MAPPING OF GROUNDWATER RECHARGE POTENTIAL IN BANGLADESH

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INTRODUCTION

- In South Asia, groundwater-fed irrigation helps to cultivate high-yielding rice during the dry season.

- World’s biggest rice-producing nations:
  
  (Scott and Sharma 2009; IRRI 2010)

  - India: second
  - Bangladesh: fourth

- In the Ganges-Brahmaputra-Indus basins:

  Current abstraction [\(\sim 246 \text{ km}^3/\text{year}\)] > potential groundwater recharge

  (CGWB 2006)
In Bangladesh, total annual irrigation water use (2004-2005):

- \( \approx 24 \text{ km}^3 \) where 18 km\(^3\) from groundwater by pumping technologies

Recent report for India and Bangladesh:

- Declining trends in GW levels: 0.1-0.5 m/year
- Reduction in aquifer storage for irrigation and urban water supplies with unsustainability
Bangladesh covers major portion of Bengal Basin

Major Geomorphologic Units:
- **Tertiary Hills**
- **Pleistocene Uplands** (Barind Tract and Madhupur Terrace)
- **Holocene Plains** (Northern Piedmont Plains, Meander Floodplains and Tidal Plains of Southern Delta)
Climate and HYDROLOGY

Headwaters of major river systems combine to GBM system:

- Drains Himalayan Mountains partly and plains of India, Nepal and Southern Tibet
- Only 7.5% (1.5 million km²) of catchment area lie in Bangladesh
- Mean annual rainfall: 300 mm (in Nepal) 11,615 mm (Cherrapunji)

Long-term mean annual rainfall in Bangladesh: 1492 mm in NW – 4097 mm in SE

Spatial distribution of mean annual rainfall (Jahan et al., 2013)
Monthly variations show:

- 85% Rainfall occurs during May - Sept. (Monsoon)
- >5% occurs during dry season (Nov. -- March)
- Effective Rainfall: Zero during dry period and agriculture not sustainable without Irrigation

Mean Annual Temp.: 24.18 - 26.67°C

Spatial distribution of mean annual Temperature
Tropical Monsoon Climate

- Mainly Humid
- NW part Sub humid (Aridity index: 20-28)
- SE part wet (Aridity index: >55)

South Asian monsoon dominates natural hydrology of Bengal Basin

Rainfall floods 30% of land surface in rainy season (JICA 2002)

Monsoon rains sufficient to fill aquifer each year nearly everywhere in basin (Burgess et al., 2002)

Climate Classifications by De Martonne Method (Jahan et al., 2013)
Monthly Evapotranspiration:
- January (70-90 mm) - March-May (180 mm)
- Stabilized: Monsoon (115-145 mm)

### Long term mean monthly rainfall and PET in Bangladesh (Rashid 1991)

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<td>September</td>
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<td>123</td>
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<td>October</td>
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<td>November</td>
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<td>Annual</td>
<td>2095</td>
<td>1602</td>
<td>2741</td>
<td>1573</td>
<td>2126</td>
<td>1429</td>
<td>1850</td>
<td>1447</td>
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Geology

Bengal Basin

- One of largest fluvio-deltaic system in the world
- Extend over 200000 Km²
- Depths more than 20 Km
- Sedimentation relevance to present day hydrogeology began in Mid. Miocene (Allison 1998)

Ganges and Brahmaputra rivers:

- Primary sediment sources
- High sediment deposition at rate of 20 mm/year during early Holocene

Despite some lateral and vertical variation trends in aquifer fabrics, also distinguished by physiographic region variations that help to study groundwater recharge potential
Surface geology:
- Quaternary sediment
- Slightly elevated (10-20 m amsl)
- Brown or tan color
- Composed of sand, silt and clay
Sediments in Sylhet depression and southern tidal-deltaic regions:
   - Silt and clay with little sand

Distributions and thickness of USC:
   - Aquifers across country overlain by silt and clay sequences (<5 to 50 m thick) (MPO 1987)

North-west (alluvial fan deposits):
   - USC unit not exist
   - Very fine-fine sands occur at surface

