Water Resource modelling in the Eastern Gangetic Plains (EGP) with examples from Bangladesh

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Australian Aid

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Introduction

This presentation is based on CSIRO's work (concluded and current) in Bangladesh – relevant to the Eastern Gangetic Plains

CSIRO started major water related modelling with the Bangladesh Integrated Water Resources Assessment (BIWRA) project funded by DFAT during 2010-2014

- done for the whole country
- identified hotspot for further detailed study

Current studies are on the hotspots:

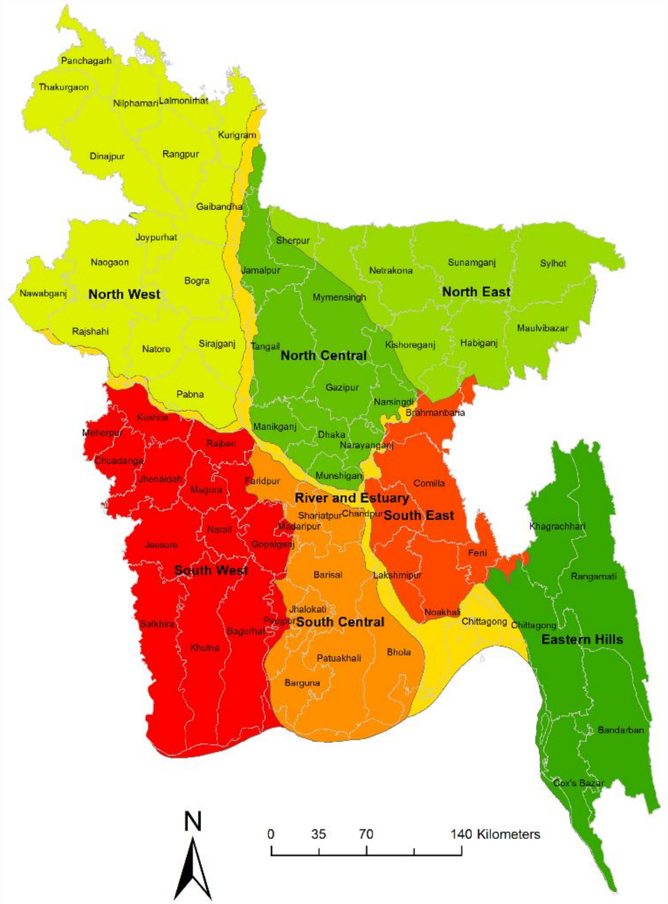
1. Improving dry season agriculture for marginal and tenant farmers in the Eastern Gangetic plain, 2014-2019, funded by ACIAR
2. Cropping system intensification in the salt-affected coastal zones of Bangladesh and West Bengal, India, 2015-2020, funded by ACIAR
3. Sustaining groundwater for food security in the northwest region of Bangladesh, 2016-2020, (SDIP Phase II funded by DFAT)

Water modelling done in the BIWRA project

- Region-wise surface water assessment and water balance
- Groundwater trend analysis
- Water quality assessment including sea water intrusion due to sea level rise
- Surface water and groundwater interaction
- Irrigation demand assessment
- National level food security analysis

Scenarios:

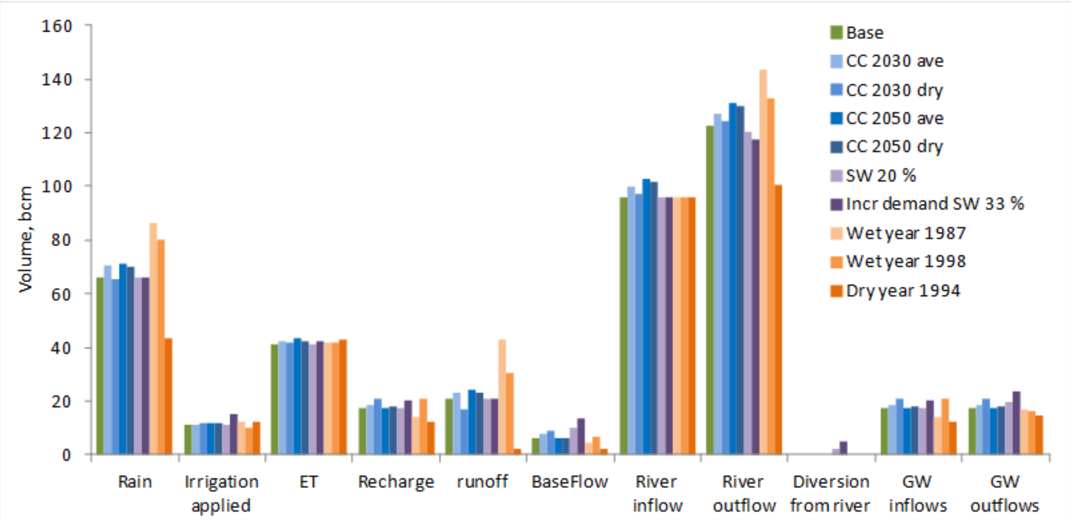
- Climate change up to 2050
- Population growth
- Upstream development

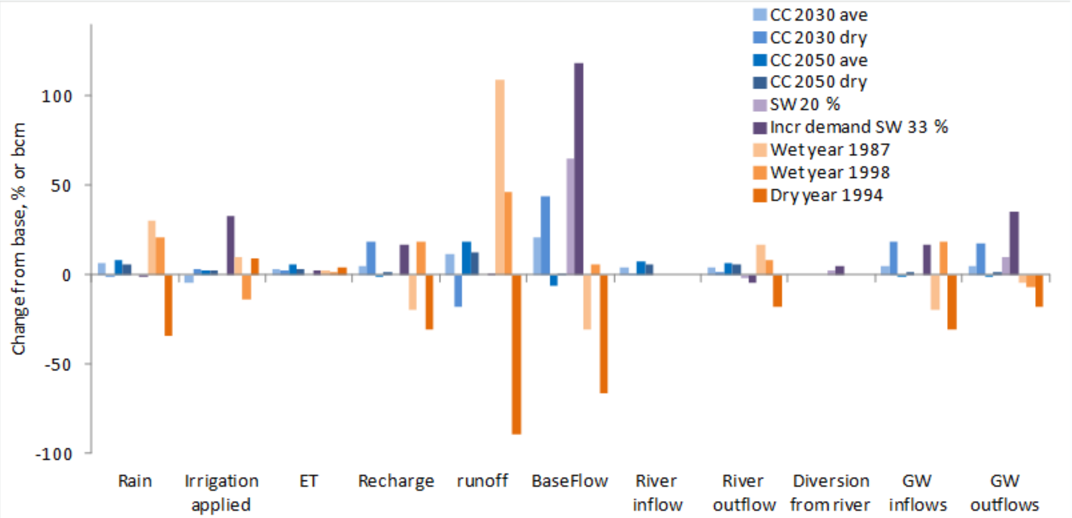


Hydrological regions of Bangladesh

Surface water assessment- regional water balance

- Done in two ways- using hydrodynamic model (MIKE-11) and using a developed program at regional level
- Water balance is essential to understand the flow of water in and out of a system
- Provide information about sustainable use
- Examined the impact of climate change; how different components are affected





Surface water assessment- flood modelling

Generated open water extension map during 1998 Flood

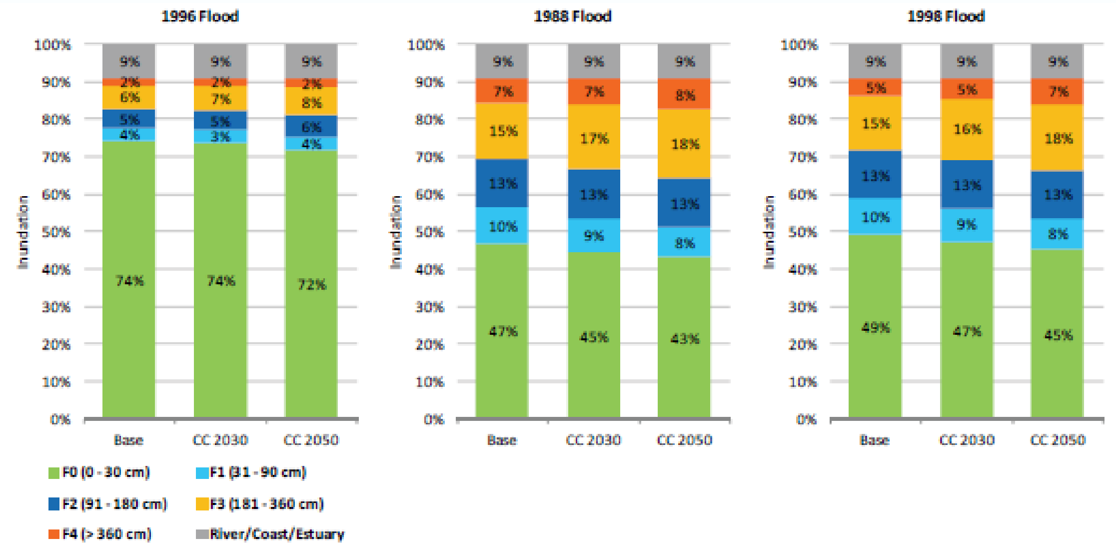
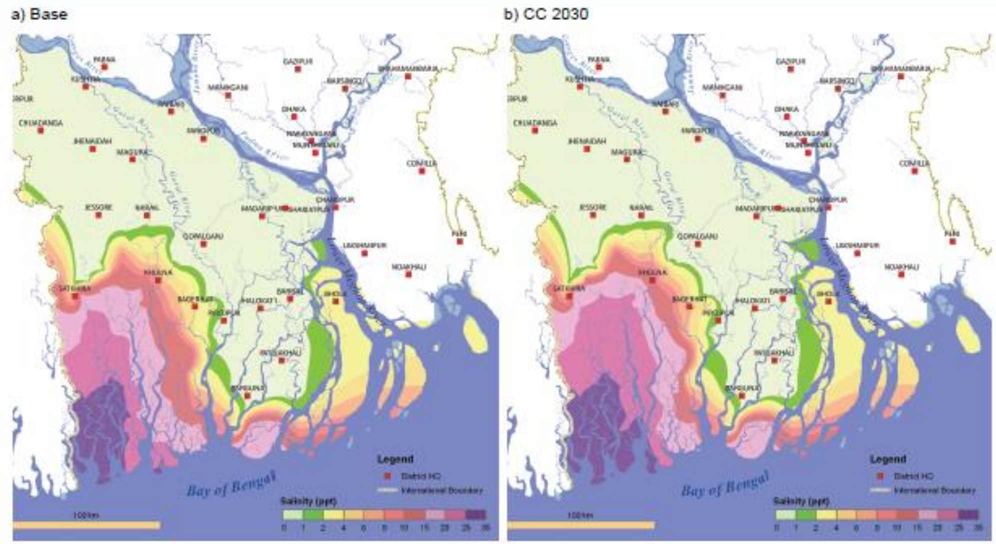


