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

CGIAR

Trade-offs and Foresight Analyses of WEF Interventions in The Ganges Basin

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INTERNATIONAL COMMISSION ON IRRIGATION AND DRAINAGE (ICID)
International Workshop on
"The water-energy-food-ecosystems nexus: trade-offs and foresight analysis for policy and investment decisions"
01 September 2024, 1300-1630 hour, Sydney, Australia (Room: E3.1)

IWMI
International Water Management Institute

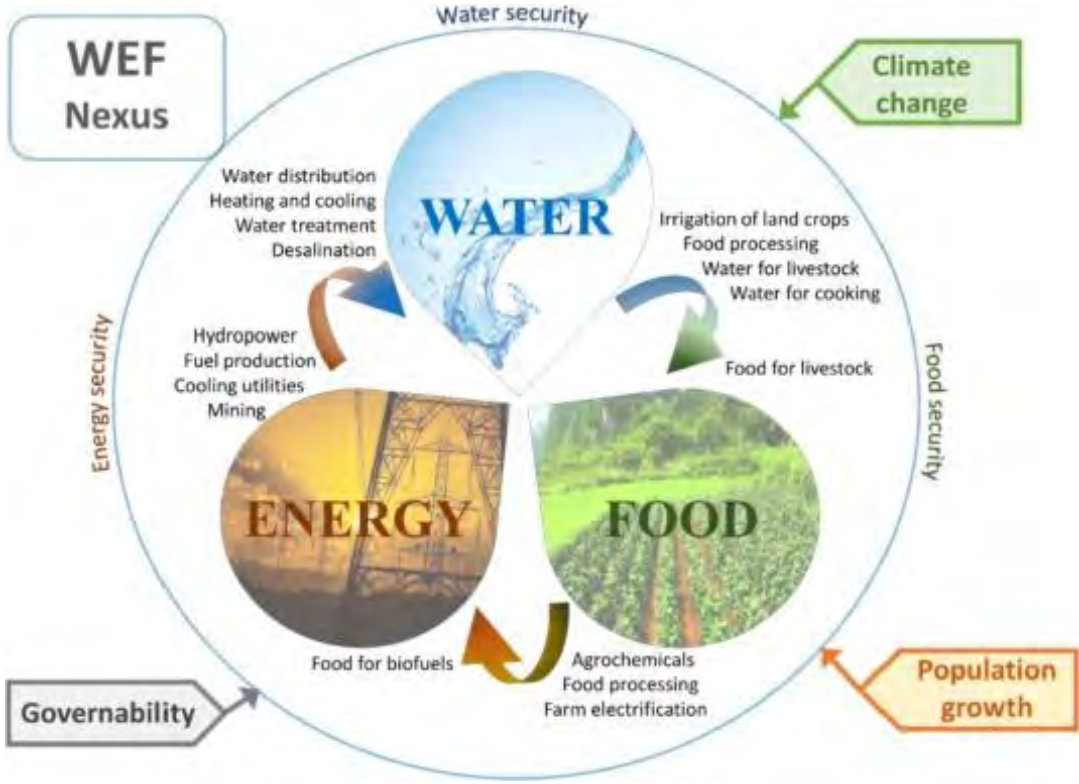
Outline of presentation

- ❑ Purpose of WEF Nexus
- ❑ Integrated Modeling Framework
- ❑ Database
- ❑ Model Setup/Adaptation
- ❑ Dashboard for Policy decision automation
- ❑ WEF Trade-off Index (composite)
- ❑ Scenario Analysis example

Purpose of WEF Nexus

- Co-developing methods for foresight and trade-off analyses tools (**Integrated modeling tools**)
- Enable the identification of losses and gains under **business-as-usual** and **alternative development pathways (scenarios)**, across various sectors (Water, Energy and Food)

- Four focal basins : Indus, **Ganges**, Aral and Nile



Incoherent WEFE policies

- Ministries have developed and announced policies concerned with their domain area.
  - water and food are State subjects
- Different policies were formed at different times.
- The policies of different sectors give inadequate consideration to the impacts of decisions on the other related sectors

National Water Policy (2012)

Energy Policy (2017)

National Policy on Biofuels (2018)

National Agriculture Policy (2004)

National Forest Policy (1988)

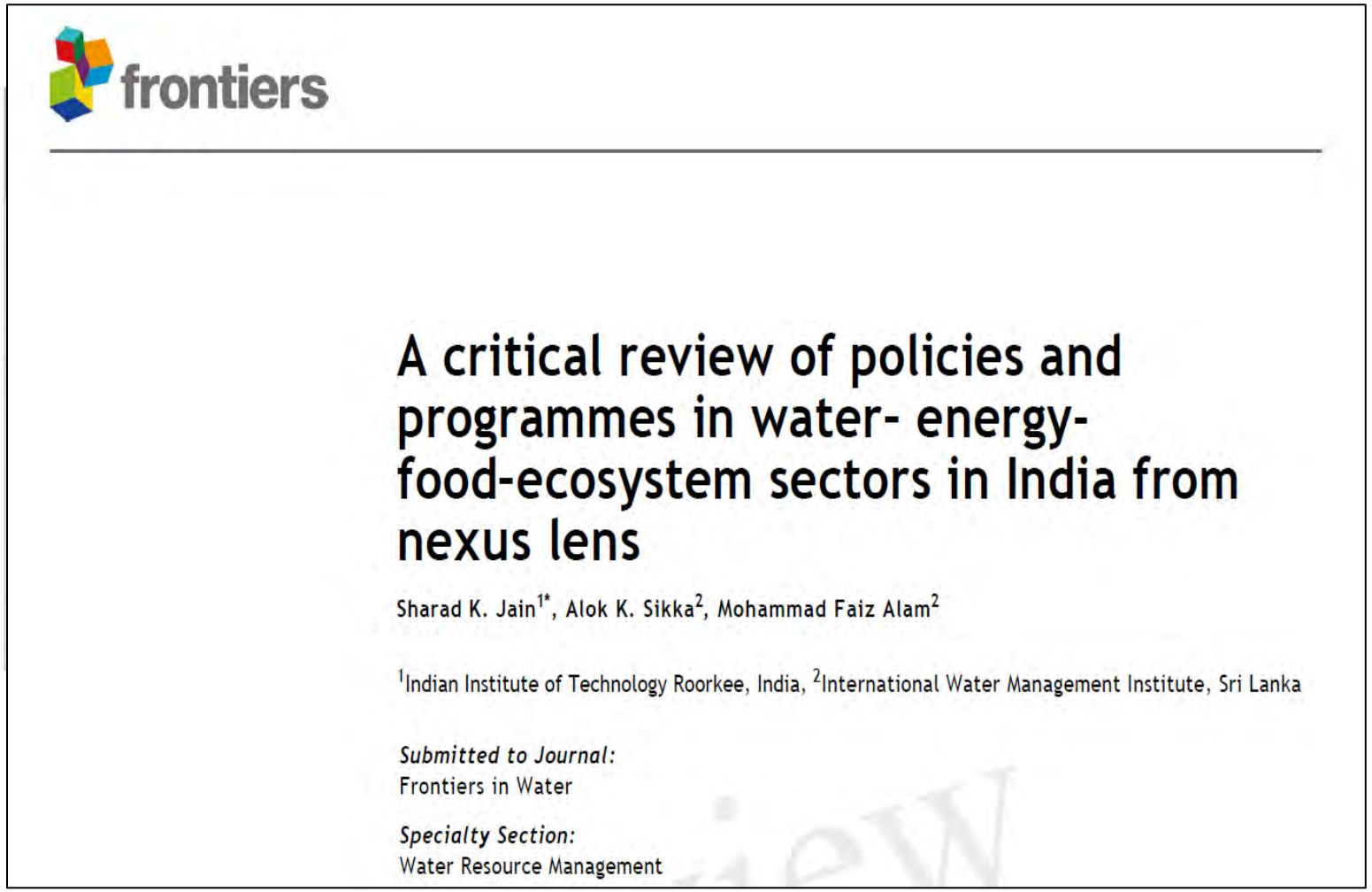
Environment protection Act (2006)

National Agroforestry Policy (2014)

National Biological diversity policy (2012)

Qualitative trade-offs of programmes

- More than ≈ 40 programmes across WEFE sectors were studied to understand the efforts underway in these sectors to attain the respective policy goals
- Significant overlaps among the programmes which could positively or negatively impact security concerns among the sector(s).
- Need to quantify the trade-offs by using **integrated approach including modeling** with the WEFE nexus lens.



frontiers

A critical review of policies and programmes in water- energy-food-ecosystem sectors in India from nexus lens

