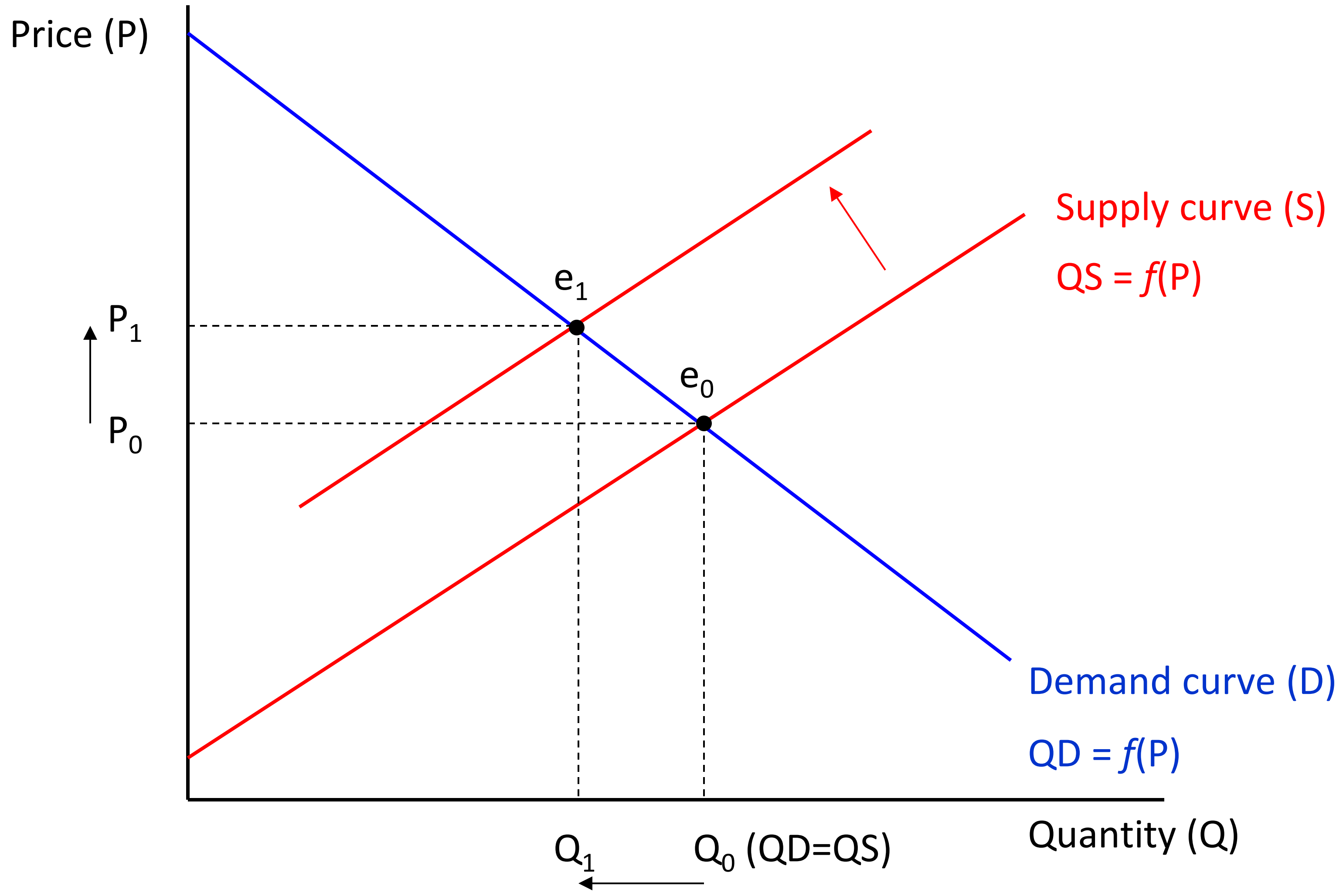
- Review of market economics for use in policy analysis
- Basics of GAMs coding and use.
- Implementing A simple multi-market model in GAMs
- Some Policy outcomes

What is GAMS?