Figure 6-6: Percentage of area under different flood type during base and climate change condition for Bangladesh

- Widely used water modelling using hydrodynamics models such as (MIKE-11, MIKE-21, MIKE-BASIN, SWAT)
- Used in flood forecasting and warning
- Area affected, depth and duration of flood is very important for Bangladesh for Aman rice, and for Boro rice in the Haor area (flush flood during early monsoon affect the Boro rice harvest)

Surface water assessment- modelling salinity intrusion

- We used models to assess the salinity intrusion
- Due to low flow in the river in the dry season, sea water travels through the river system up to 100 km inland
- This is already further exacerbated by the sea level rise due to climate change
- Salt affected area is increasing in the coastal region affecting livelihood and food security of the people; this is likely to be exacerbated in the future



Surface water salinity map of base and 2030 CC

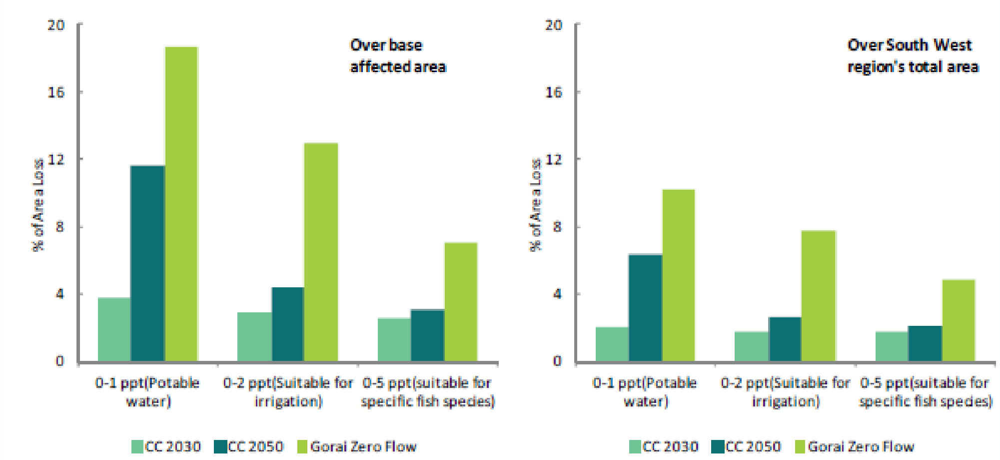


Figure 7-5: Percentage of area loss due to climate change and Gorai River's zero flow over base condition.

Surface water assessment- low flow modelling and water requirements for the irrigation projects

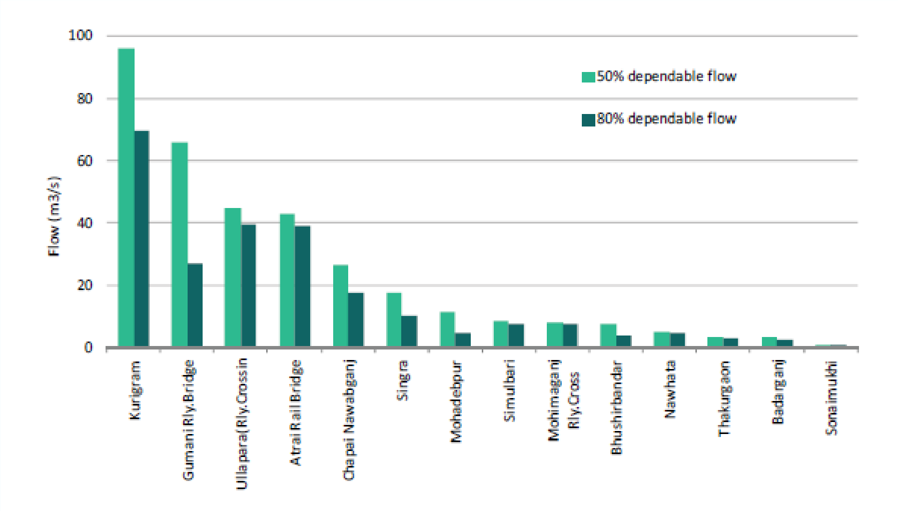


Figure 8-9: Dry season dependable flow of North West rivers

Modelled low flow in the river systems in the dry season to understand dependable flow for irrigation planning in the surface water irrigation system (e.g. Teesta Irrigation Project)

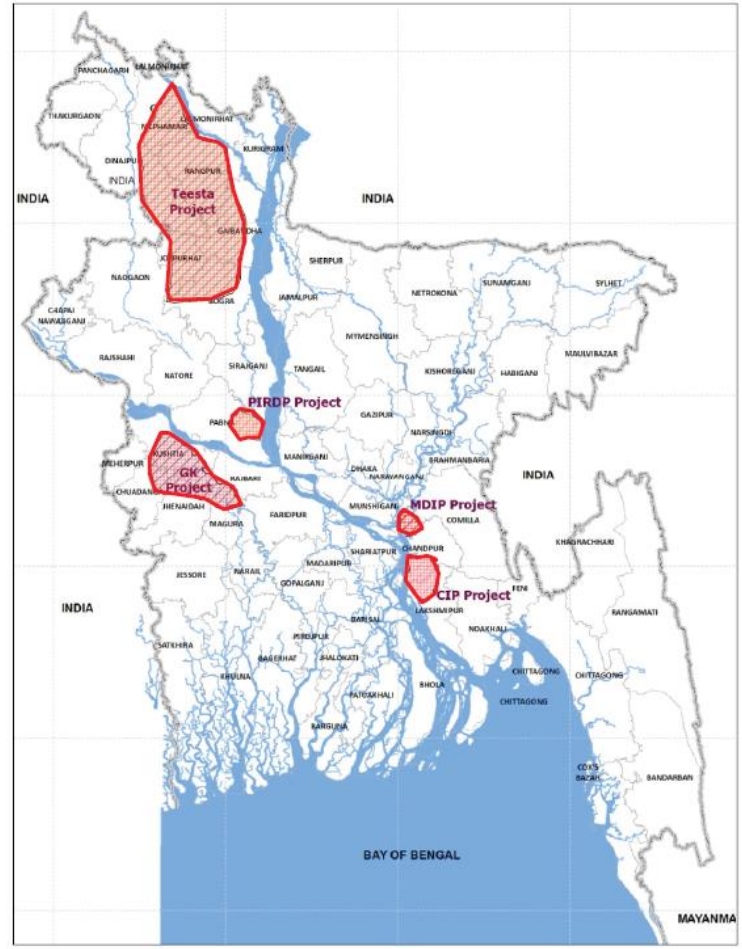
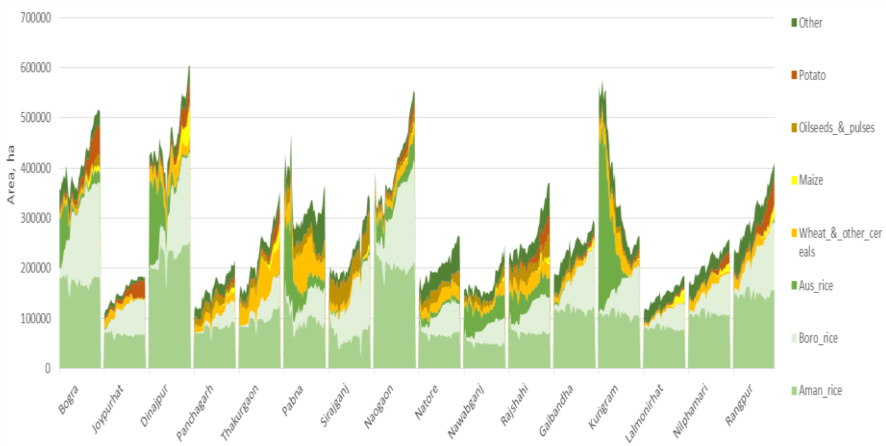
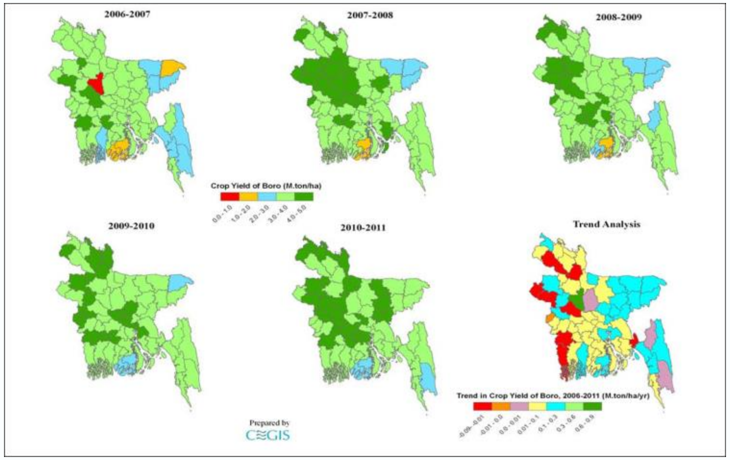