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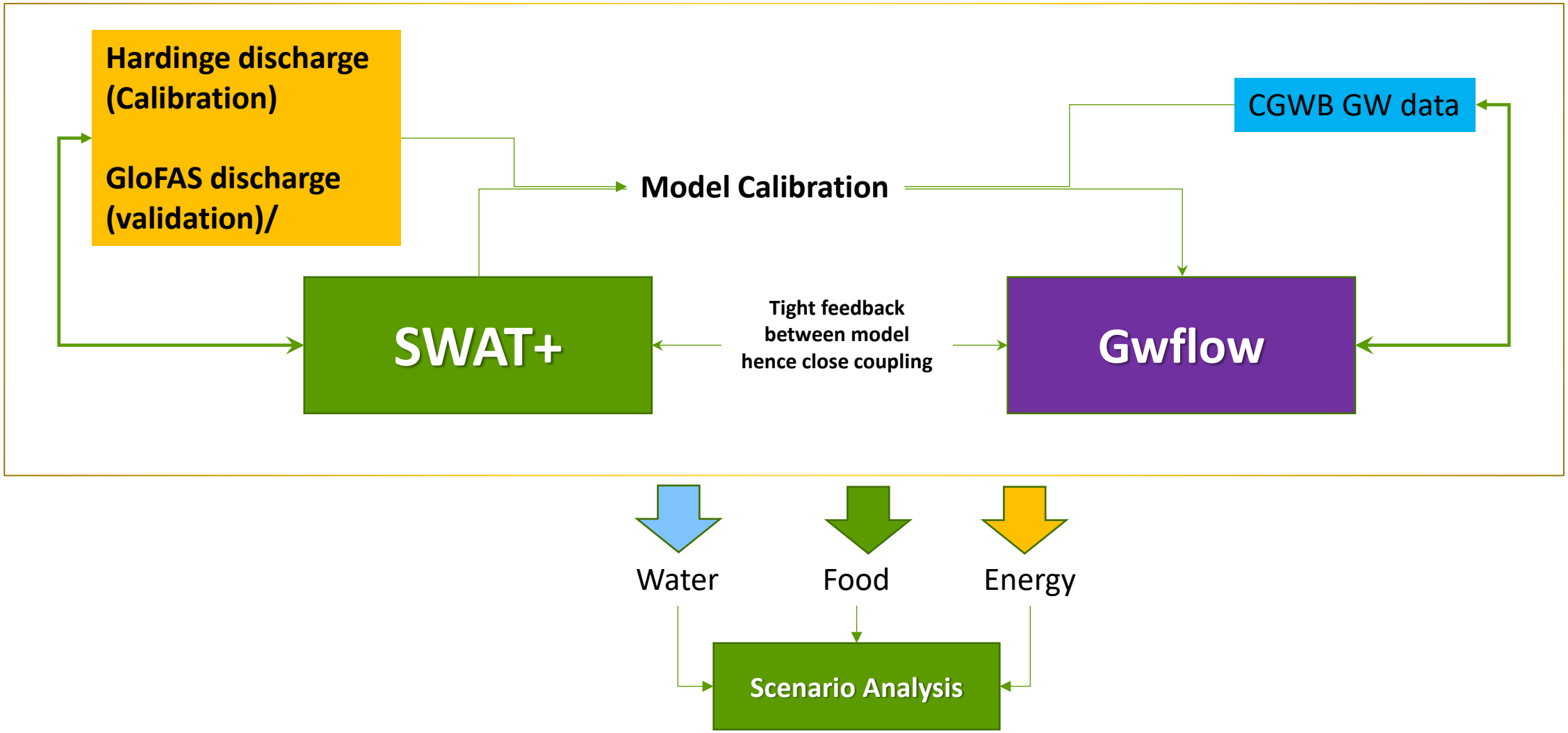
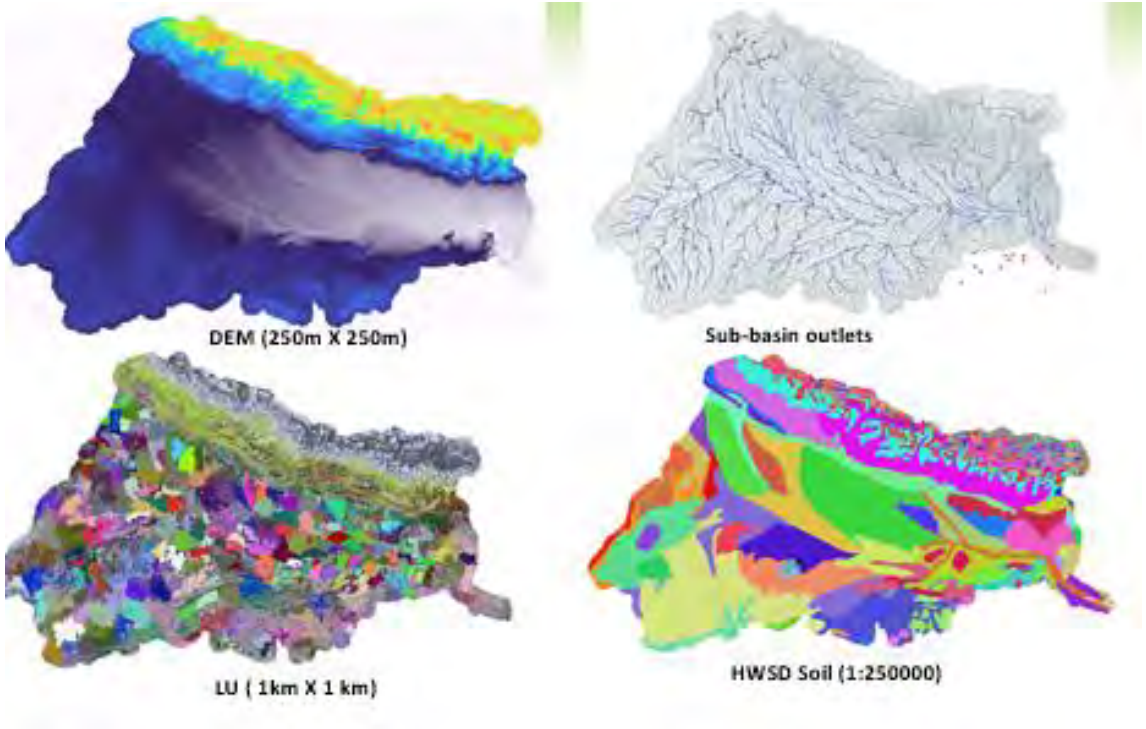
Submitted to Journal:
Frontiers in Water

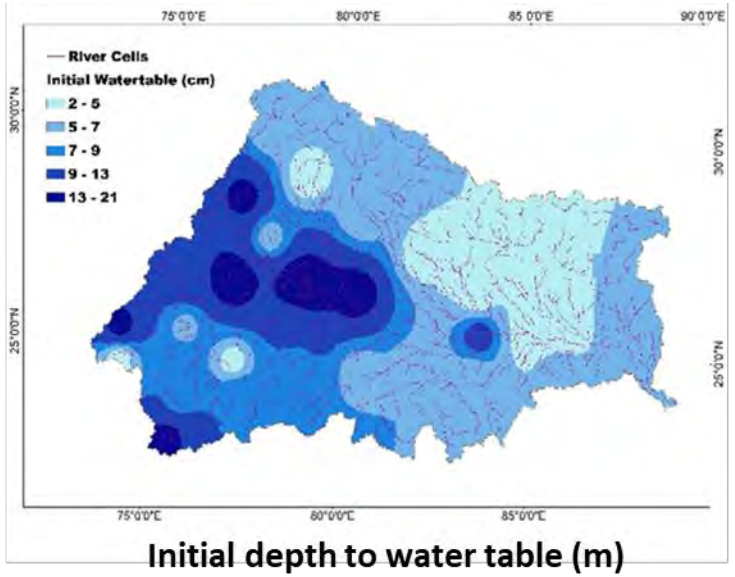
Specialty Section:
Water Resource Management

Integrated Modelling Framework

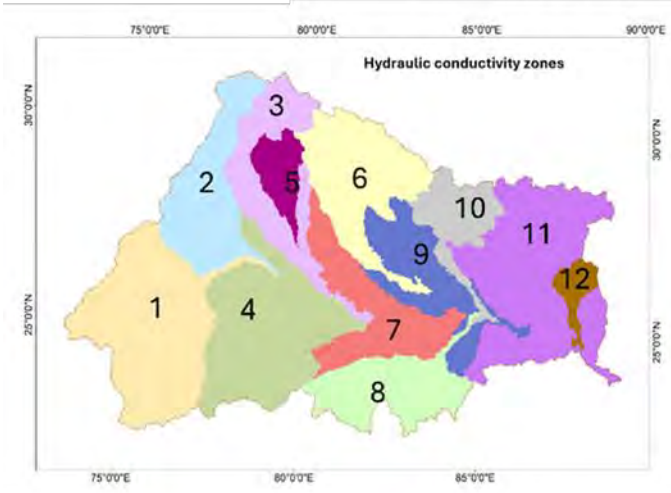


Database (all open access)

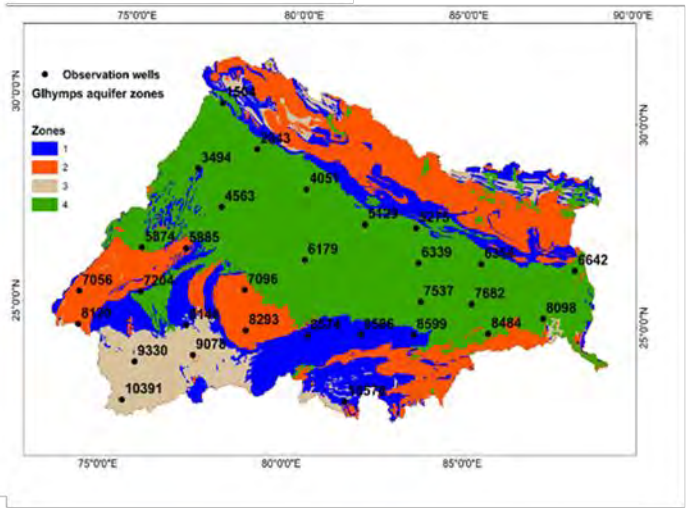




Initial depth to water table (m)



