“Improved Water Allocation for Agriculture in the Arab Region”

Technical meeting
26-27/09/2022

Water Accounting

Dr. Salvadore Elga
We cannot plan and manage what we do not measure
Session 1: Water Accounting Principles and examples from past applications

What is Water Accounting?

What can I do with Water Accounting?
  How can WA+ support IWRM?

What types of Water Accounting Systems exist?
  The WA+ is a WA system based on Remote Sensing data

Examples
Data alone is not sufficient for effectively manage water resources

Have decision makers access to the necessary data?

Can decision makers work with these datasets?

Are these datasets alone sufficient for making water allocation plans?
Water accounting is a tool to support decision making
Name comes from financial accounting
Identification and tracking of sources of revenue and expenses

“Water Accounting makes sense of how much water is available and how to use it”

“Water Accounting is the systematic quantitative assessment of the status and trends in water supply, demand, distribution and accessibility”

Definitions from: FAO, Water Accounting for Water Governance and Sustainable Development

Reporting system to translate data to useful information
What is Water Accounting

Water Accounting analyses water resources and their use in a specific geographical domain.

**Irrigation Scheme Level**

Bing VirtualEarth and data from the Irrigated Agriculture Improvement Project (Cambodia)

**Basin Scale**

Tonle Sap basin elevation, HydroSHED data

**Country Scale**

Cambodia and the Mekong river system
Water Accounting uses a three-step approach:

1. **Data collection**
   - gaps identification

2. **Data analysis**
   - from data to information

3. **Communication**
   - making information available to stakeholders
What is Water Accounting?

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Examples
Water Accounting: A simple idea to track a complex system

How much is the water use?

Which sector is consuming how much?

Demand vs. Supply

Availability driven by the hydrological cycle and infrastructure

Consumptive
Non-consumptive use
Water Accounting: A simple idea to track a complex system

Simple rules for Water Sustainability

1. Water Accounting (sources, users, consumptions, re-uses)

2. Setting the limits of consumption (overall, by allocation; balancing water in & out)

3. Adopt all measures to maximize the benefit of each drop of water (e.g., WP, HiTech, governance, etc.)
All water flows are embedded in drainage basins
creating interdependencies between uses and users
Global water partnership (2000) defines IWRM –

“IWRM is a process, which promotes the coordinated development and management of water, land and related resources, in order to maximize the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystem.”
IWRM

• Water Resource Management of a river basin requires monitoring
  – water availability and
  – water demand

• To monitor water availability and demand:
  – Accurate identification and delineation of catchment and river channels
  – Characteristics of the basin – soil and vegetation, lakes and reservoirs, aquifer/groundwater storage
  – domestic, agricultural, and industrial within the basin

• Organized data and information at river basin level are key factor in order to implement Integrated Water Resource Management
Water Accounting: A multi-stakeholders platform

Water managers
Farmers
Irrigation specialists
Mayors
Lawyers
Energy utilities
Environmentalists
Industry representatives

Data Democracy
Standardized Framework
River basin reports
Data requirements

- To manage water resources you need to know
  - How much water is available
  - How much is being used and by which sector
  - Where is the water used
  - How efficient is water being used
  - ...

Requiring spatial disaggregated data on water availability and utilisation
Water Accounting is a tool for long-term planning.

Source: Tapi River Basin Management Plan
Session 1: Water Accounting Principles and examples from past applications

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What can I do with Water Accounting?

How can WA+ support IWRM?

**What types of Water Accounting Systems exist?**
The WA+ is a WA system based on Remote Sensing data

Examples
Main Differences between WA frameworks

- Scale of application
- Type of data used
- Overall approach: what are they tracking and how
Main Categories of WA frameworks

Two main categories:

**FLOW ACCOUNTING:** tracking and accounting actual flows, deliveries, and abstractions
focusing mostly on blue water in cross-sectoral context

**DEPLETION ACCOUNTING:** focusing on water consumption with a landscape prospective

depleted water: ET, sinks, water in products
Consumptive use of water

Depletion accounting can also include the concept of **non-recoverable** or **non-utilizable** water.
Examples of consumptive use of water

- Environmental flow
- Crop transpiration
- Storage change
- Irrigation losses
- Downstream releases
- Interception evaporation
- Drainage
- Soil/water evaporation

Non-consumptive vs. Consumptive Use
Non-beneficial vs. Beneficial
History of Water Accounting Frameworks

- Irrigation efficiency
- AQUASTAT
- IWM
- ICID
- SEEA
- AWAS
- WA+

Legend:
- Flow accounting
- Depletion accounting

Scale of application:
- Agricultural systems
- Administrative (country)
- River basins
Overcoming data issues

Use of remote sensing data, open source models and global datasets

Advantage for us:
- data is available near-globally
- data is available in a predictable manner