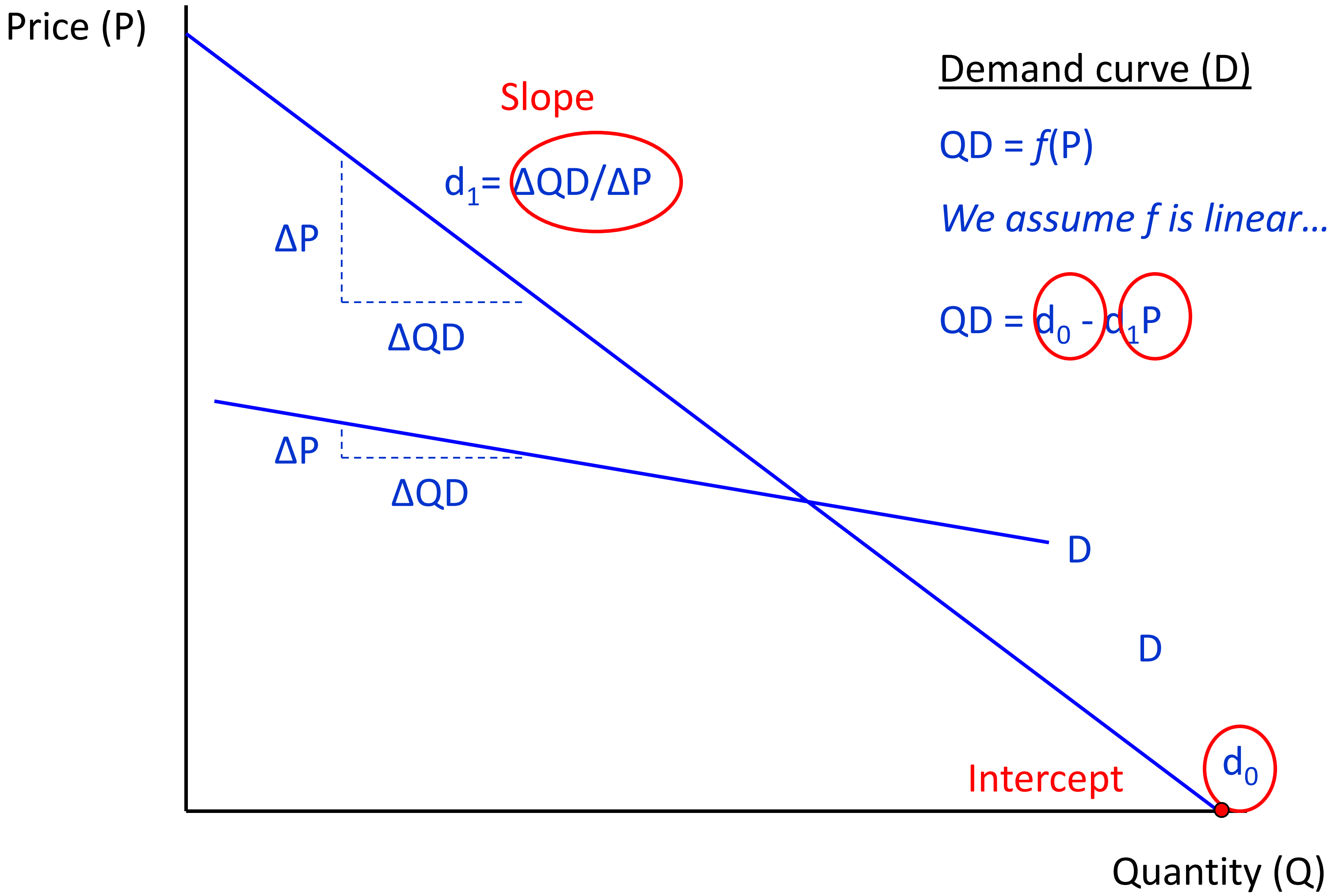
- General Algebraic Modeling System
- Mathematical programming environment
  (not for statistics like Stata, SPSS)
- Solves systems of equation

  (easy to do vector or matrix calculations)
- Solves problems that involve optimization
  (like maximize income, minimize costs, etc)