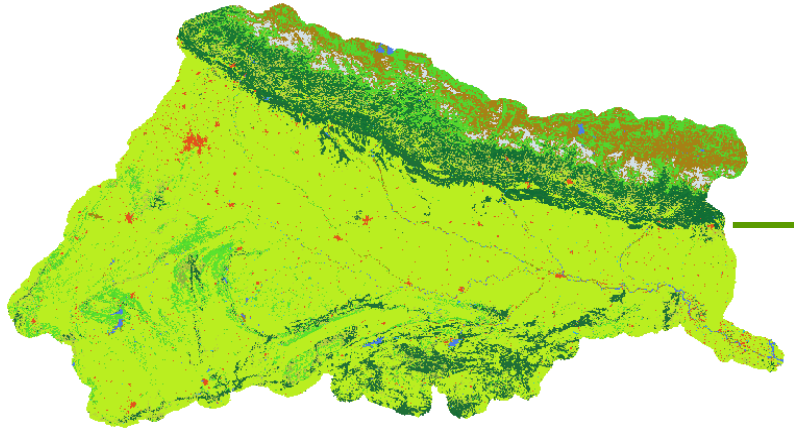
Hydraulic conductivity zones



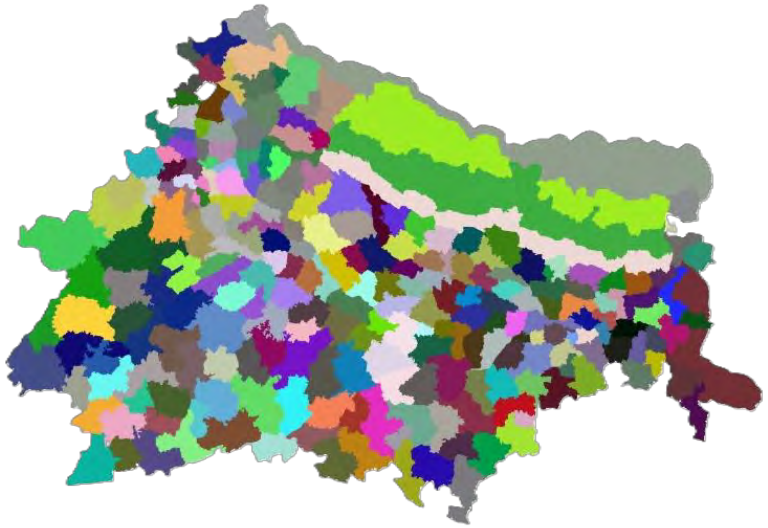
Specific Yield Zones

(SWAT+) + gwflow

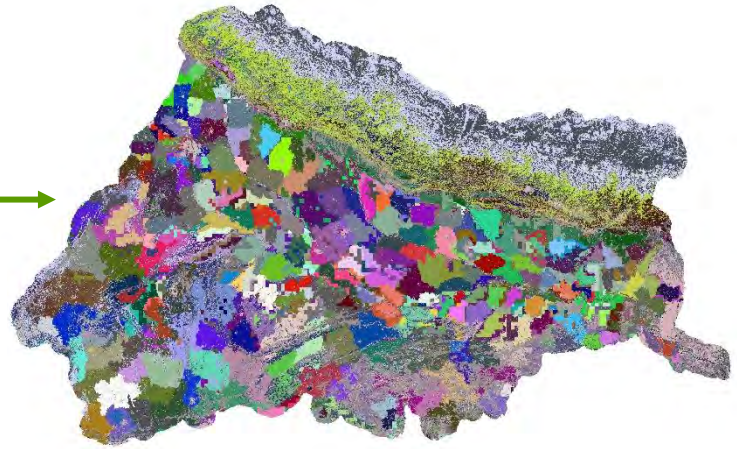
Land use Modification



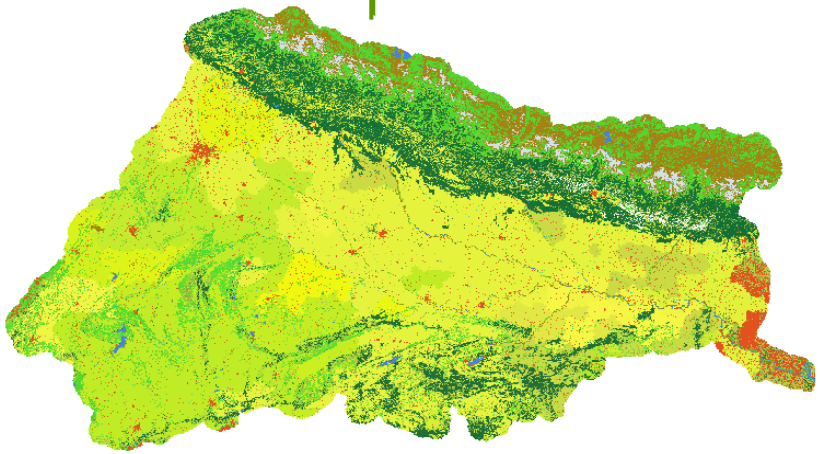
Copernicus Land-use



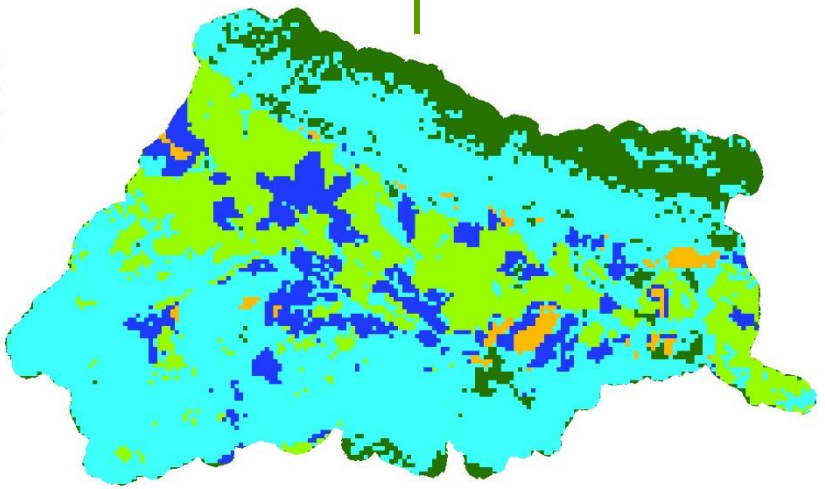
District



Final Land-use



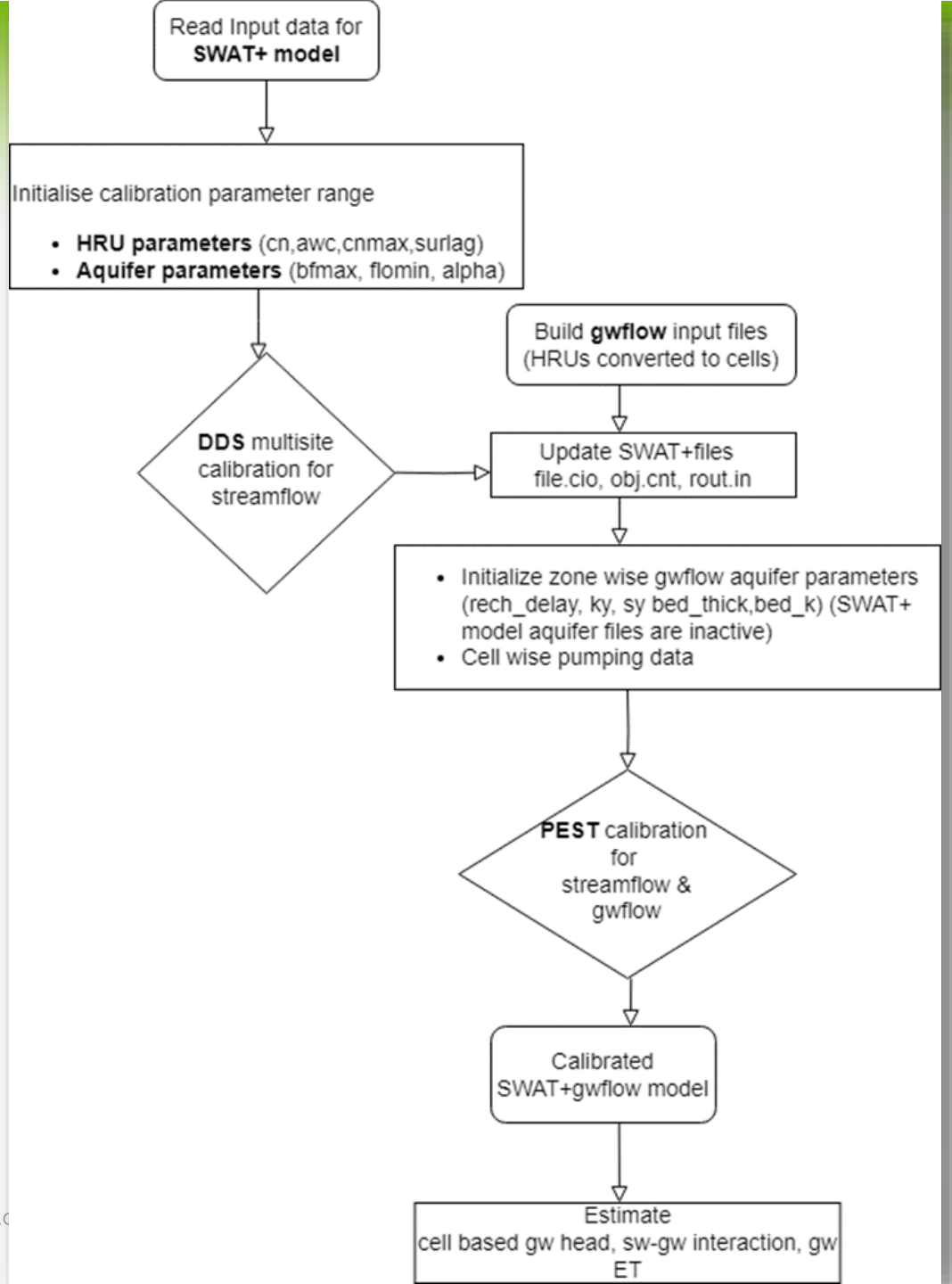
Cropping Pattern
(district-wise)

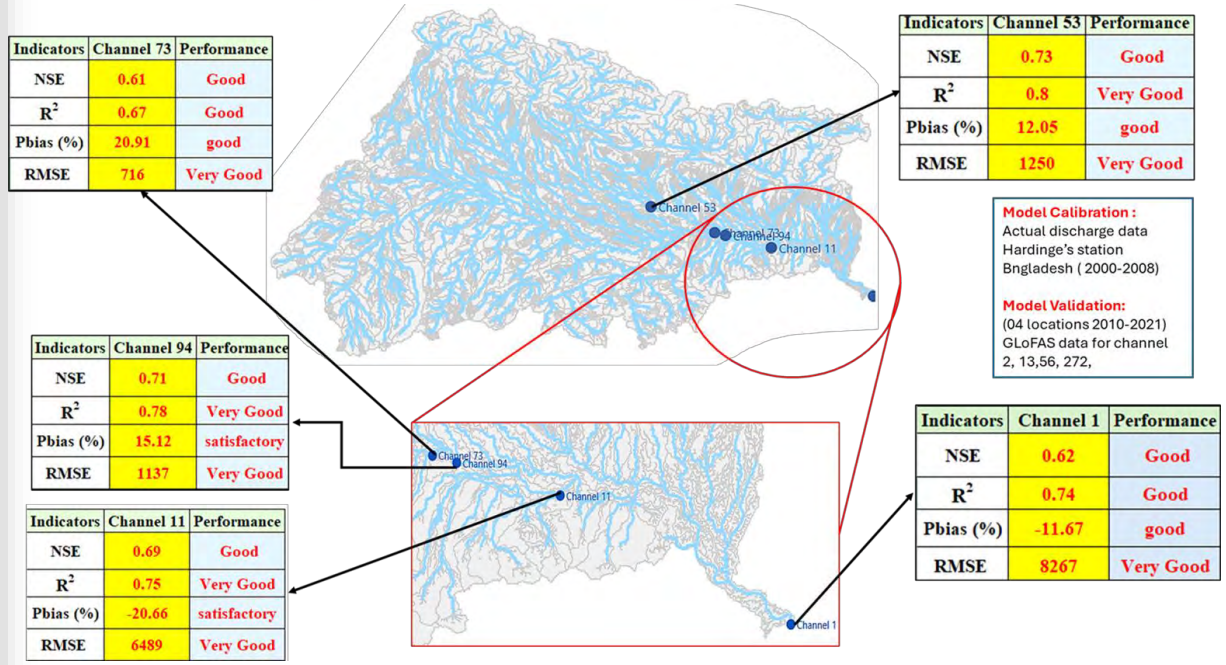


Sources of water

https://aps.dac.gov.in/APY/Public_Report1.aspx

Flow chart for SW-GW coupling





Indicators	Channel 73	Performance
NSE	0.61	Good
R^2	0.67	Good
Pbias (%)	20.91	good
RMSE	716	Very Good

Indicators	Channel 53	Performance
NSE	0.73	Good
R^2	0.8	Very Good
Pbias (%)	12.05	good
RMSE	1250	Very Good

Model Calibration :
Actual discharge data Hardinge's station Bngladesh (2000-2008)

Model Validation:
(04 locations 2010-2021) GLoFAS data for channel 2, 13,56, 272,

Indicators	Channel 94	Performance
NSE	0.71	Good
R^2	0.78	Very Good
Pbias (%)	15.12	satisfactory
RMSE	1137	Very Good

Indicators	Channel 11	Performance
NSE	0.69	Good
R^2	0.75	Very Good
Pbias (%)	-20.66	satisfactory
RMSE	6489	Very Good

Indicators	Channel 1	Performance
NSE	0.62	Good
R^2	0.74	Good
Pbias (%)	-11.67	good
RMSE	8267	Very Good