Figure 9-1: Location of five major irrigation projects of Bangladesh

Trend in land use and crop production



District wise trend in area of crops in the northwest region



Spatial variation and trend in the yield of Boro rice during 2006-07 to 2010-11

Done for the period of 1985-2016, at district level

Important to understand historical change in water demand

Currently we are analysing historical (2000-2016) land use change and actual ET using remote sensing in the northwest region

Irrigation demand modelling

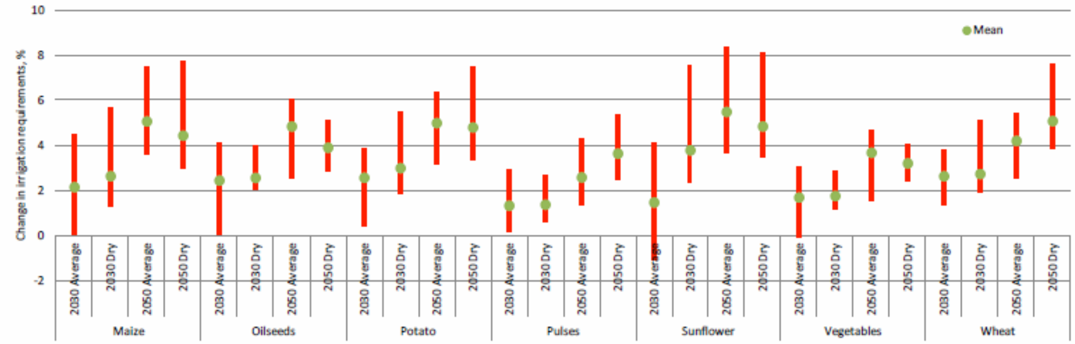
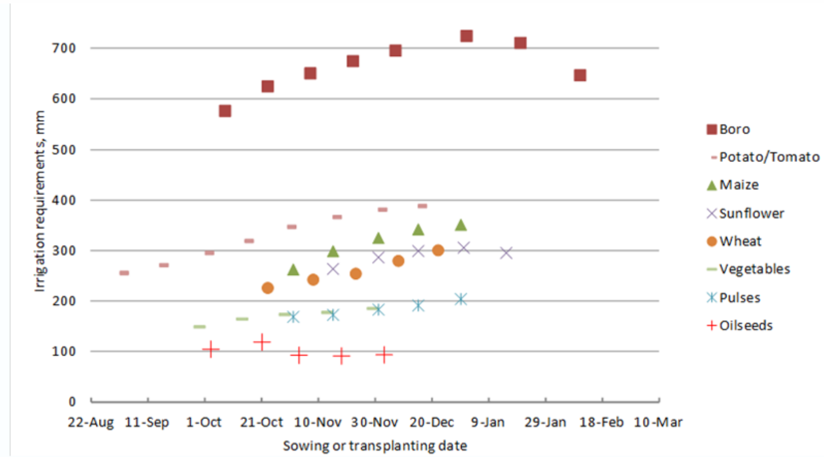
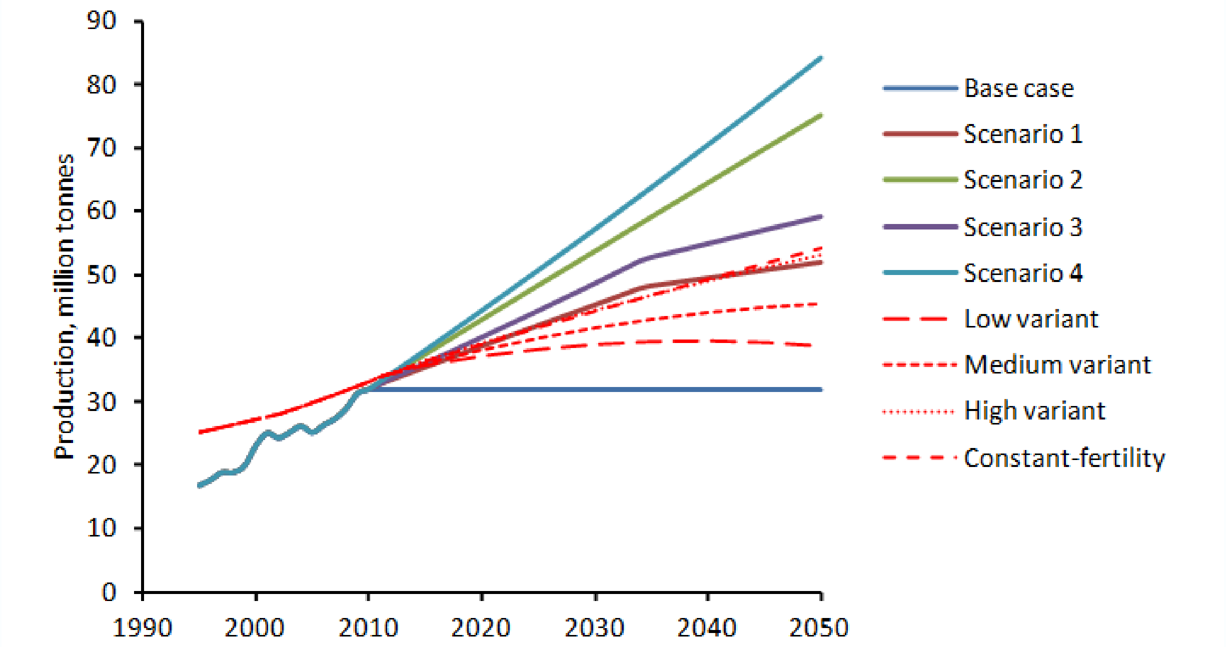


Figure 4.18 Change in net irrigation requirements of Rabi crops for base case planting (the vertical bar shows the spatial variation) due to climate change



- Modelled irrigation requirements of all major crops on daily basis using different planting/sowing dates for the period of 1985-2016
- Essential information for sustainable water resource planning
- Modelled the impact of climate change on irrigation requirements of different crops

Food security modelling at national level



- RICE only shown
- Note, for wheat there will always be a deficit

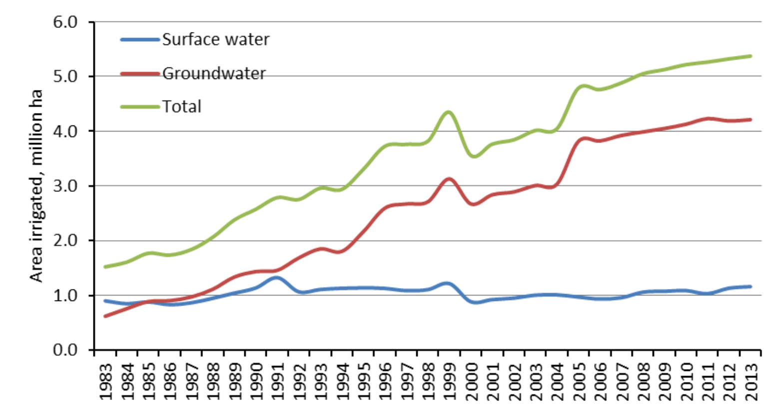
Using all the information, modelled food security (rice and wheat) at the national level up to 2050 considering current trends in production, population growth, water availability, and climate change impacts

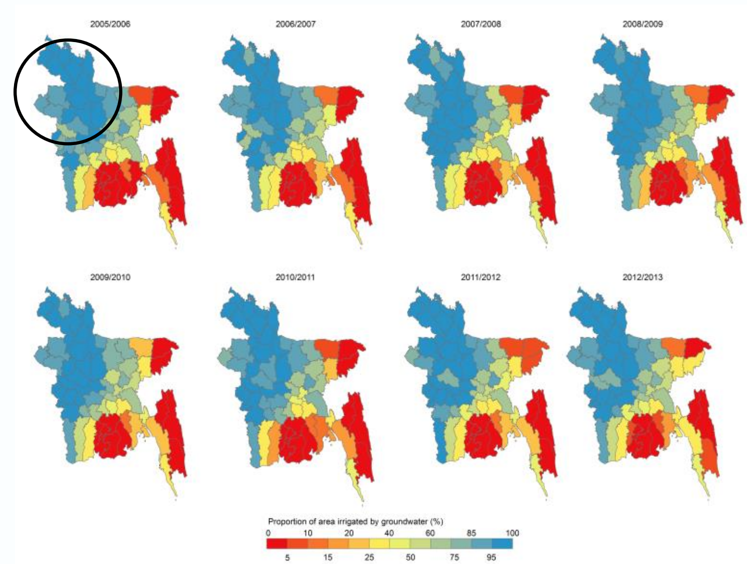
Increases in yield appear to be sufficient to maintain rice grain security