Simplest Demand-Supply Model



Specifying the demand curve



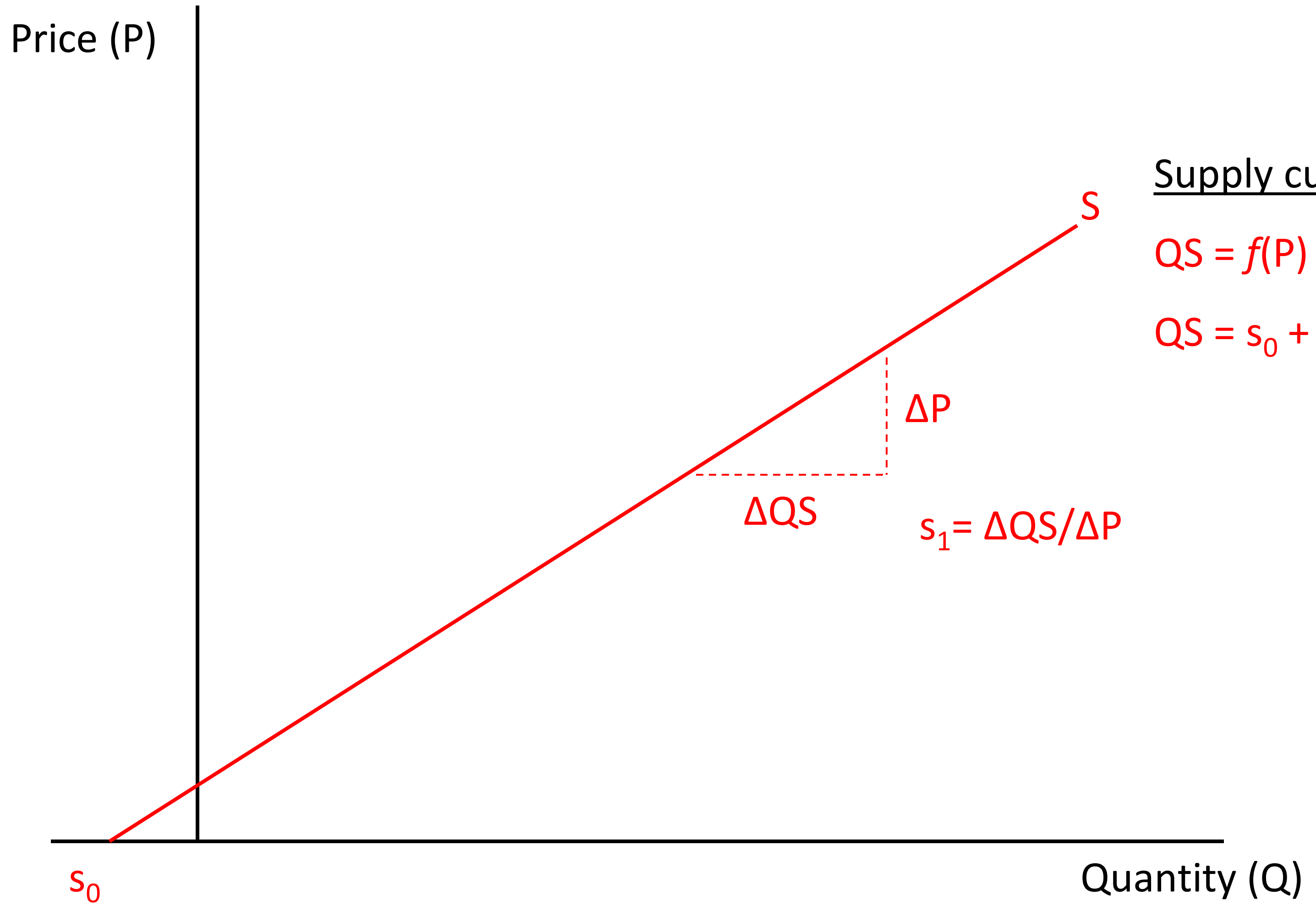
Demand curve (D)

QD = f(P)

We assume f is linear…

QD = d_0 - d_1P

Specifying the supply curve



<u>Supply curve (S)</u>

$QS = f(P)$

$QS = s_0 + s_1 P$

Mathematical equations

Demand curve

$$QD_c = d_c^0 - d_c^1 \cdot P_c$$

Supply curve

$$QS_c = s_c^0 + s_c^1 \cdot P_c$$

Equilibrium

$$QD_c = QS_c$$

where c is a set of commodities

So if we have two commodities (e.g. agricultural and industrial goods), then we have two demand, supply and equilibrium equations (one for each commodity)

How elasticity is derived in GAMS exercise: Example: Simple equilibrium conditions

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$$Elasticity\ of\ Demand = \frac{\Delta demand}{\Delta Price} * \frac{P}{Q}$$

$$Slope = Elasticity * \frac{Q}{P} = \frac{\Delta demand}{\Delta Price}$$

$$Qd = 600 - 4P; \quad Qs = 80 + 1P$$

$$Demand\ = Supply$$

$$600 - 4P = 80 + 1P$$

$$5P = 520$$

$$P(Equilibrium) = 104$$

$$Qs = 80 + 1(104)$$

$$Qs = 184$$

And

$$Qd = 600 - 4(104)$$

$$Qd = 184$$

Mathematical equations

Demand curve $$QD_c = d_c^0 - d_c^1 \cdot P_c$$

Supply curve $$QS_c = s_c^0 + s_c^1 \cdot P_c$$

Equilibrium $$QD_c = QS_c$$

where c is a set of commodities

This set of equations and the equilibrium relationship can be modelled in a software called **GAMS** !