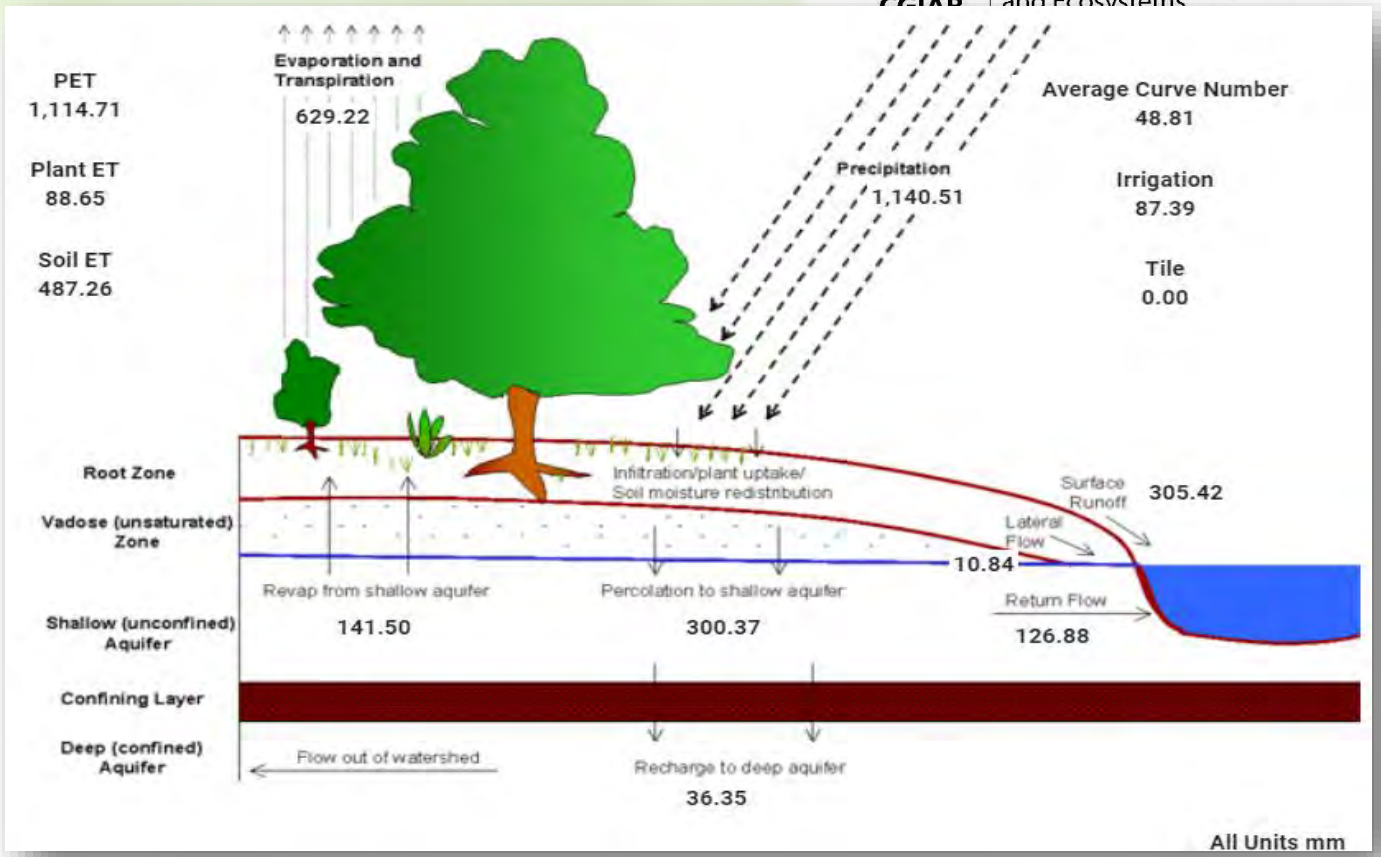
Database for calibration/ Validation

- **Calibration** Streamflow data at Hardinge Bridge (Bangladesh)
  (2000-2008)

- **Validation** GLoFAS data (2012-2021) - *https://cds.climate.copernicus.eu/cdsapp#!/dataset/efas-historical?tab=form*

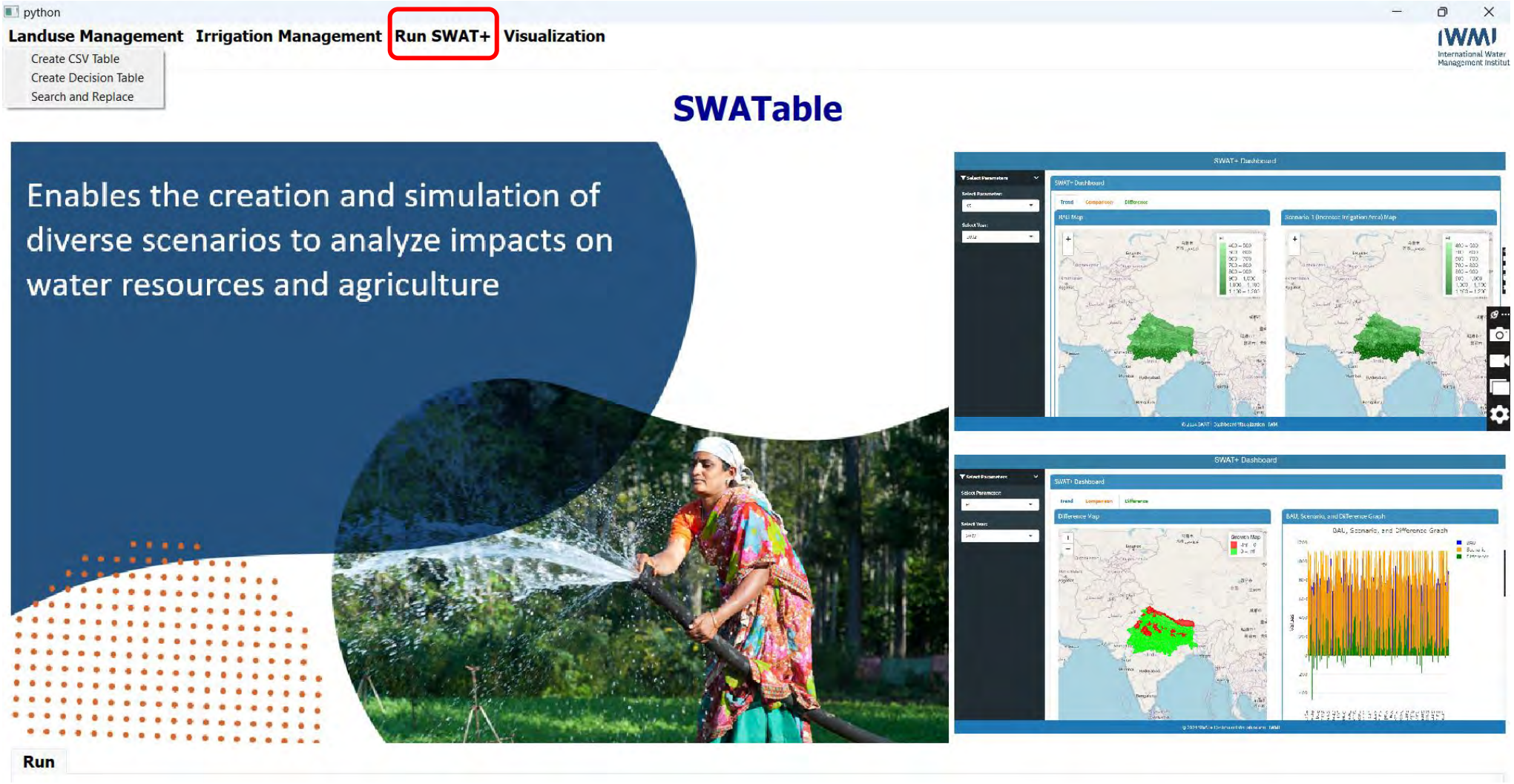
Water balance of Ganges Basin

Sl	Flux Contribution	% of Precipitation	Previously reported*
A)	AET	55%	(32%-84%)
B)	Streamflow	39%	(25%-38%)
	(a) Runoff	27%	
	(b) Baseflow	12%	
C)	Groundwater Recharge	26%	(17%-29%)



Kumar et al. (2010); Kumar et al.(2016); Mishra et al.(2007); Khan et al., (2019); Dhar & Nandargi (2013); Mishra & Singh (2007); Sharma et al. (2016)