Advantage for stakeholders:
- accounts are reproducible, based on open source code and data
Opportunities and limitations for using RS data for WRM&P

- In last decade reliability of RS data for WRM has improved significantly
- Continuous data set for various water resources related data sets (P, ET) for 10+ years
- Provides estimation of water consumption of largest water user (agriculture)
- Provides spatial information

But

- Need for adjusting hydrological models for incorporating water consumption data
- Requires ground validation data
- Long time series missing (>30 year) needed for trend analyses
- Methodology for scenario assessments (eg climate change etc) to be developed
- Water quality not well presented
Water Accounting Plus (WA+) – a water accounting procedure for complex river basins based on satellite measurements

P. Karimi¹,², W. G. M. Bastiaanssen¹,³, and D. Molden⁴

¹International Water Management Institute, Battaramulla, Sri Lanka
²Faculty of Civil Engineering and Geosciences, Water Management Department, Delft University of Technology, Delft, The Netherlands
³eLEAF Competence Centre, Wageningen, The Netherlands
⁴International Centre for Integrated Mountain Development, Kathmandu, Nepal
Water Accounting Plus (WA+)

Developed by IHE Delft in partnership with IWMI and FAO

- Geographical domain: river basin
- Combination of flow and depletion accounting
- Data acquisition
  - Open access spatial data bases and remote sensing data
  - Other open access data and information
  - Validated using ground observations and literature values
- Data analyses
  - Standardized analyses
  - Using open access programming tools and scripts (python, QGIS)
- Reporting
  - Standardized sheets, maps, tables and graphs
WA+ attempts to make WA scalable, spatially explicit, and temporally detailed.
Water Accounting Plus (WA+): using RS for water resources management

Rainfall

Evapotranspiration

Land use

Soil Moisture

Water Levels

Groundwater

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Rainfall, GPM: NASA Goddard Space Flight Center from Greenbelt, MD, USA [Public domain]
Evapotranspiration, and biomass WaPOR: FAO, IHE-Delft. WaPOR quality assessment
Water Accounting Plus (WA+)

Finger diagram ➔ thematic accounting sheets
Water Accounting Plus (WA+): river basin management options

- Modify water flows
  - Diversions
  - Retentions
  - ....

- Modify land use practices
  - Cropland
  - Urban
  - Forests
  - ....

Protected Land Use

Utilized Land Use

Modified Land Use

Managed Water Use
Water Accounting Plus (WA+): concepts of green and blue water

**Global water use**

Rainfall (thousands of cubic kilometers per year)
- **110**
- **100%**

Landscape **56%**
- Rainfed agriculture **4.5%**
- Crops livestock
- Crops livestock aquaculture
- Irrigated agriculture **0.6%**
- 1.4%

Green water
- Soil moisture from rain

Blue water
- Rivers
- Wetlands
- Lakes
- Groundwater
- Water storage
- Aquatic biodiversity
- Fisheries
- Cities and industries **0.1%**
- Open water evaporation **1.3%**

Ocean **36%**
General overview at river basin scale of
water availability vs water consumption
exploitable flows
manageable vs unmanageable flows
over-exploitation
green and blue water
Examples of the application of WA+ in India

Results from a recent ADB funded project
## Case Study: 3 Krishna sub-basins in Karnataka

![Map of the Krishna sub-basins in Karnataka](image)

<table>
<thead>
<tr>
<th>Sub-basin</th>
<th>Area in Karnataka (km²)</th>
<th>% area of Krishna basin in Karnataka</th>
<th>Average elevation (m) (min and max)</th>
<th>Average yearly rainfall (mm/yr), CHIRPS (2006-2018)</th>
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<tbody>
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<td>15,829</td>
<td>13.93%</td>
<td>530 (308-796)</td>
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<td>K3: Gatprabha</td>
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<td>6.02%</td>
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## Data Collection

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Data Validation and Analysis

CHIRPS data validated with 139 stations

Monthly average Precipitation [CHIRPS], K2

Monthly average 2007-2019

→ strong seasonal variation

<table>
<thead>
<tr>
<th>Dataset</th>
<th>Average NS</th>
<th>Average Pearson Coefficient</th>
<th>Average Relative Bias</th>
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<td>0.48</td>
<td>0.78</td>
<td>0.71</td>
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</table>
The 3 sub-basins are highly modified by human activity.

2010 → 2018

Cultivated area –16.5% (especially double and triple crops)
SSEBop was the only RS open access product available in recent years in India at the time of this study. Low values of ET (100-300 mm/yr) seems too low for this climatic zone (up to 600 mm/yr rainfall).

→ Additional validation required!
Data Selection: RS yearly water balance v.s. in-situ measurements

We need to know the physical boundaries of the watersheds, and inflows and outflows.