Breaking up the problem in GAMS

Demand curve $$QD_c = d_c^0 - d_c^1 \cdot P_c$$

Supply curve $$QS_c = s_c^0 + s_c^1 \cdot P_c$$

Equilibrium $$QD_c = QS_c$$

When you program GAMS you break up the problem into its components…

Sets	indices (agricultural goods, industrial goods)
Variables	endogenous variables (price, quantity demand/supplied)
Parameters	exogenous variables (slopes, intercepts)
Equations	structural relationships between variables and parameters
Model	collection of equations

Resources on CGE modeling and/or GAMS

- The following websites provide plenty of materials and links:
  - www.gams.com
  - www.gtap.agecon.purdue.edu
  - /www.agrodep.org/model/gams-training-toolbox

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GAMS IDE Demo

INPUTS of CGE-W Model

SOCIAL ACCOUNTING MATRIX

Economic Side

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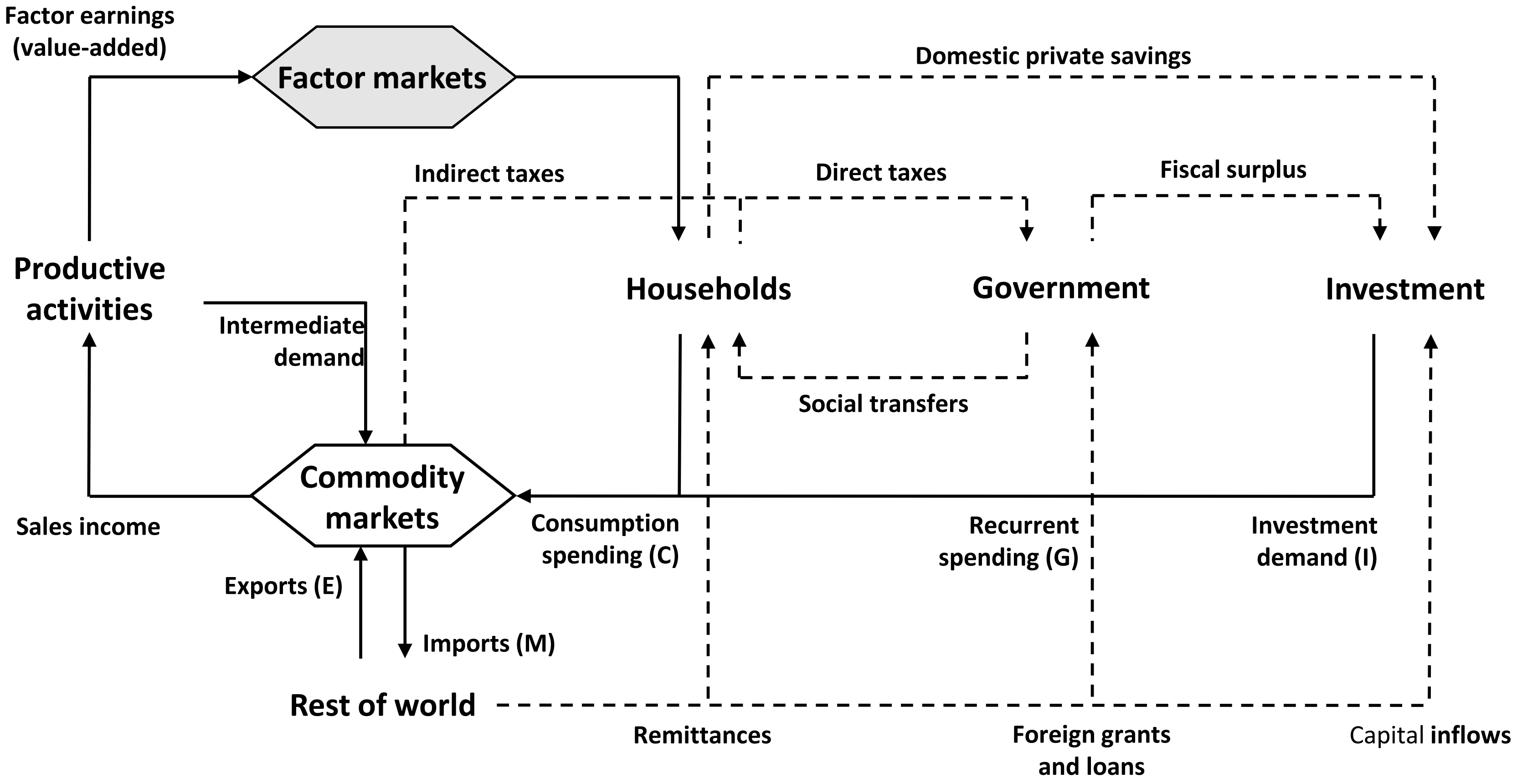
CIRCULAR FLOW DIAGRAM OF THE ECONOMY