SWATable Interface



Dashboard for Automated Scenario Generation

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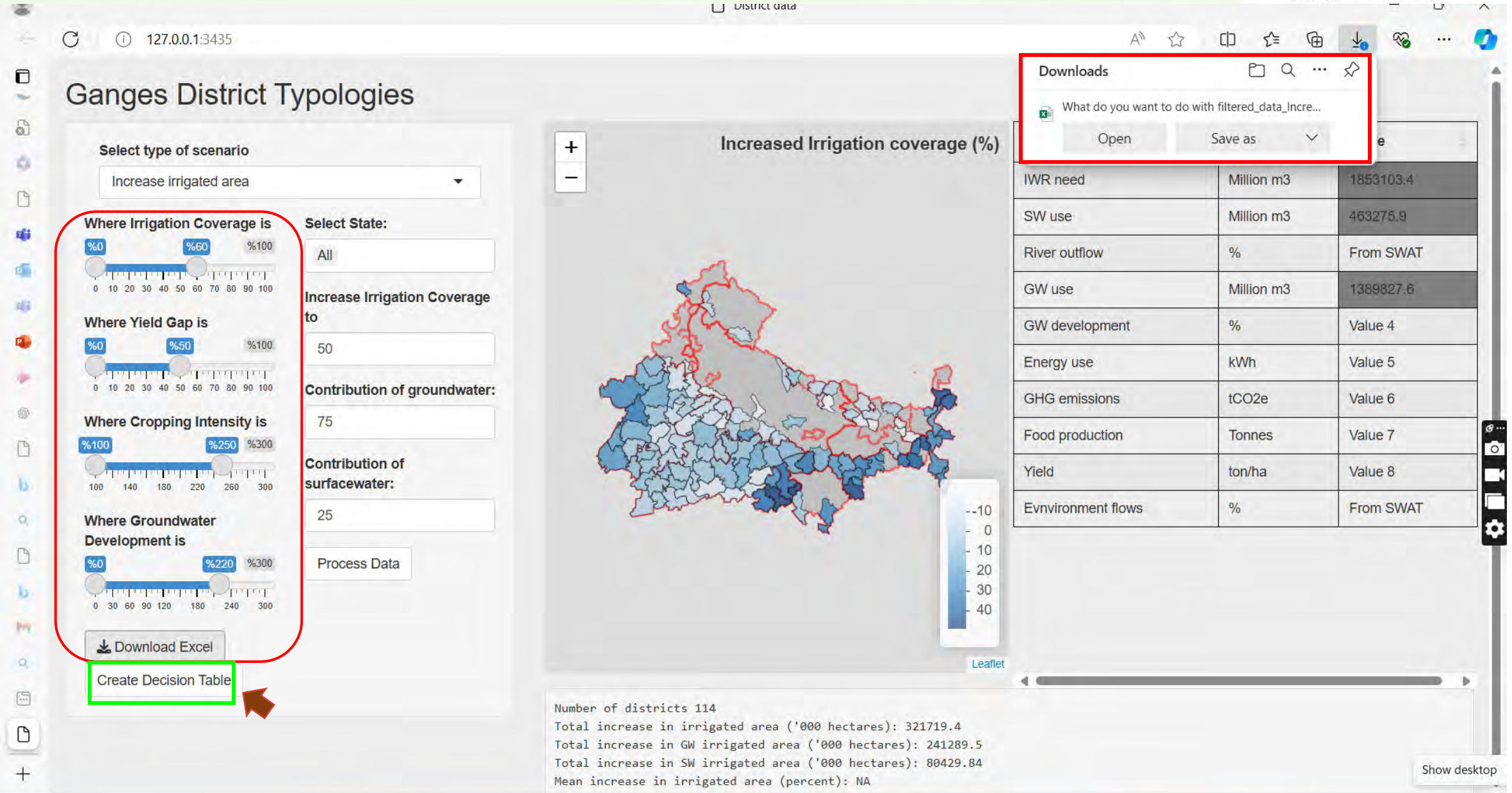
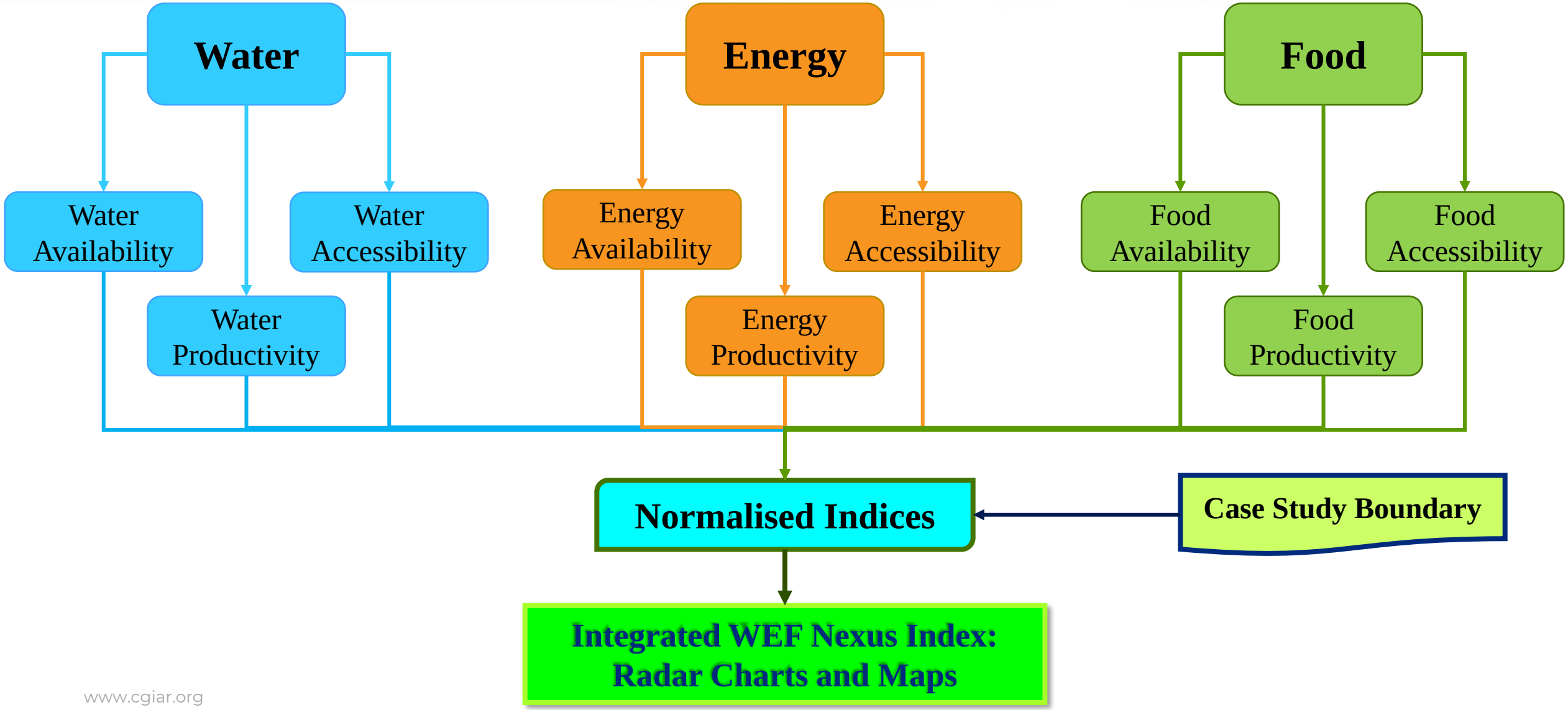
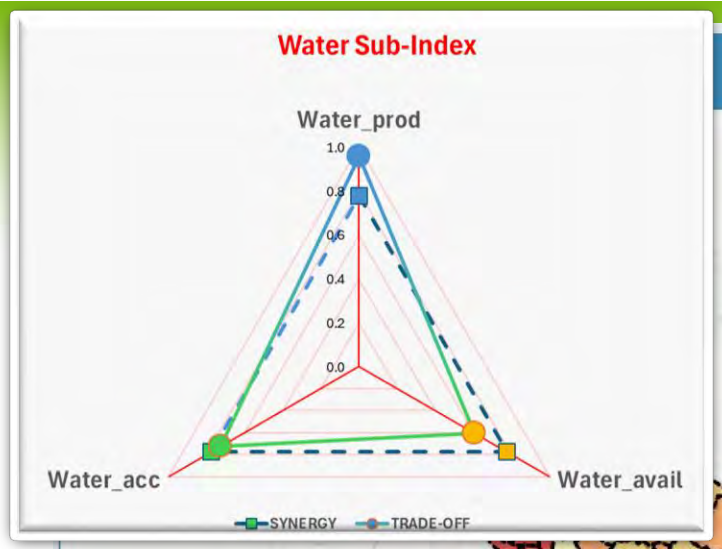
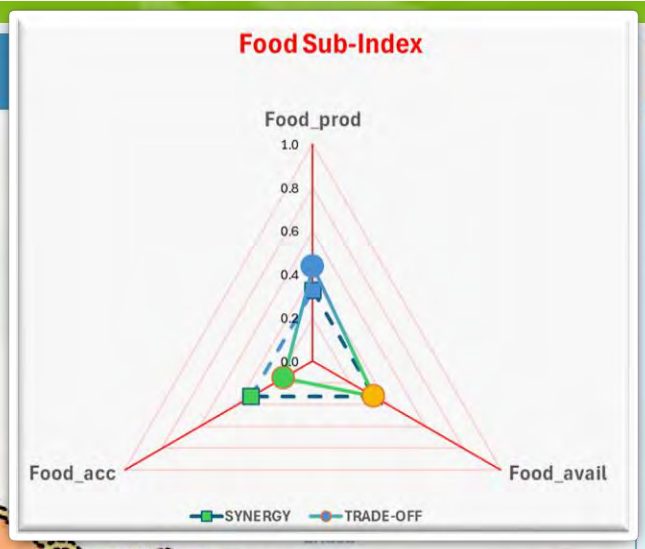
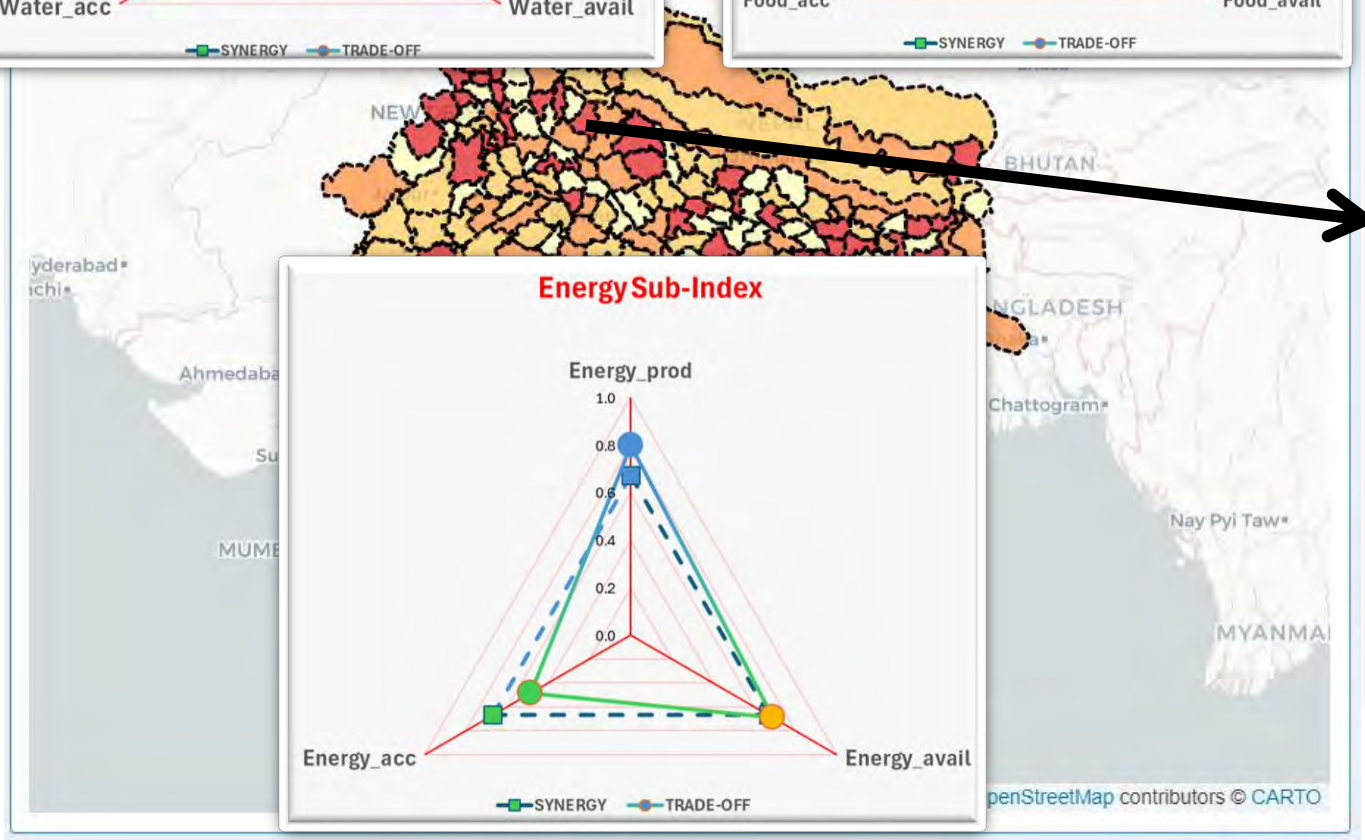