Conversion of agricultural land to urban and industrial area is the main constraint for food security in the future

Development of Irrigation

- Current self-sufficiency in rice production and overall agricultural development was possible due to phenomenal growth in irrigation
- Driven by the use of groundwater - rapid increase in the adoption of STWs
- 97% of the irrigated area in the northwest region are by groundwater
- 95% of the DTW are operated by electric motor
- 83% of the STW are operated by diesel engine
- Now there are large solar pumps (run by NGOs), not individuals





▪ Deep tube well

▪ Shallow tube well

	Bangladesh	N-W Region
DTW	36,034, 92% electrical	23,516 (65%), 95% Electrical
STW	1,563,791, 82% diesel	726,579 (47%), 83% diesel

Groundwater assessment – trend analysis

Heavy use of groundwater led to decline in water level in some areas

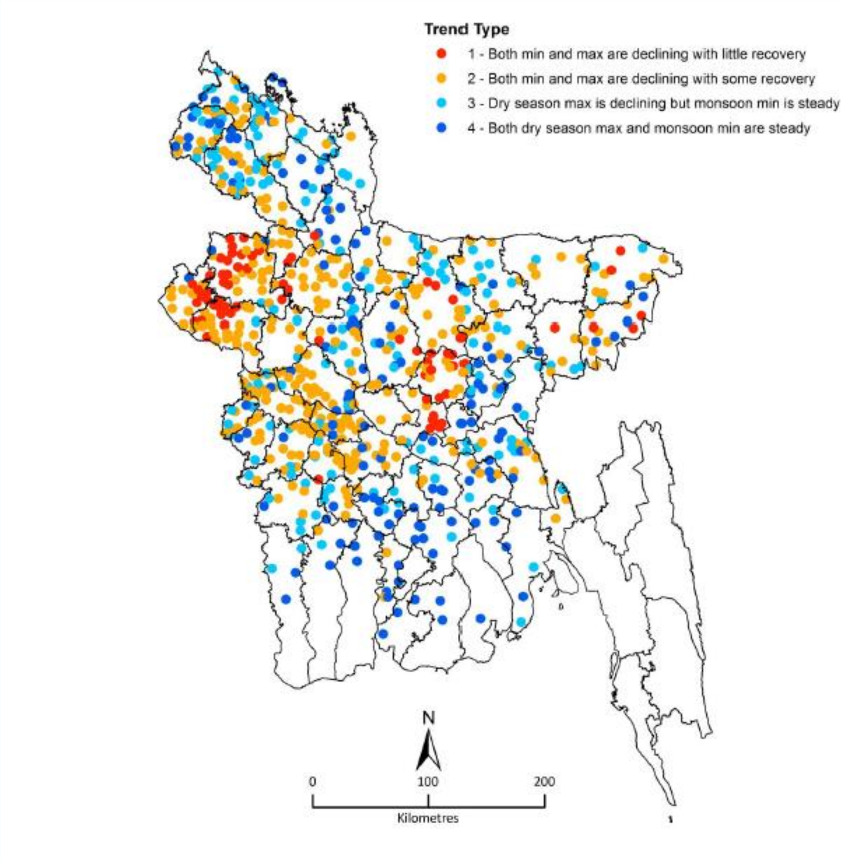


Figure 3-11 Distribution of well trend types for the long term trends (1985-2010)

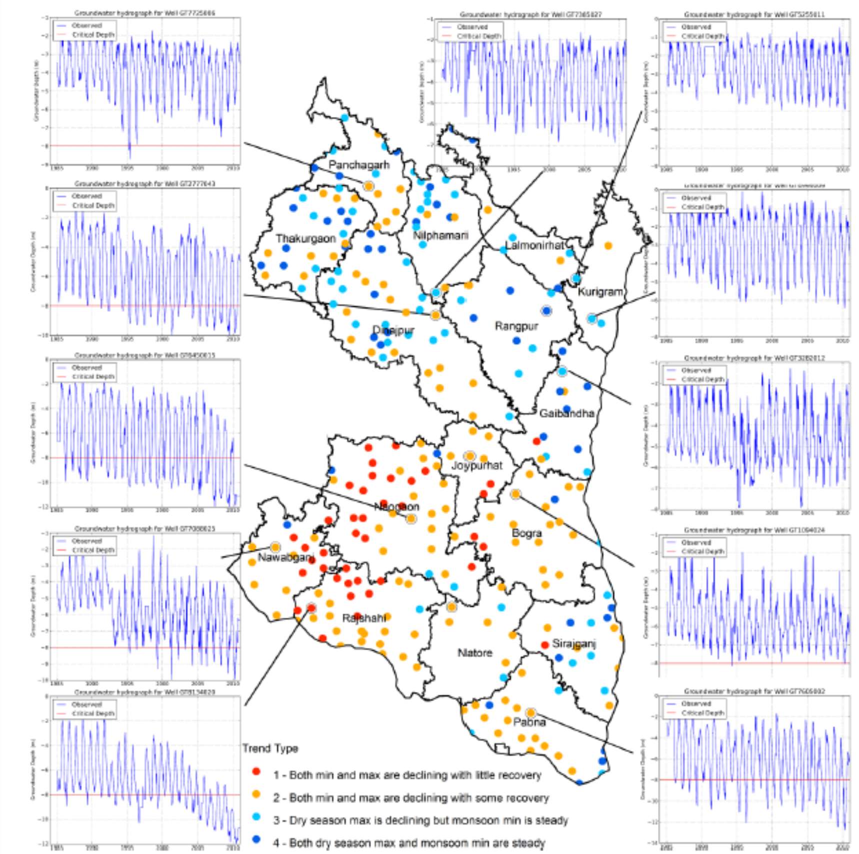
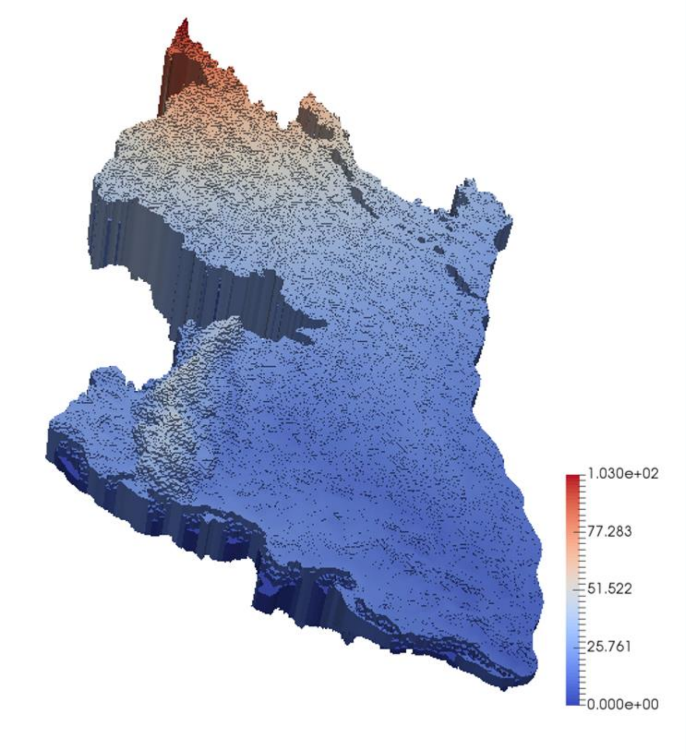


Figure 3-13 Trend types and selected hydrographs for the North-west hydrographic region.