Source: Breisinger, Thomas, and Thurlow (2009)

Social Accounting Matrix- Okara

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In billion RS

Income rows	Activities				Commodities				Factors	Households	Government	Investment	Rest of world	Total
	Agriculture		Livestock	Non-Ag	Agriculture		Livestock	Non-Agg						
	Crops	Processing			Crops	Processing								
Activities					168.3	65.9	174.8	253.6						662.6
Commodities	78.9	41.5	31.7	78.0	15.9	13.8	18.1	68.9		198.9	31.7	12.0	353.0	942.4
Factors	86.3	24.3	127.0	179.0									87.0	503.6
Households									559.7		0.3		-259.2	300.8
Government				-3.9					11.8	3.7	-3.9	12.9	11.0	31.6
Savings										28.4				28.4
Rest of world	3.6		16.1		20.4	1.6	11.3	129.5	2.2		3.5	3.6		191.8
Total	168.7	65.9	174.8	253.2	204.7	81.3	204.3	452.0	573.7	231.0	31.6	28.4	191.8	

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

Indus Basin Water Balance (Young et. al 2019)

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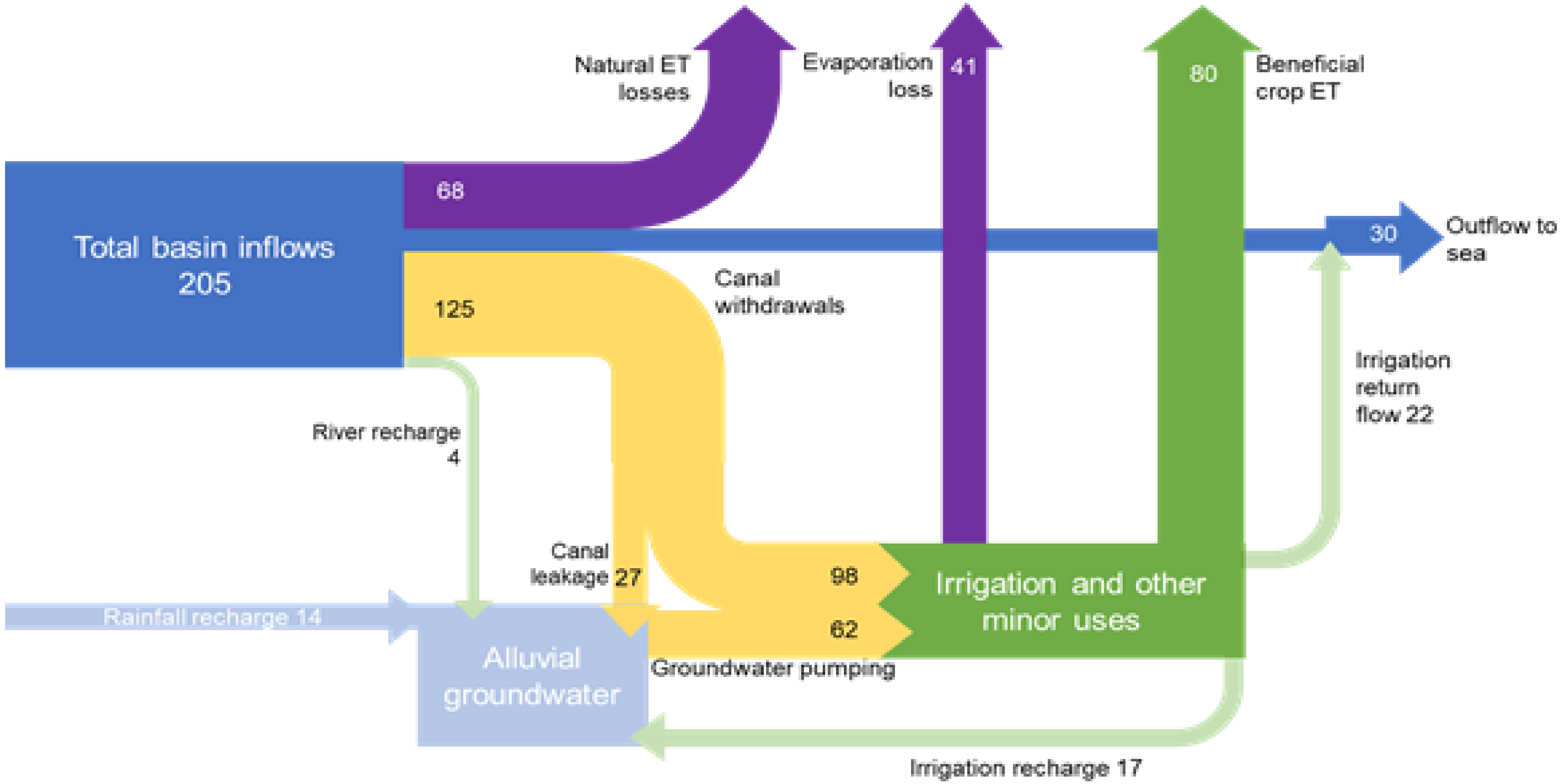