WEF Nexus Sustainability Index

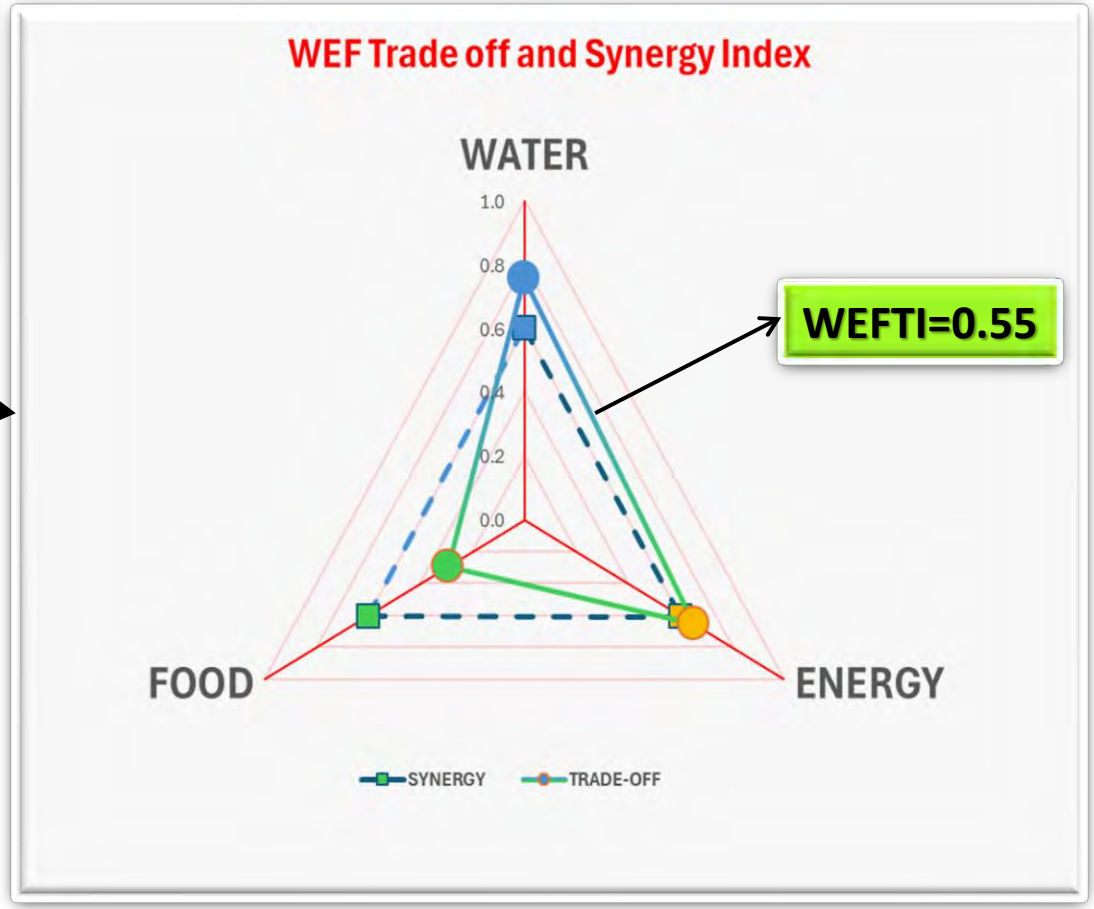



Water Sub-Index
Water_prod
Water_acc
Water_avail
SYNERGY
TRADE-OFF

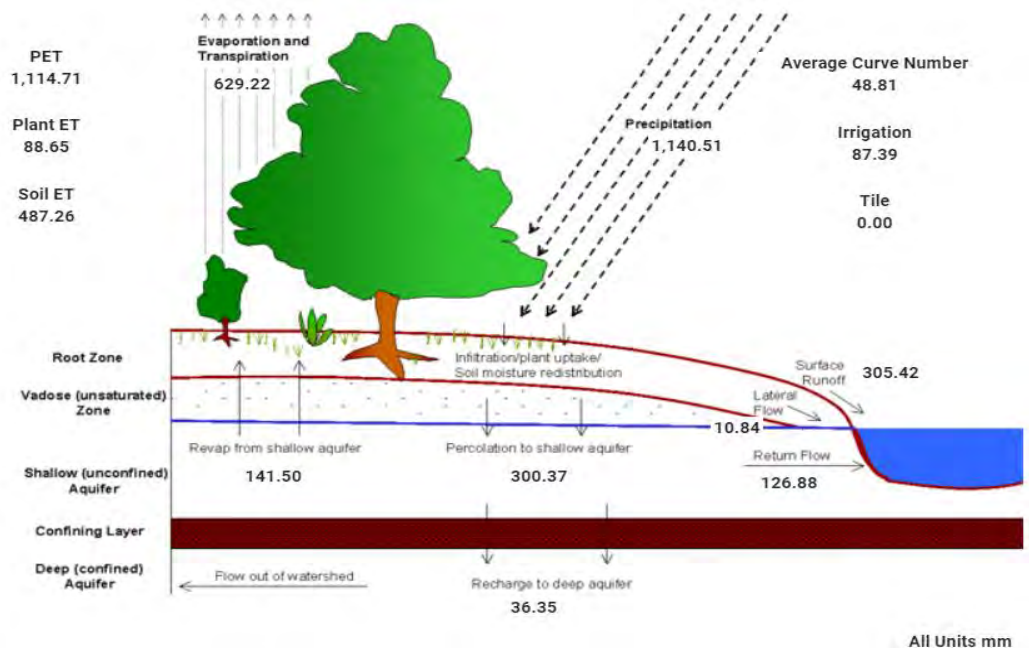

Food Sub-Index
Food_prod
Food_acc
Food_avail
SYNERGY
TRADE-OFF


BHUTAN
Chattogram
Nay Pyi Taw
MYANMAR
OpenStreetMap contributors © CARTO

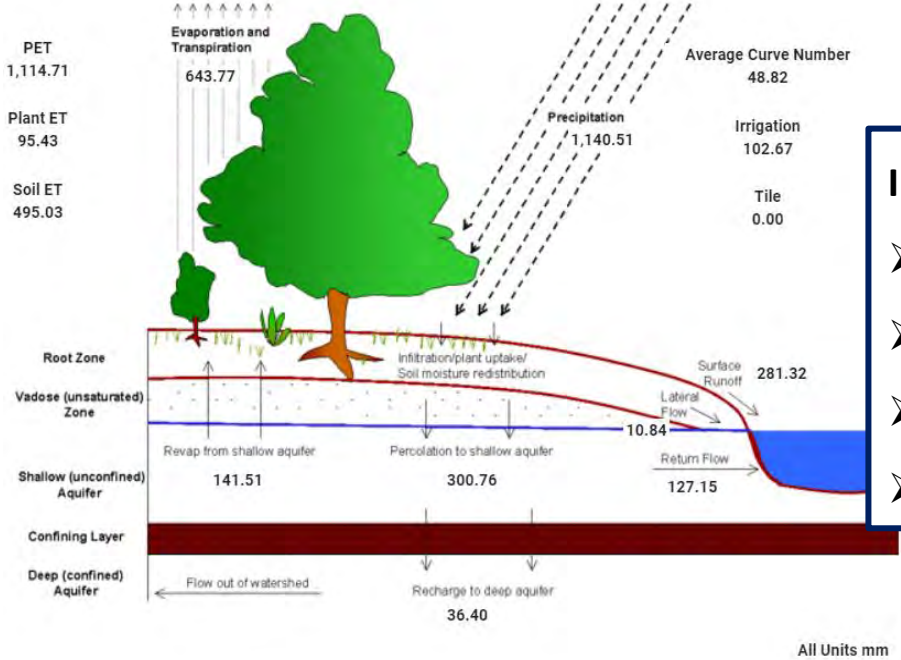
Energy Sub-Index
Energy_prod
Energy_acc
Energy_avail
SYNERGY
TRADE-OFF


WEF Trade off and Synergy Index
WATER
FOOD
ENERGY
WEFTI=0.55
SYNERGY
TRADE-OFF

Example of



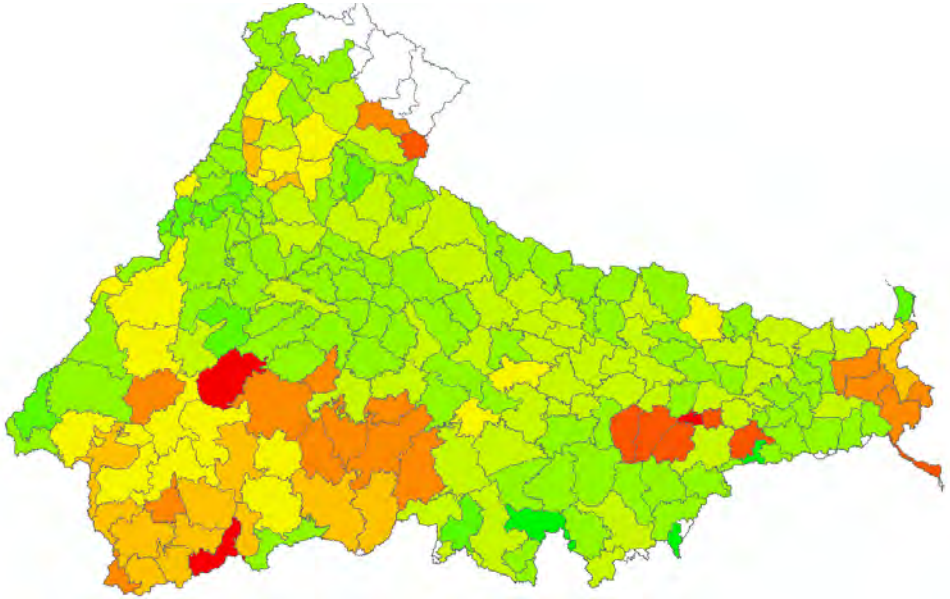
BAU



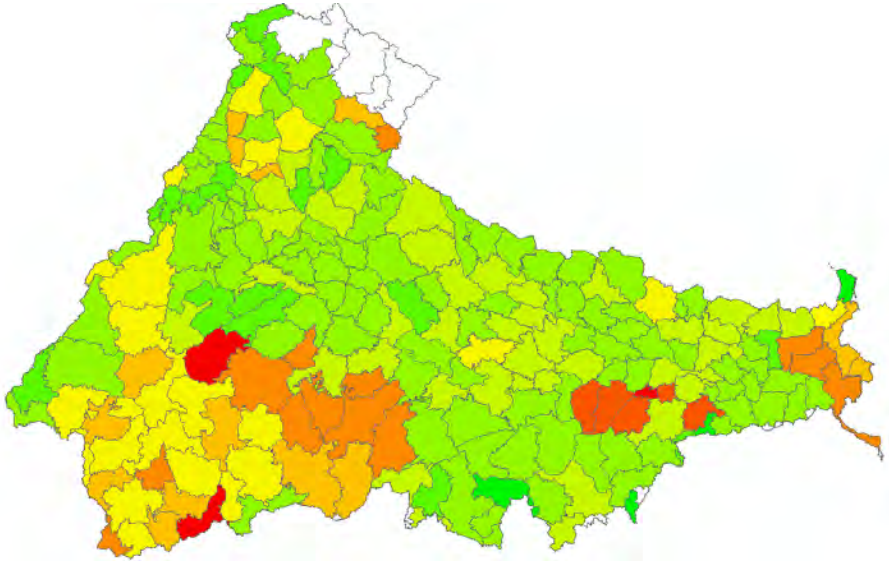
Increase in irrigation efficiency

IE (38% to 78%) ↑

- AET ↑ = 2.32
- Runoff ↓ = -8.65
- GWR ↑ = 0.08
- Baseflow ↑ = 0.32

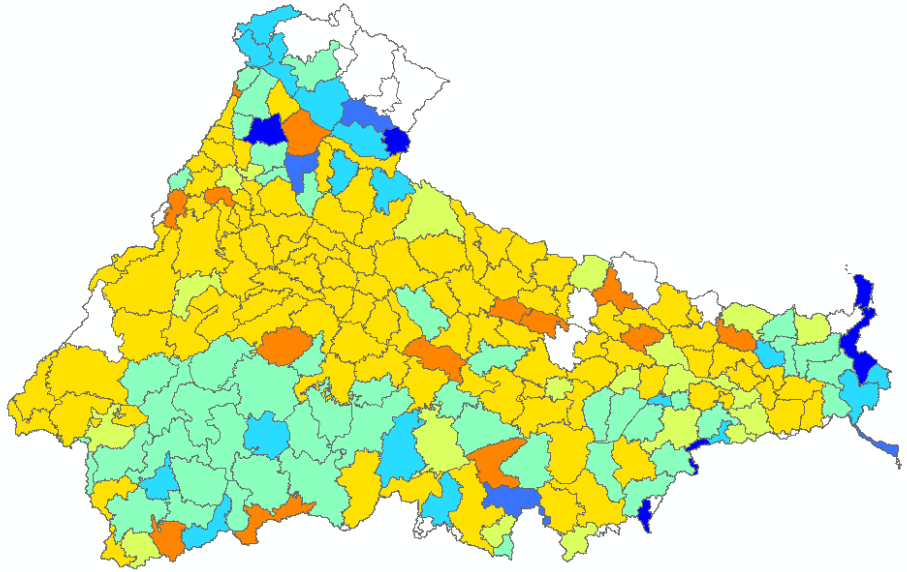


BAU



Increase in Irrigation Efficiency

Legend
WEF
- < 0.45
- 0.45 - 0.5
- 0.5 - 0.55
- 0.55 - 0.6
- 0.6 - 0.65
- 0.65 - 0.7
- 0.7 - 0.75
- 0.75 - 0.8
- > 0.8