Shallow aquifers:
   - Occur at relatively deeper depths (>15 m bgl) in Pleistocene area, Surma basin, and southern GBM Delta
     - With thick USC unit

Soil composition
   - Predominantly Sandy: Alluvial Fans, river valleys and Tertiary deposits in eastern hills
   - Mainly Clayey: Pleistocene terraces (Madhupur Clay Formation), Tidal delta, and Marshy peat-land
Aquifers types according to depth (Ravenscroft 2003):

- Shallow aquifer (upper 80-100 m bgl)
- Deep aquifer (>100 m bgl)

Groundwater depth in Bangladesh:

- Follow surface topography.
- Shallow (<10 m bgl) depth in alluvial deposits (MPO 1987).
- Higher in NW
- Low in south and Sylhet and Atrai depressions.

Deep aquifers provide municipal and industrial water supplies in urban areas and drinking-water supplies in coastal areas where shallow groundwater is mostly saline (UNDP 1982; BGS and DPHE 2001).
## Hydrological Properties

<table>
<thead>
<tr>
<th>Aquifer</th>
<th>Lithology</th>
<th>Age</th>
<th>Transmissivity (m²d⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brahmaputra-Tista Fan and Brahmaputra basal gravels</td>
<td>Gray coarse sand, gravel and cobbles</td>
<td>Late Pleistocene and Holocene</td>
<td>3500-7000</td>
</tr>
<tr>
<td>Ganges, Lower Brahmaputra and Meghna main channel</td>
<td>Gray coarse to medium sands and gravel</td>
<td>Late Pleistocene and Holocene</td>
<td>3000-5000</td>
</tr>
<tr>
<td>Deeper cyclic aquifers of main delta and coastal areas</td>
<td>Gray medium to coarse sands</td>
<td>Early to Middle Pleistocene</td>
<td>1000-3000</td>
</tr>
<tr>
<td>Old Brahmaputra and Chandina fluvial aquifers and fine silts of the Sylhet basin</td>
<td>Red-brown medium to fine grained weathered sands</td>
<td>Early to Middle Pleistocene (Dupi Tila?)</td>
<td>300-3000</td>
</tr>
</tbody>
</table>
Groundwater–fed Irrigation

A few irrigation wells installed in NW parts initially,

Millions of drinking water and shallow irrigation wells installed during international campaign of ‘Clean Drinking Water Decade (1980-1990)’

By 2006, 78% of irrigated rice-field supplied by groundwater of which 80% derived from STW

Rest (22%) irrigated by DTW to produce Boro rice (BBS 2009)
Groundwater-fed irrigation (STW and DTW):

- Highest in NW and SW districts
- Lowest in eastern and southern deltaic regions

(BADC 2008)
Previous estimates of groundwater recharge

Potential recharge using a water-balance method (UNDP 1982):
- High (<600 mm) in eastern part
- Low in Western part (135-275 mm)

MPO (1987, 1991) using finite-difference recharge models:
High potential area: Rivers Brahmaputra (Jamuna) and Meghna, and eastern parts of Bangladesh
Water-Table Fluctuation Method:

- Water-table fluctuation technique (Healy and Cook 2002) applied to estimate net groundwater recharge
- Principal of method: Rises in water level of an unconfined aquifer result from recharge arriving at water table

In Bangladesh:

- Majority (>90%) of recharge to unconfined shallow aquifers occurs during monsoon season (UNDP 1982)
Groundwater recharge estimates

Estimates of groundwater recharge for periods:

- Pre-developed gGW-fed irrigation (PGI) period (1975-1980)
- Post-developed groundwater-fed irrigation (DGI) period (2002-2007)
- Long-term mean recharge (LGI) period (1985-2007) (Shamsudduha et al., 2009)

Results show:

Actual / Net recharge:
Higher in NW and Western parts > southern and eastern parts except Comilla district

Magnitude of groundwater recharge varies between PGI and DGI periods
Net recharge increases:

- In NW regions and along rivers floodplain Brahmaputra and Ganges
- Mean annual recharge 2002-2007 > 1985-2007 in NW and in river floodplains of Brahmaputra
- increased recently in Jessore, Khulna district, Mymensingh and Comilla regions
- Changes in recharge are limited in rest of country
Spatio-temporal trends in recharge

Recharge increase 5-15 mm/yr in:
§ NW and western
§ NC districts
§ Comilla district in east

Increases in net recharge between PGI and DGI periods coincide with areas of intensive groundwater-fed irrigation.