Crop Water Requirements

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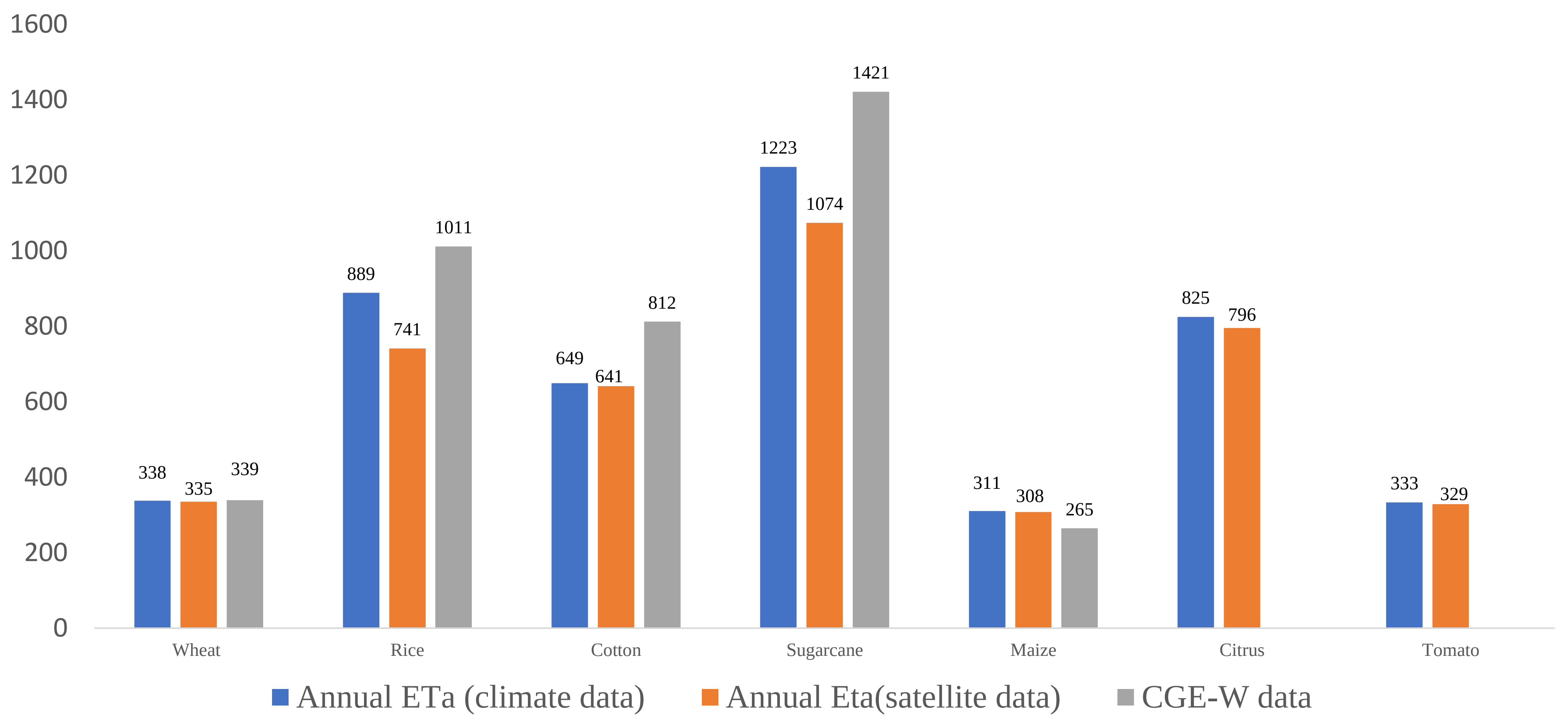
Annual Crop Water Requirement (mm/year)