Change in WEF

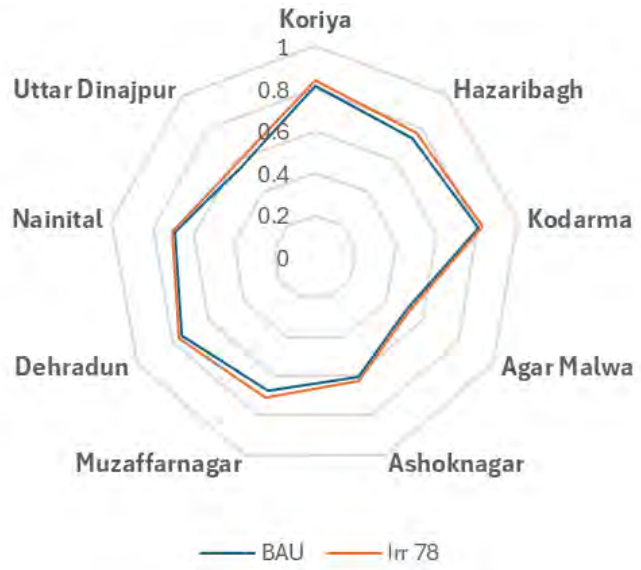
Legend
Change in WEF
- No Change
- 0.01 - 0.4
- 0.41 - 0.8
- 0.81 - 1
- 1.1 - 2
- 2.1 - 3
- 3.1 - 4
- 4.1 - 6.0