1200 observation wells record were used to classify 4 types of trends (coloured dots). Red dots are the places where groundwater level are declining with no recovery

Modelling sustainable level of groundwater use

- Yet there is no information about what is sustainable level of use
- Under SDIP II project (sustaining groundwater irrigation for food security) we are now using two different modelling platforms (MIKE-SHE and MODFLOW) to understand the sustainable level of groundwater use for irrigation considering current and future conditions

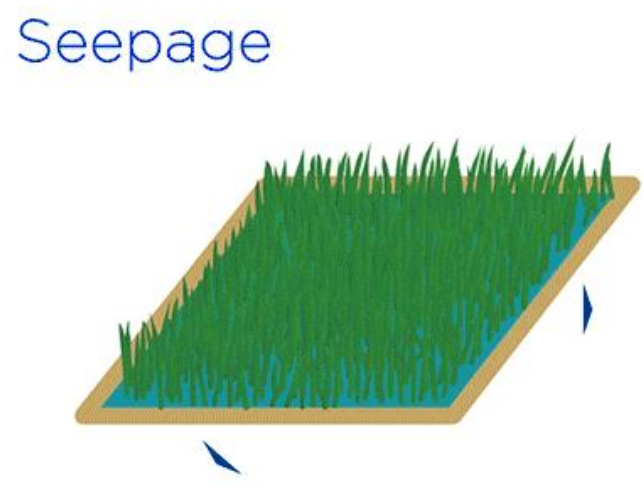


Modflow model grid

Field scale model vs regional scale model

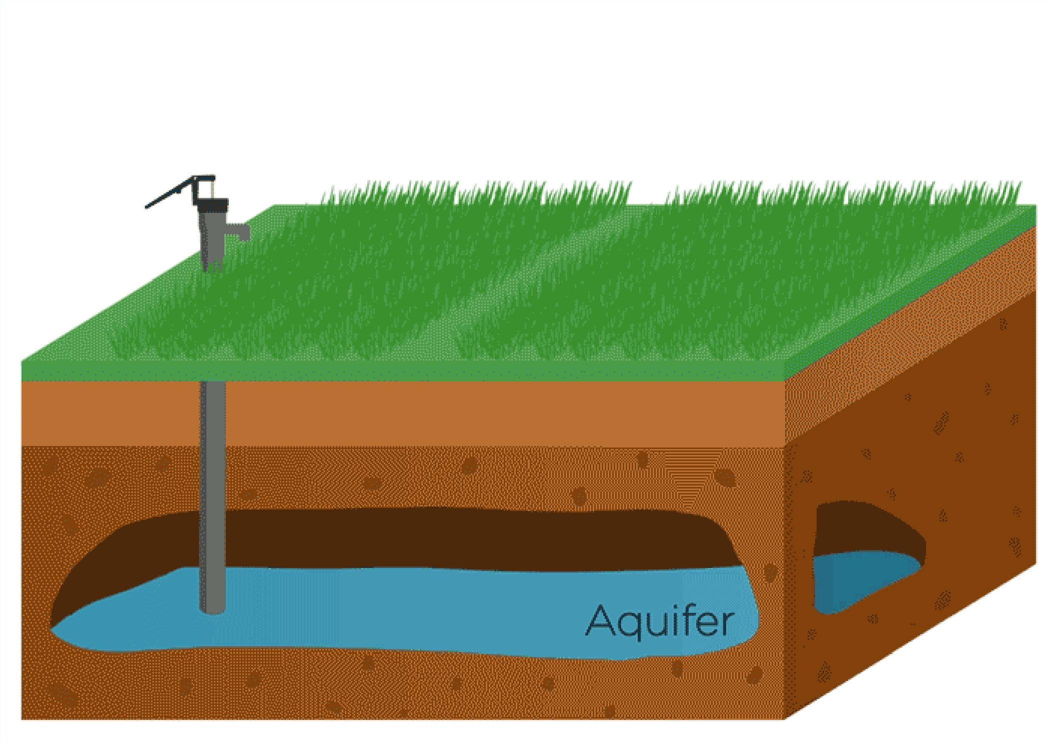
- There are serious misconception about groundwater irrigation and the current measures to declining groundwater level
- Lot of these measures (such as water saving irrigation, AWD, conservation agriculture, etc.) are based on field/plot scale modelling, which may not have any impacts on the groundwater sustainability
- Boro rice is the main crop (about 65-70% of the total area in the northwest region) irrigated in the dry season
- There is seepage and percolation from the rice field. Varies from 2 to up to 6 mm/day based on the soil condition
- For an individual plot (field/plot scale model) seepage and percolation is considered as ‘losses’
- **But are they really ‘losses’?**

Field scale model vs regional scale model – seepage from the rice fields



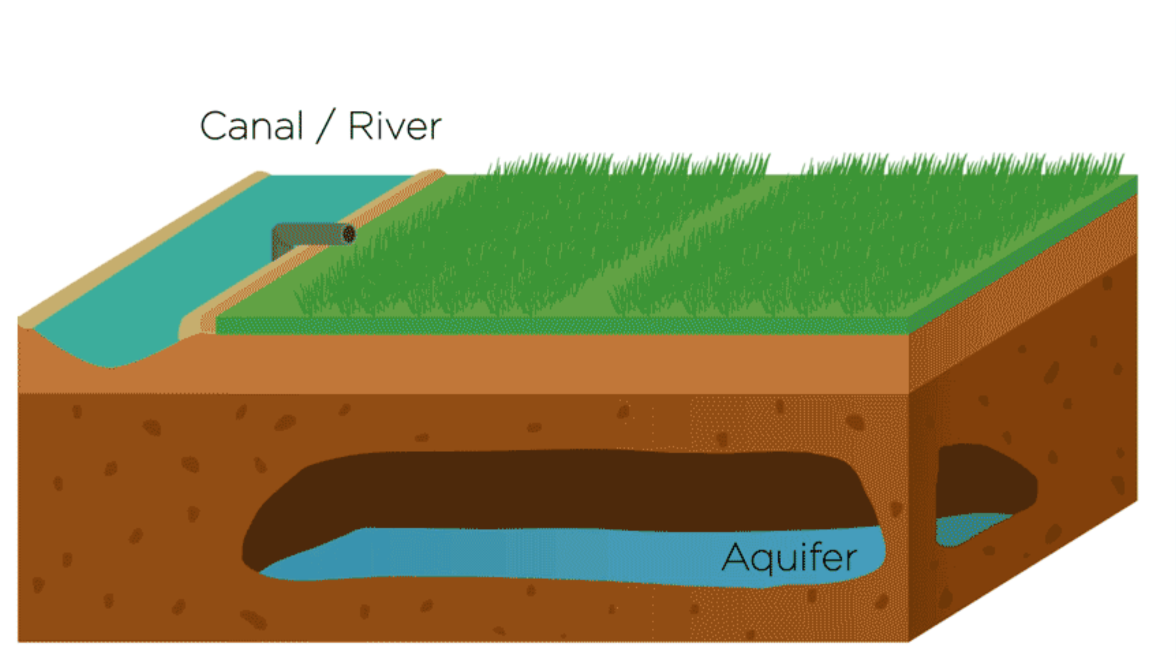
Seepage is not really 'loss', only at the edge of the field there are some loss – but used by other plants at the road side or evaporated from the ditch

Field scale model vs regional scale model– percolation from the rice field



- Percolation is recharging groundwater during the irrigation season – so they are not lost from the system in the groundwater based irrigation system
- The irrigation in the EGP is predominantly based on groundwater

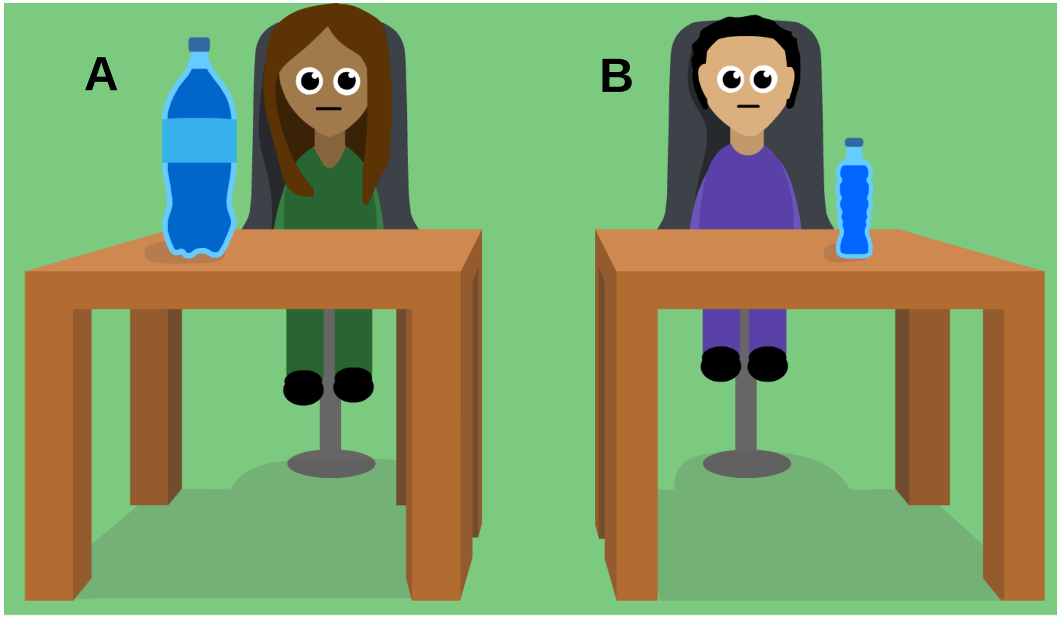
Misconception of groundwater irrigation – percolation from the rice field



- Percolation is loss if water is pumped from surface sources (river, canal, reservoir) and the underlying groundwater is not used due to poor quality or other factors
- Coastal region of Bangladesh and West Bengal is an example. Groundwater cannot be used due to salinity. There percolation from the field is loss

Field scale model vs regional scale model – water saving irrigation

- Current water saving measures (such as AWD, etc.) are based on conception of less pumping of water from the aquifer – no study on whether **they reduce ET**
- Less pumping – does not mean aquifer is saved unless this reduces the **ET from crop**
- But less pumping **saves cost** and **reduce emission** (economic and environmental benefit)