Source. Authos’ estimation

High Rice Growth and Climate outcomes in Punjab from the IFPRI CGE Model

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	Okara	Punjab				
	% Output Chg		Water Use (MAF)		Land Use (mm Acr)	
	10 years Okara	16 years Simulation	Base	LFPHE	Base	LFPHE
Wheat	-3.7	1.3	-1.5	-0.4	-3.5	-2.7
Rice B	5.9	6.9	3.9	-0.6	3.4	-0.4
Rice I	--	6.8	5.9	-1.6	1.9	-0.9
Cotton	-18.3	0.6	-2.5	1.7	-1.2	0.8
Sugarcane	1.5	2.1	0.1	-0.6	0.0	-0.2
Maize	3.5	2.2	-0.2	-0.1	-0.3	0.0
Potato	5.8	4.5	0.0	0.7	0.6	1.1
Other	--	4.5	-2.5	3.4	0.5	4.8
Net Effect			3.24	2.52	1.37	2.60

Outputs of the CGE-W Model

CGE-W Simulations changing prices 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

Results from Sugarcane and Rice Reduction Paper

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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

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

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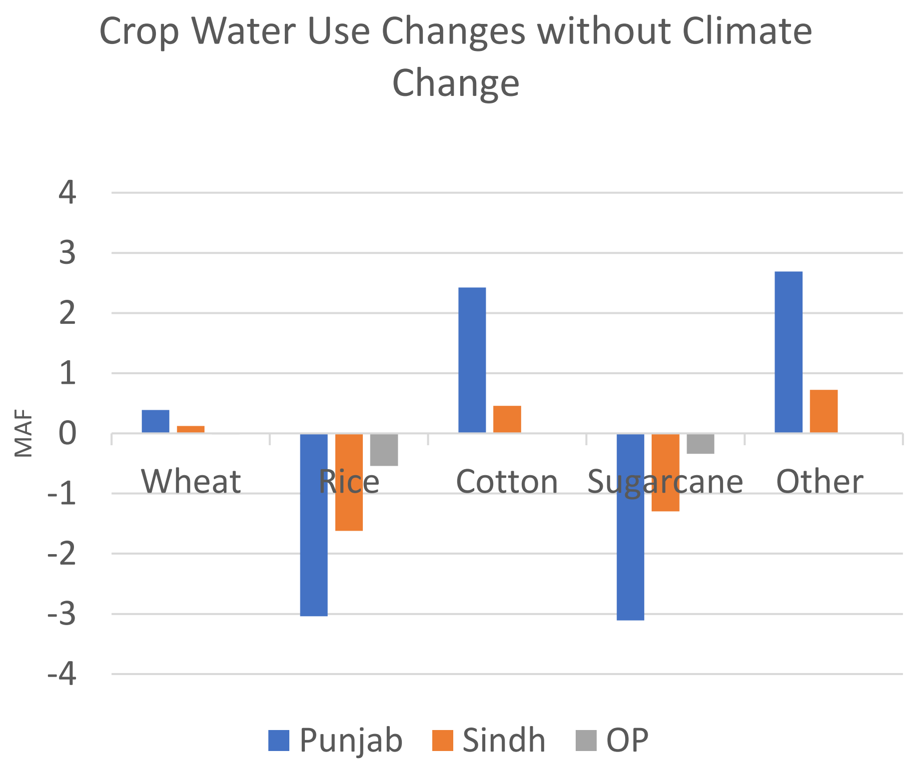