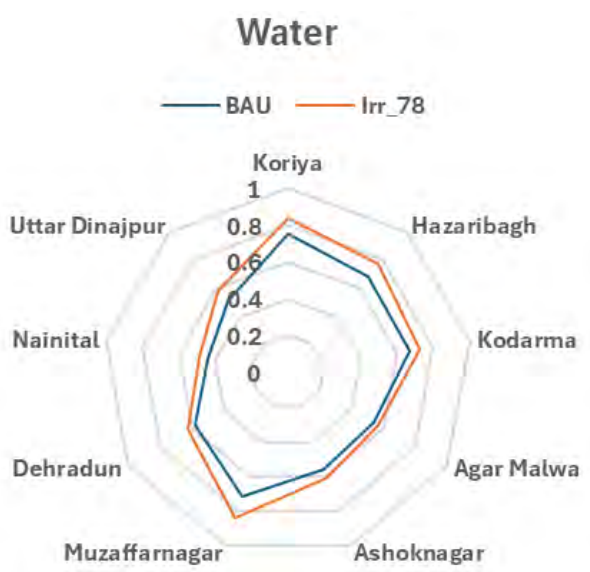
WEF of overall Basin

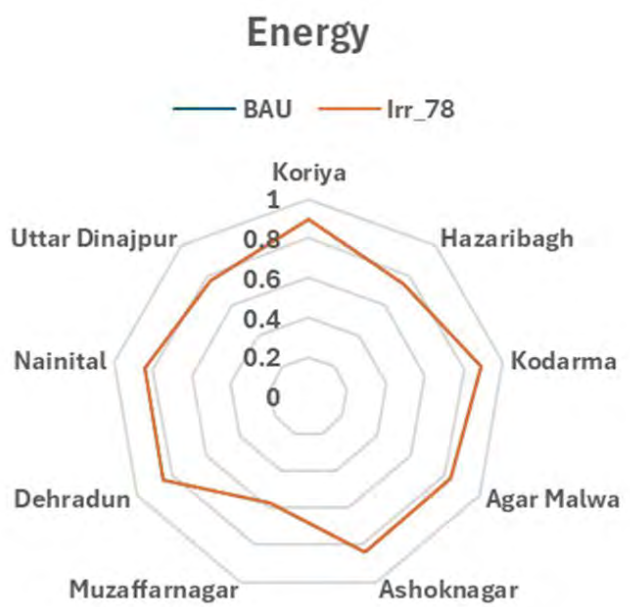
BAU = 0.660

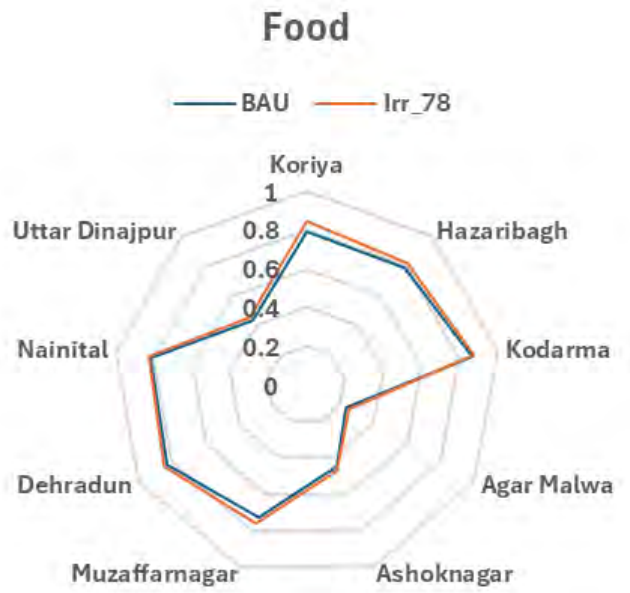
Irr_78 = 0.667

Some districts representing WEF indices across the Ganges basin



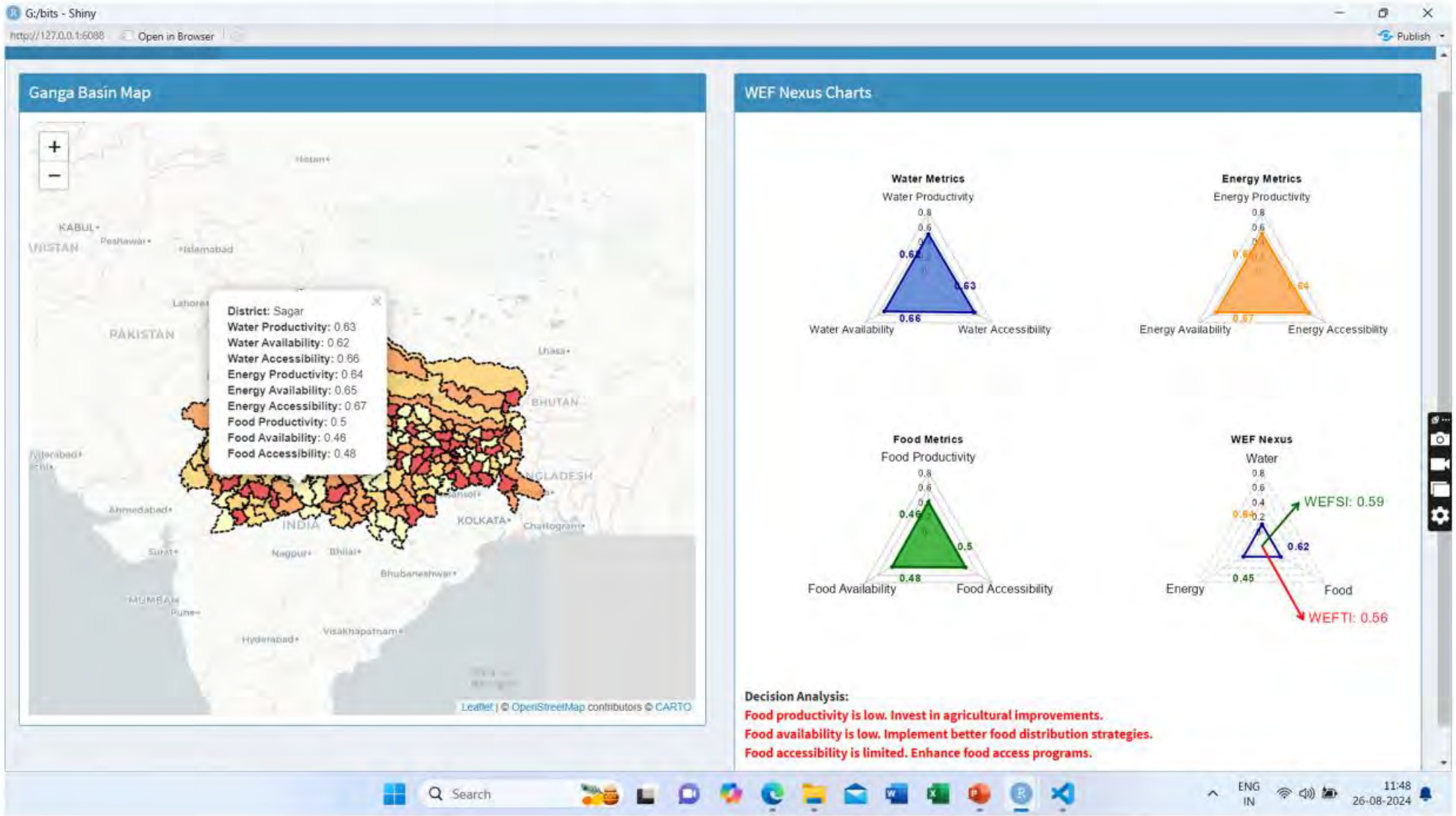






WEF-Nexus Interface

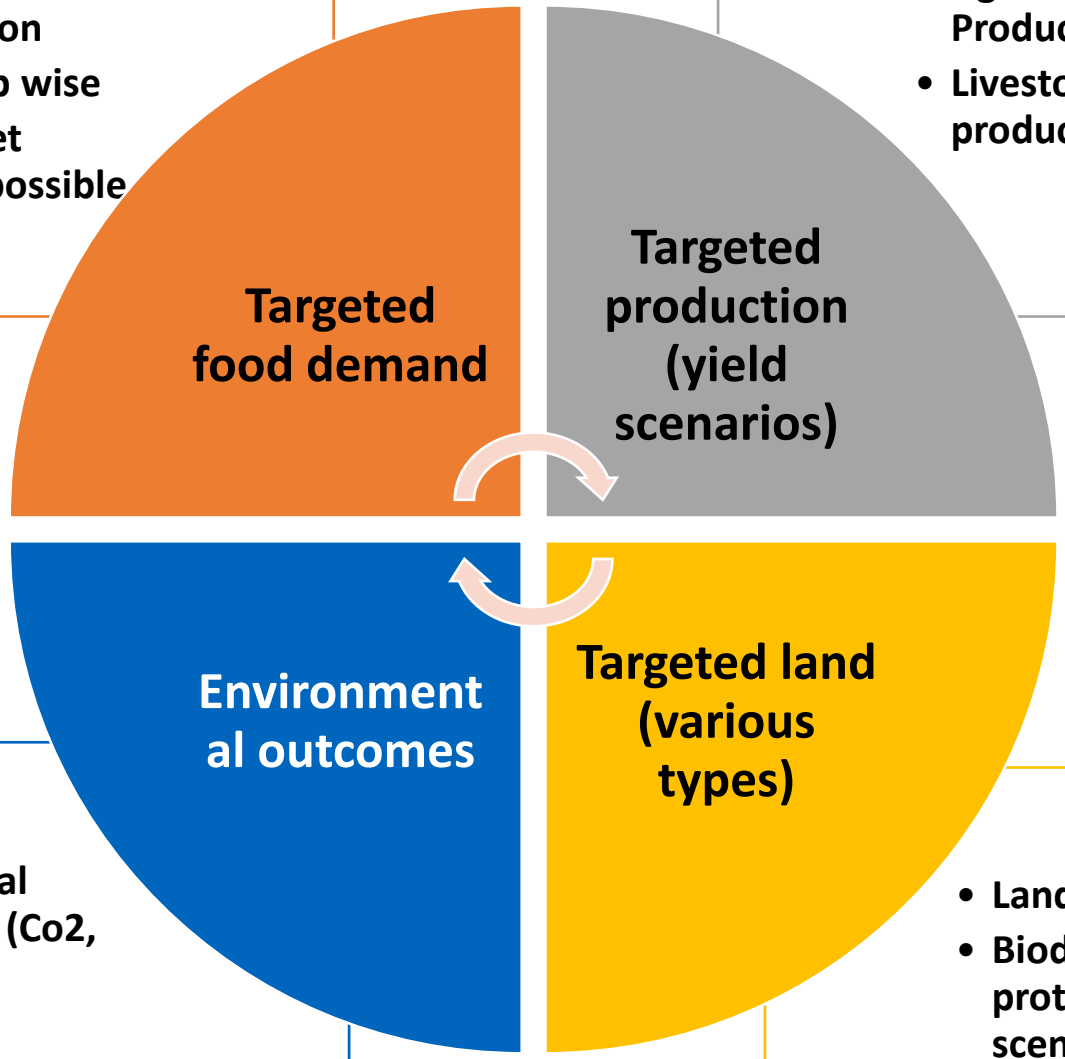
NEXUS Gains:
Realizing Multiple Benefits
Across Water, Energy, Food
and Ecosystems



SWAT- FABLE Calculator soft linkages (ongoing)

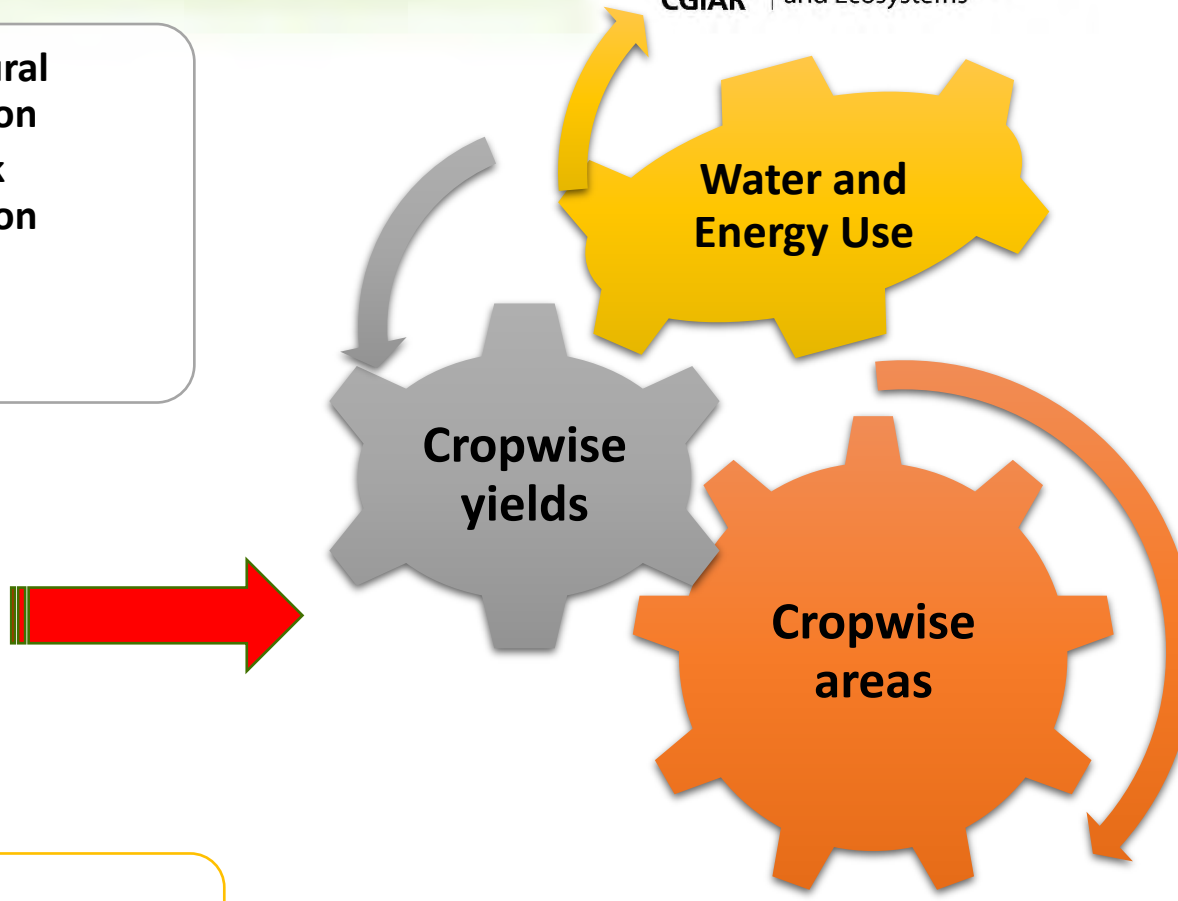
- Food Consumption
- Food-group wise
- Healthy diet scenarios possible

- Agricultural Production
- Livestock production



- Agricultural emissions (Co2, N20, CH4)
- Water use

- Landuse change
- Biodiversity protection scenarios, cropland restriction



NEXUS Gains-WP1

Realizing Multiple Benefits Across Water, Energy, Food and Ecosystems (Forests, Biodiversity)

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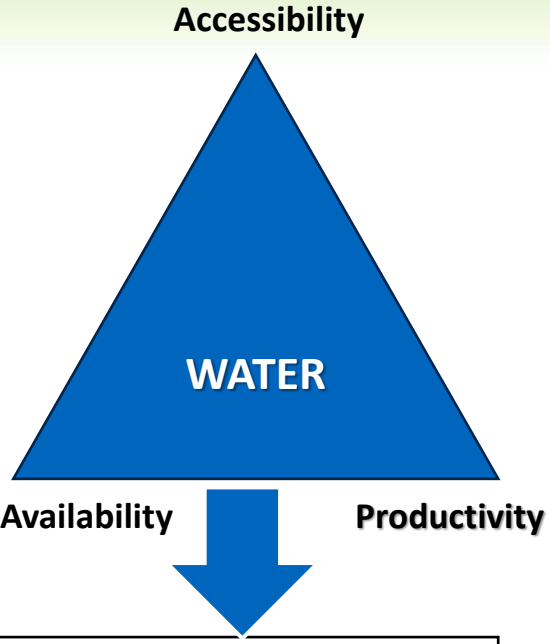
Formulation of WEF index (Agriculture context)

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



Availability

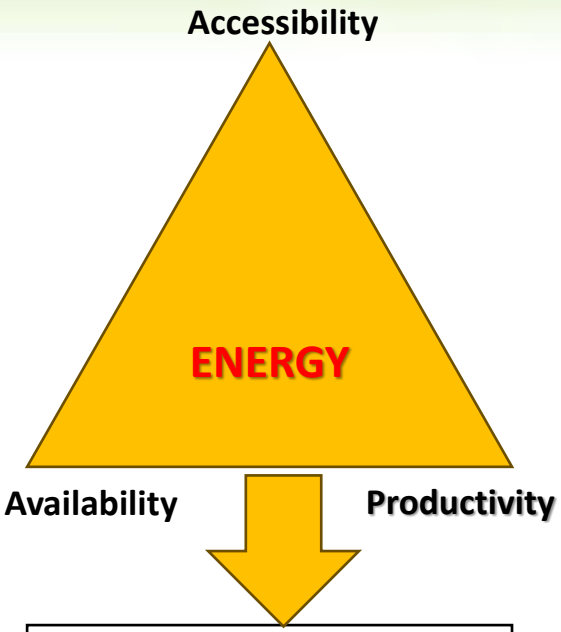
Total water resources available for agriculture (80% of WYLD+PERC data of SWAT+) (m^3/ha)

Accessibility

% of area has access to irrigation (GIAM)

Productivity

Applied Water productivity (Rice equivalent yield) (kg/m^3) (SWAT+)



Availability

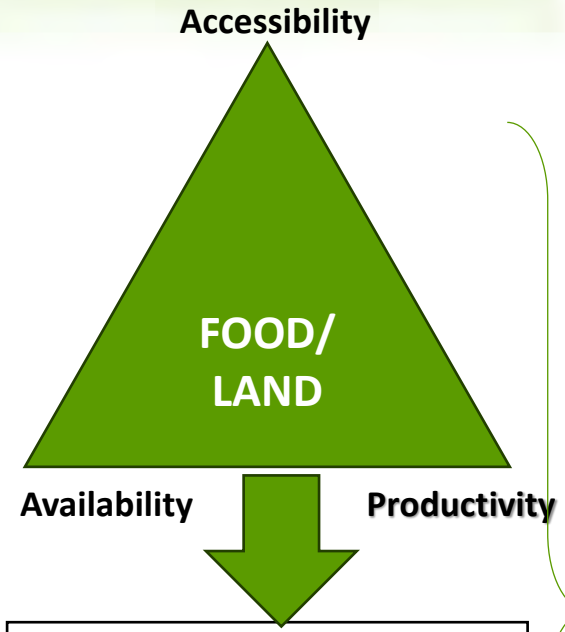
Total energy output (food crop) (Eo) and energy available to extract 75% of groundwater recharge.

Accessibility

Energy spent for irrigation/ha + Energy requirement for crops (KW/ ha) (secondary data) (Ei)

Productivity

Energy productivity = REY/ΔE(Eo-Ei)



Availability

REY (Kg) per capita

Accessibility

Dietary nutrition per capita (Govt. secondary source)

Productivity

Land productivity = REY/A_{agri}