Nine stations:

\[
\frac{\Delta S}{\Delta t} = P - ET - Q_{out} + Q_{in}
\]

10 year period
More in-depth analysis at Tinthini station

No significant long-term trend in storage change was observed by GRACE (slightly negative)

Largest watershed

The water balance computed with CHIRPS data has a closer match to the observations
Water Yield (P-ET)

$P > ET \rightarrow \text{runoff generation (blue)}$

$P < ET \rightarrow \text{net consumption (red)}$

Most of the runoff is generated in the upstream mountainous areas.

Agricultural areas and reservoirs are net consumers.

The long-term average of $P-ET < 0$ in K2 and $P-ET > 0$ in K3 and K4.

$\rightarrow$ K3 and K4 are generating water, part of which is then consumed in K2.

- **Inflow**: 17.6 km$^3$/yr
- **Storage Change**: -1.7 km$^3$/yr
- **Total ET**: 9.9 km$^3$/yr
  - **Rainfall ET**: 6.7 km$^3$/yr
  - **Incremental ET**: 3.2 km$^3$/yr
- **Outflow**: 13.5 km$^3$/yr
  - **Dry weather outflow**: 4.6 km$^3$/yr
  - **Wet weather outflow**: 18.4 km$^3$/yr
- **Available**: 20.6 km$^3$/yr
- **Utilized flow**: 2.1 km$^3$/yr

K2 15,800 km$^2$
Sheet 1: Resource Base (km³/year)

Basin: K2
Period: 2010-2017
K2: the available water in the basin is 8-10 times the utilized flow

High water availability because of inflows.

The available water has a high inter-annual variability (11-26 km$^3$/year)

K4: the available water in the basin is 2-3 times the utilized flow

During dry years most of the available water is utilized
K2: storage change monthly scale

K2 as the other two basins has a strong seasonal variability → monsoon

Delicate balance
Evapotranspiration
Beneficial and non-beneficial ET inter-annual variability

Non-beneficial fraction is increasing mainly due to increased soil water evaporation

→ More efficient irrigation techniques should be considered
The agricultural sector is responsible for 80% of the beneficial consumption.
### Biomass Production and Biomass Water Productivity

#### K2 2015-2016

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<th>Rabi</th>
<th>Zaid</th>
<th>Double/Triple Crop</th>
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#### K2 2016-2017

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<td>1.70</td>
<td>2.27</td>
</tr>
</tbody>
</table>

#### K2 2017-2018

<table>
<thead>
<tr>
<th></th>
<th>Kharif</th>
<th>Rabi</th>
<th>Zaid</th>
<th>Double/Triple Crop</th>
<th>Forest Plantation</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>ET</strong></td>
<td>0.77</td>
<td>0.19</td>
<td>0</td>
<td>1.95</td>
<td>0.01</td>
</tr>
<tr>
<td><strong>GBP</strong></td>
<td>3467</td>
<td>7757</td>
<td>624</td>
<td>7535</td>
<td>4656</td>
</tr>
<tr>
<td><strong>GBWP</strong></td>
<td>1.09</td>
<td>3.00</td>
<td>0.73</td>
<td>1.38</td>
<td>1.65</td>
</tr>
</tbody>
</table>
Biomass production and biomass water productivity

Kharif 2015-2016 (May → October)

Higher productivity zones in the upstream areas → water availability
Biomass production and biomass water productivity

Rabi 2015-2016 (Nov → Apr)

Similar patterns
→ K4 is more productive
Than the other two basins
Conclusions and recommendations

• We have analysed three basins (K2, K3, K4) using RS data in a 8 year period 2010-2011 → 2017-2018

• The three basins are highly modified by human activity (agriculture)

• Monsoon climate and high spatial variability of rainfall

• The upstream areas generate most of the runoff while agriculture and reservoirs are net consumers

• P-ET is negative in K2 and positive in K3 and K4
  → K3 and K4 generate water, part of which is then consumed in K2
Conclusions and recommendations

• The three basins are highly dependent on upstream flows (72% of the available water resources in K2). Evaluation of scenarios where inflows are reduced should be tested.

• There is a strong seasonal variability due to the monsoon climate. The storage change (both surface and groundwater) should be carefully monitored at monthly/seasonal scale.

• The amount of non-beneficial water consumption is high in all basins (up to 70% of the total ET) → unproductive soil evaporation. Measures limiting soil evaporation should be considered.
Conclusions and recommendations

• Additional validation and a field survey should be carried out for evaluating the WA+ results and for improving accuracy of the land use map.
Thank you for your attention!

Website: https://wateraccounting.un-ihe.org/

Open Source software on GitHub: github.com/wateraccounting
References