Recharge decrease -0.5 to -1 mm/yr in:
§ Southern GBM Delta
§ Sylhet depression

Remained unchanged in rest of Bangladesh.
a. Map shows max. depth (mbgl) to recent (2002-2007) static water table in aquifer. It highlights areas where available pumping technologies for drinking water and irrigation water supplies are unusable during dry season.

b. Map shows part of potential recharge available for further groundwater development in 64 districts. Further increase in net recharge due to increased abstraction in western parts constrained by limited potential recharge and surface geology.
Relation between actual (net) and potential groundwater recharge

- Net recharge in NW and Western parts > Eastern parts
- Potential recharge higher due to greater annual rainfall
  - Net recharge: 300-600 mm
  - Potential recharge: 500-700 mm
- Northwestern parts of GBM Delta:
  - Net recharge: 250 to 600 mm
  - Potential recharge: Approximately similar
- Southeastern GBM Delta and Sylhet regions:
  - Potential recharge (400-2000 mm) > Net recharge
Reductions in net groundwater recharge areas:
- Sylhet depression
- Lower Ganges floodplains
- Tidal deltaic areas

Abstraction for groundwater-fed irrigation here lower (<30%) than rest of Bangladesh

Groundwater-fed irrigation slightly decreased in Sylhet and coastal regions:
-0.5 to -1 mm/year (1985-2007)
Impacts of groundwater abstraction on recharge

- Net groundwater recharge increased in many areas since 1980s where intensive dry-season irrigation sustains *Boro* rice cultivation.

- Numerical modeling of regional groundwater flow suggests actual (net) recharge increased:
  - 70 mm/year (before 1970s) - 250 mm/year recently
  (Michael and Voss 2009)

- Estimates of net recharge show mean recharge increased:
  - 132 mm/year (1975 -1980) to 190 mm/year (2002-2007)

- Area of irrigated land by groundwater increased
  - <1% (1965) - 78% (2007) (Shamsudduha et al. 2009)
Recharge increased in areas where dry-season groundwater levels have declined 5-10 m since pre-irrigation period.

Steady rise in net recharge occurred without any increasing trend in annual rainfall.

Increases in actual groundwater recharge limited in areas of intensive abstraction.

Example: Monitoring well RJ086_AB (Tanore Thana) in higher Barind Tract (low-permeable geology)
- Net groundwater recharge increased: 200-230 mm from PGI to DGI periods
- But groundwater-fed irrigation increased: <50-375 mm over the period of 1985–2007
Constraints of groundwater recharge

- Shallow aquifers reach ‘aquifer full’ condition by monsoon recharge

- Greater abstraction in many places can reduce dry-season groundwater levels so irrigation no longer possible by low-cost pumping technologies
Objectives

- To create an approach to estimate qualitatively recharge of water into the subsurface media
- To produce a map showing different zones of recharge potential

Methodology

- Sliding window method is applied to calculate drainage and lineament frequency.
- Arc View 3.2a is applied for integration of factors, which contain a particular weight *i.e.*, degree of effect.
- Remote sensing technique mainly *ERDAS Imagine* software is used to identify linear features of study area.
- A weighting approach must be created for factor integration.
Lithological map classification based on water percolation rate

Drainage frequency map

Lineament frequency map

Land cover/land use Classification based on water percolation rate
Interactive Influence of Factors Concerning Recharge Potential

Recharge potential zones of study area

Weighting approach
Conclusions and Recommendations

- Low recharge potential: 85% area
- Moderate recharge potential: 15% area
- Total volume of rain water: $1136.19 \times 10^6$ m$^3$/year
- Rain water infiltrating downward and recharge groundwater reservoirs: 8.6%
- Such study should be applied for whole Bangladesh territory in micro level to get more precise information about surface signature that governing groundwater recharge potentiality
Thank You