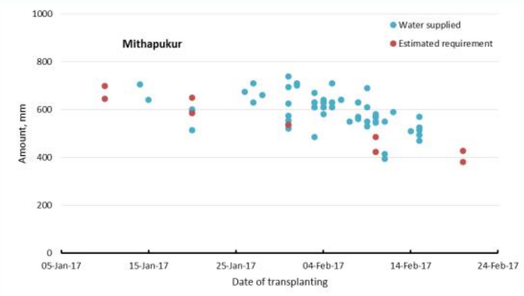


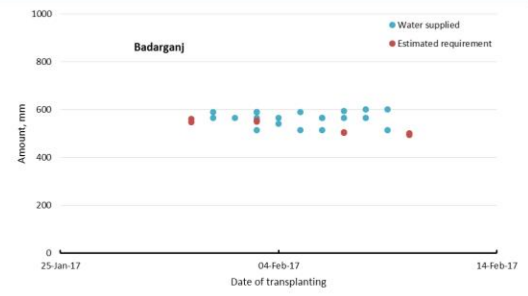
Can we say **'A'** drinks more than **'B'** as she is having a bigger bottle of water? No

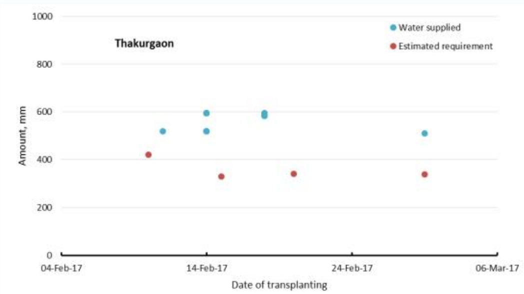
It is necessary to measure how much is taken or how much is left in the bottle

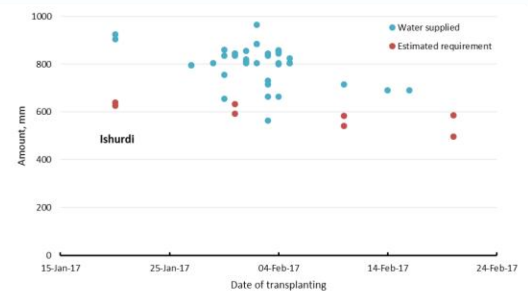
Then we need to know what happened to the left over water in the bottle. That is water balance.

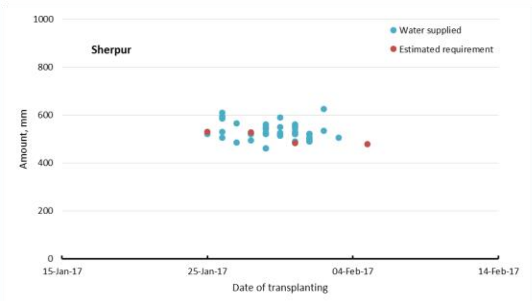
Over application of water – general perception vs reality

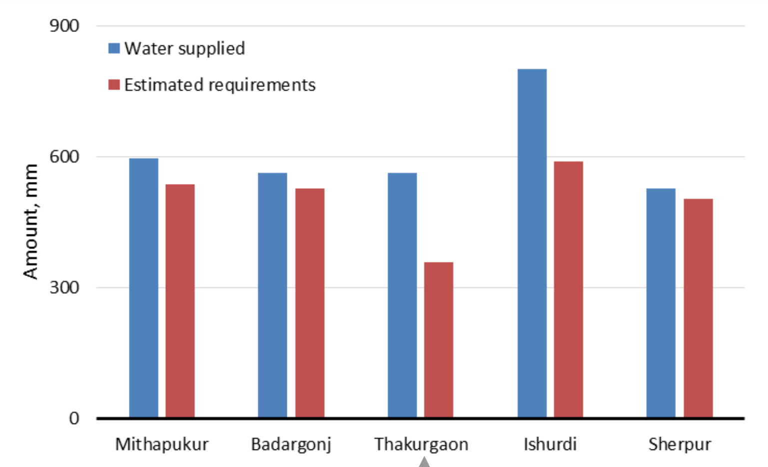












Comparison of water supplied with the estimated requirements

Deep tube well site

- Monitored irrigation application in 235 rice plots in 2015-16, and 185 plots in 2016-17 and compared with the estimated requirements
- In general, in STW sites farmers are very efficient in applying water – water is very costly
- DTW sites have some oversupply

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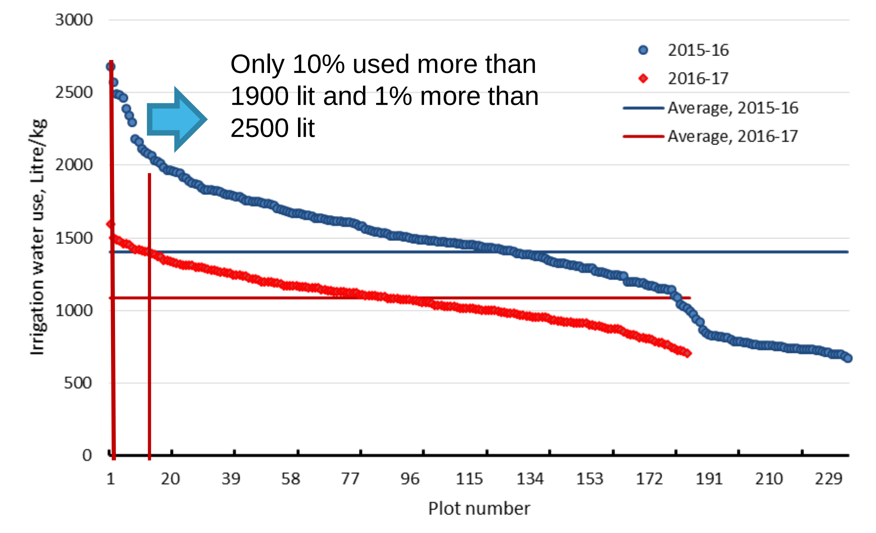
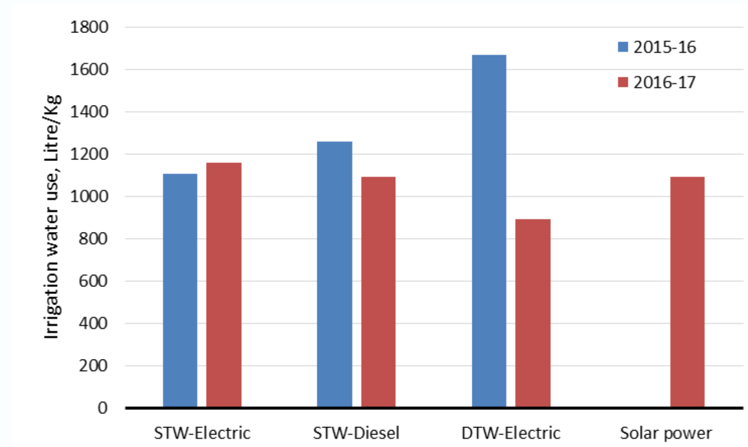
Use of water for growing rice – perception vs reality



Actual water supplied to the plots in descending order



this figure included canal conveyancing losses from old system

- General perception is 3000-5000 lit of water is required to grow a kg of rice (that originated from inefficient surface irrigation system decades ago)
- Average of 2015-16 was 1402 lit/kg, 2016-17 1086 lit/kg, that was supplied to the field not all used by plants (seepage and percolation contributed to the aquifer as return flow)
- Water supply in DTW area is higher particularly in 2015-16, low cost
- Water is costly in STW, so farmers are prudent in applying water

What causes decline in GW level in the northwest region of Bangladesh

There are multiple reasons:

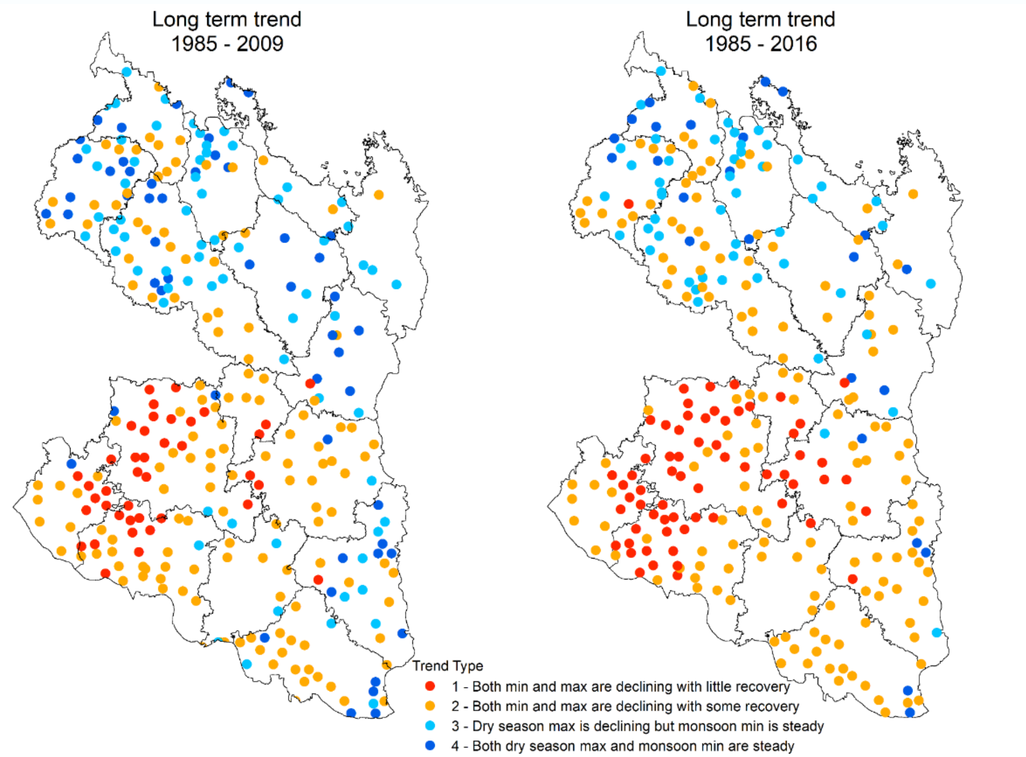
- Use is more than the annual recharge
- The use has been stabilized over the last 5 -6 years, yet there is decline in groundwater level. Why?
- There are other factors which has significant impact on the decline in GW level. These are:

  - Significant decline in rainfall in recent years

  - Characteristics of rainfall is changing - more intense heavy rainfall (less recharge)

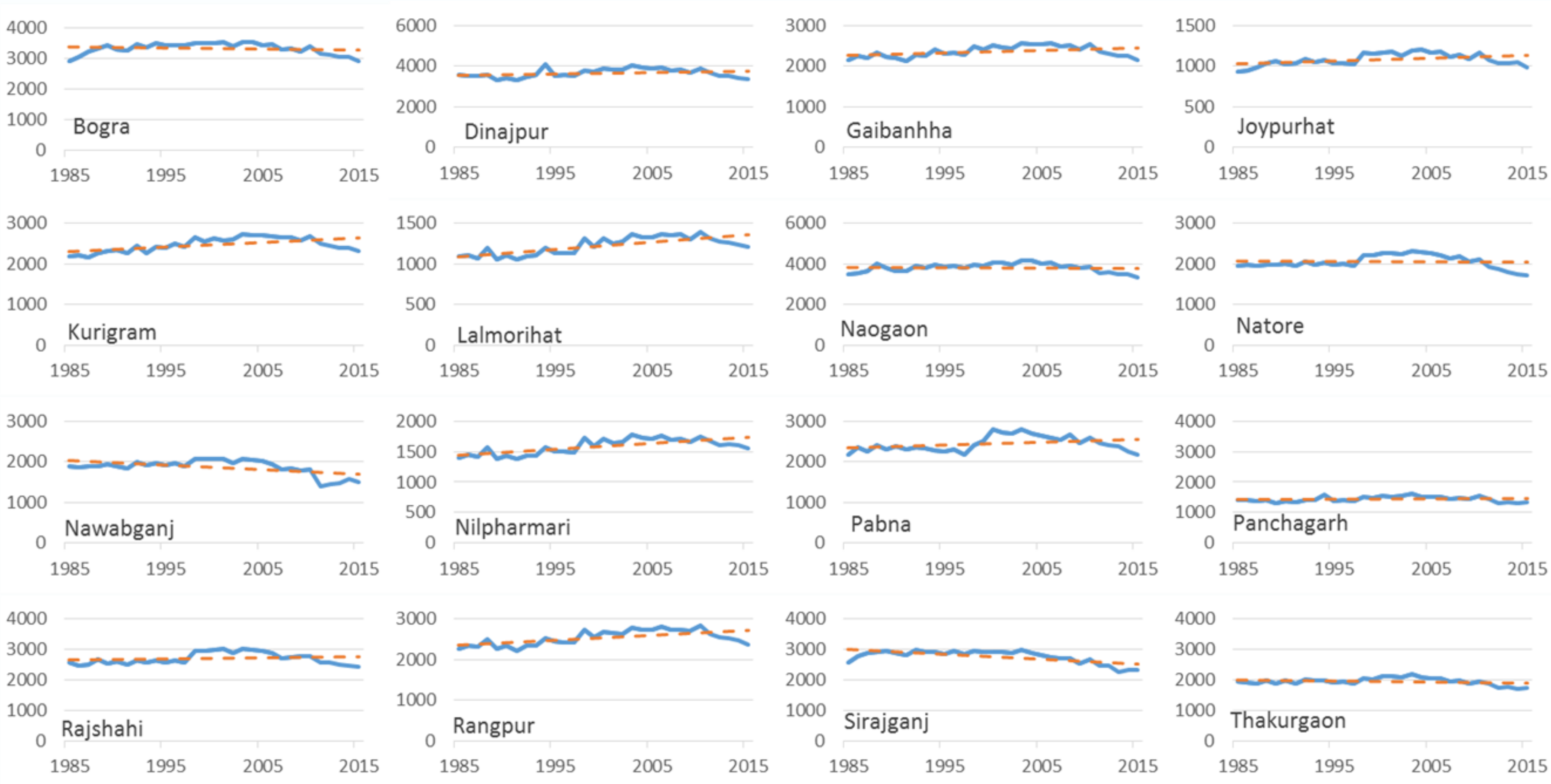
  - Less permeability of the soil (plough pan, conservation practice)

  - Low flow in the rivers in the dry season, more base flow from the aquifer



More red and yellow dots in the right side map

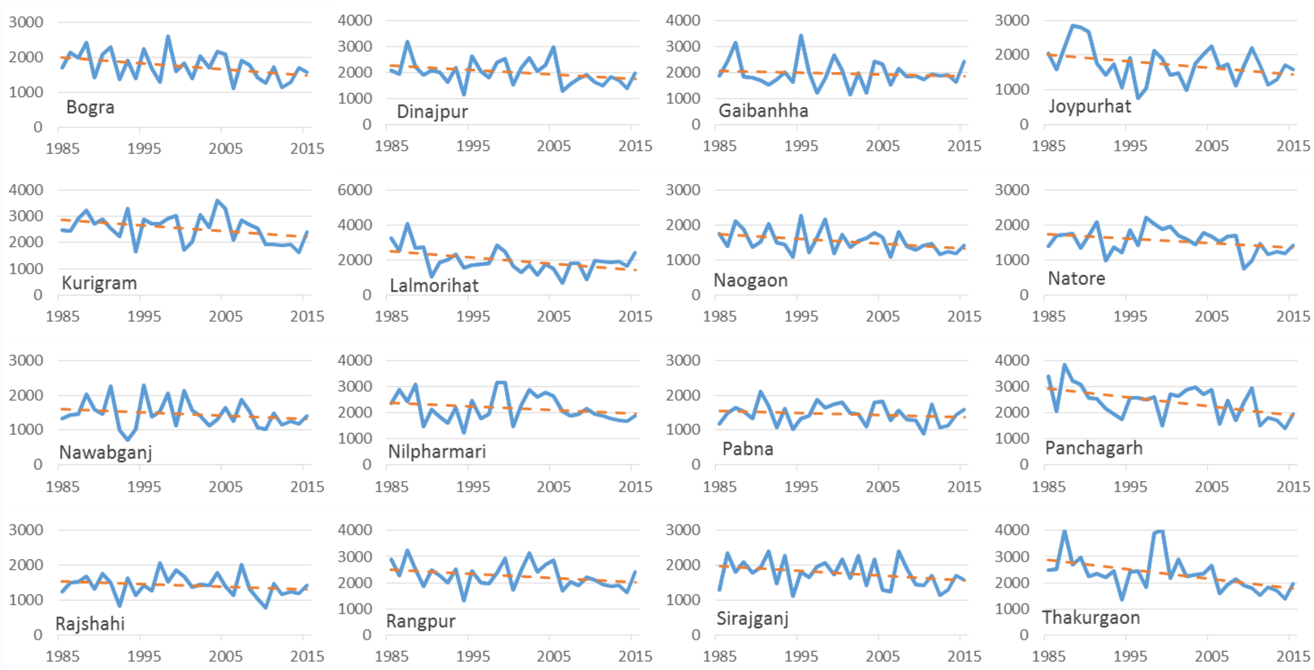
What causes the decline in GW level - Annual Et_a



Positive and negative trends - no overall picture

Why not? Swap of high ET from natural to irrigated, little change)