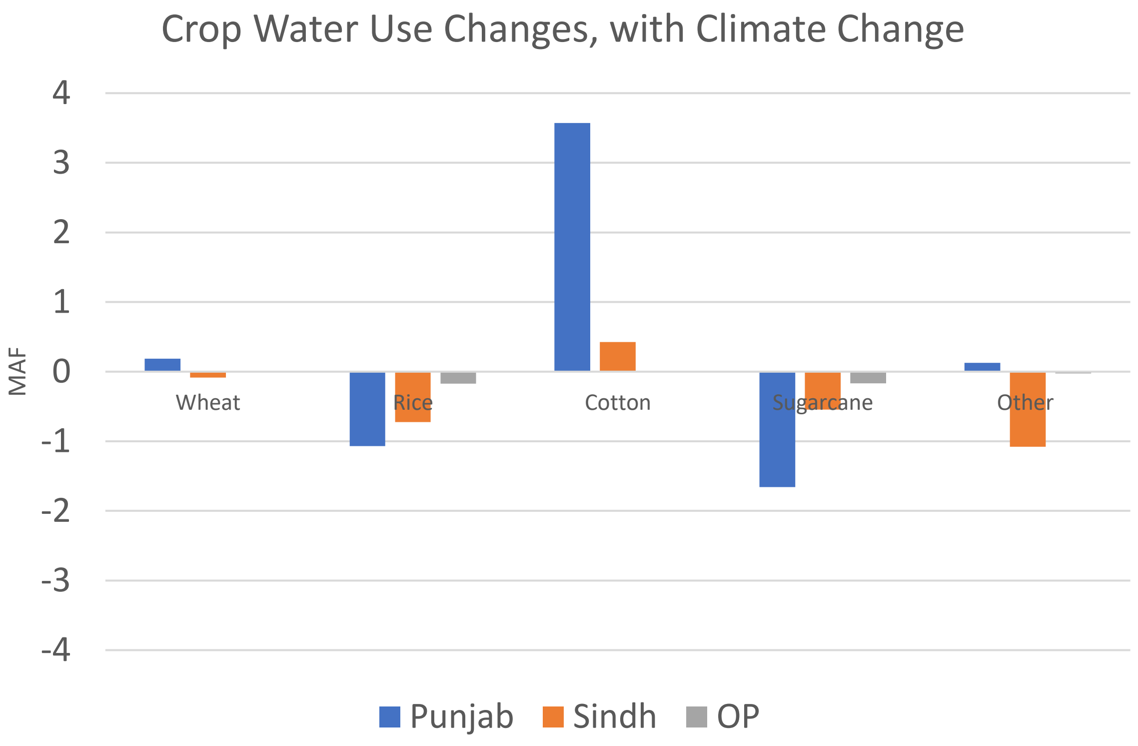

DASHBOARD

Decision Support Tool for Policy Making

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DASHBOARD

Team developed an interactive dashboard that will allow users to explore model outputs.

The dashboard will facilitate user-friendly access to complex simulation results, aiding decision-makers in their planning .


https://hedss-iwmi.vercel.app/dashboard/home
IWMI International Water Management Institute
HYDRO-ECONOMIC DECISION SUPPORT SYSTEM
Search...
HEDSS-IWMI
Home
Modules
Land Resource Management
Water Resources Management
Labor and Resource Productivity
Crop-Specific Strategies
Population Dynamics
Logout
Hydro-economic Decision Support System
This dashboard provides insights into the Water-Energy-Food-Environment (WEFE) Nexus in Pakistan. Explore different policy scenarios and their impacts on resources.
Project Objectives
Visualize trends over time and across provinces.
Gain insights into land resource management.
Analyze water resource allocation.
Evaluate labor productivity and crop strategies.
Explore impacts of population dynamics.
Our project aims to support sustainable development by optimizing resources across water, land, energy, and ecosystems. We encourage cross-sectoral collaboration to make informed decisions.
CGIAR NEXUS Gains
Resource Utilization Trends
100
50
0
Jan
May
Jun
Monthly Resource Allocation
100
50
0
Jan
Feb
Mar
Apr
May
Jun
Resource Usage
Resource Distribution
Water
Crops
Land
90
80

BREAKOUT SESSION

Reporting Structure

- What are two or three main policy and investment options government, or other stakeholders should consider as approaches to encourage performance in the area you're considering.
- What simulation results would be helpful to make arguments about which of these policies would be most effective?
- What do you suppose policymakers' concerns would be basing their decisions on model outcomes?
- What could be the limiting factors that keep policymakers from implementing the simulations/ and conclusions from simulations results

Thank You!