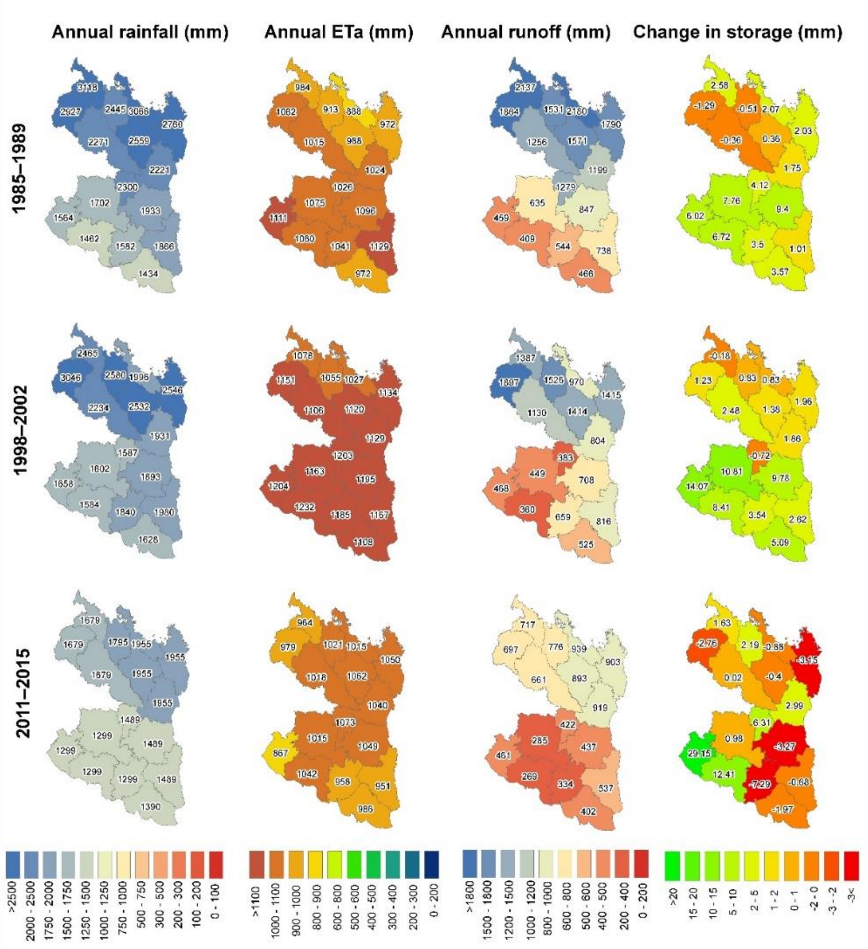
Annual rainfall – district in the northwest region



Rainfall has declined - 10 to 45 mm / year

11 out of 16 districts have statistically (at 90%) significant decline

Annual water balance – northwest region

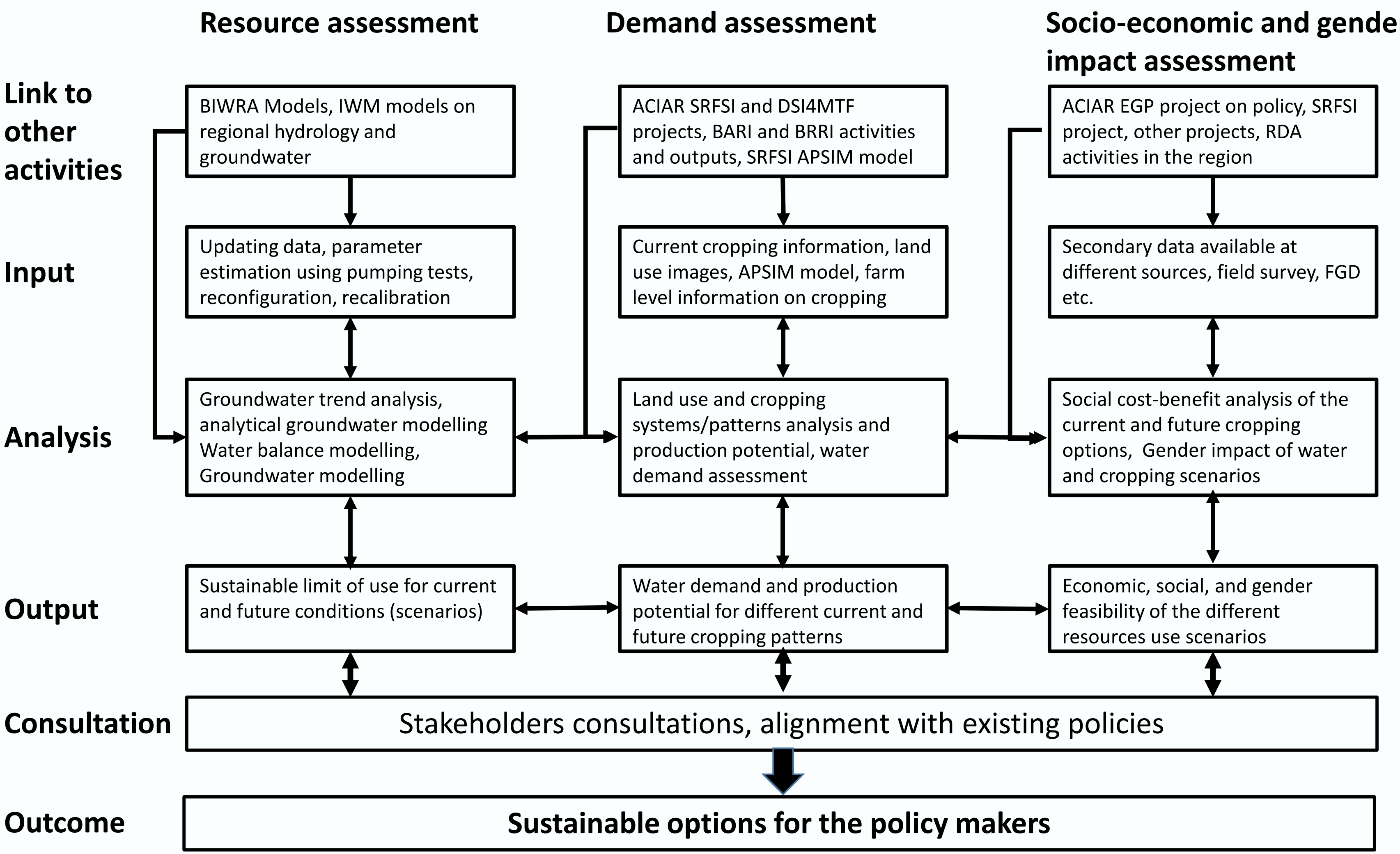


- Decline in rainfall mostly results in a reduction in runoff
- Groundwater storage generally decreases (positive values), more in the southern districts

How to make groundwater irrigation sustainable?

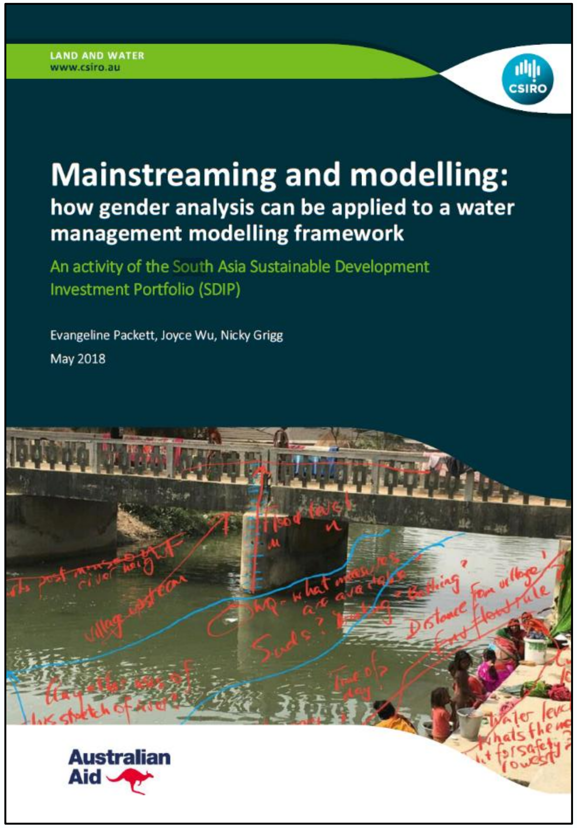
- Need to understand clearly the causes of decline and their relative magnitude
- That will help identify the measures such as reduction in overall ET (replacing rice with other crops), augmenting recharge to the aquifer (deep ploughing in the wet season to increase water retention in the field and higher recharge), recharge ponds and storages, etc.
- Current focus by the government and by the policy makers are on pumping only – **which is based on field scale modelling of so called 'water savings'**
- Sustaining groundwater irrigation is essential for future food security and livelihood of the people
- So , integrated modelling is required
- We are addressing some of these under SDIP Phase II project in northwest Bangladesh

SDIP Phase II project - integrated modelling



Socially inclusive modelling practice

- Modelling needs to be socially inclusive
- In the SDIP Phase II project
- We are specifically examining the impact of future water availability on the irrigated agriculture, regional socio-economy, livelihoods, women and girls
- Conducting gender-disaggregated social cost-benefit analysis of potential scenarios, investments or policies



Packett, Evie; Wu, Joyce; Grigg, Nicky. Mainstreaming and Modelling: How gender analysis can be applied to a water management modelling framework. Canberra: CSIRO; 2018. csiro:EP181176. https://doi.org/10.25919/5b7b0fb725fac

Challenges in water resources modelling

"Essentially, all models are wrong, but some are useful."
--- Box, George E. P.; Norman R. Draper (1987). Empirical Model-Building and Response Surfaces, p. 424, Wiley. ISBN 0471810339.

- Models are simplifications of reality. They can help us explain, predict and understand the system and all its various components
- But we need good data to build a representative model – otherwise it would be *garbage in garbage out*
- Within the EGP, Bangladesh has good data and they are also available
- In other countries, there are data – some of them are highly classified and may be not available
- However, it is possible to build simple dependable model with available data

Conclusions

- EGP is one of the most densely populated areas of the world
- Also may have the highest number of extremely poor people, and food insecure people
- Water availability is central to agricultural production – current and future (about 60% of the total rice production in Bangladesh are from irrigated rice)
- Sustaining irrigation needs clear understanding of water availability and its different drivers
- Models are useful tools to build that understanding

Thank you

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