Virtual Water Values (ViWA)

GROW – Collaborative Project ViWA:
Multiscale Monitoring of Global Water Resources and Options for their Efficient and Sustainable Use
The collaborative project ViWA is sponsored by the Federal Ministry of Education and Research (BMBF) as part of the funding measure „Water as a Global Resource“ (GRoW) in the framework program FONA (Research for Sustainability).
ViWA - the point of departure

- 96% of today’s water use is through food and energy production in agriculture. Water use efficiency links food and energy production to water consumption (water-food-energy nexus).

- Sustainable development postulates that natural resources, like water, be used with the highest possible sustainable efficiency; globally – regionally – locally.

- The question for ViWA therefore is not - “how much virtual water is used by agriculture” but - “how can the water footprint of crops be made more efficient and sustainable”
ViWA – research goals

• to develop a new real time monitoring/modelling system for global agricultural water use efficiency (WUE) and sustainable water availability based on the latest COPERNICUS Sentinel satellite data streams,

• to simulate impact scenarios of agricultural WUE on global agricultural trade through coupling DART-WATER (CGE-model) and PROMET (biophysical model) to identify trade options that favor more sustainable water use and

• to carry out a sustainability evaluation of global (mainly agricultural) and regional water use and to develop indicators for unsustainable water use, which can continuously be monitored globally with high resolution.
ViWA concept – global, regional ...

Key issues global:
- Monitor Actual Water Use Efficiency of Agriculture
- Identify regional water scarcities and lack of efficiency
- Determine unsustainable water use in agriculture
- Analyse trade-offs of options of more efficient water use through global trade

Key issues regional:
- Validate global results in detail
- Analyse real and virtual water flows in detail
- Investigate water resources scenarios and resulting competition among sectors and ways to solve conflicts
- Assess sustainability of water uses

Global
- Danube 817,000 km²

Zambezi
- 1,390,000 km²
...and local: Time Series of Sentinel 2 Observations

- Near St. Louis (USA)
- Near Toungo (Nigeria)
- Near Nanchang (China)
- Near Albacete (Spain)
Hi-res global meteorological model drivers

ERA INTERIM 50 km dynamically downscaled to 12.5 km resolution
DART-WATER- General Computable Equilibrium global trade model and its coupling with PROMET

Exogeneous      Endogeneous
Population growth, Consumption patterns, Demography, Land regulations, Technological progress, Economic policies

Demand          Supply
Price & quantity
Marginal profitability of crops, Cultivated area
Crop allocation (profit maximisation)
Agro-economic yield

Change in agricultural productivity

Capital, Labour, Land, Water Intermediates

PROMET
Natural conditions, Climate
Yield, water content, water use efficiency
Land availability
Land regulations

DART-WATER

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Environmental Sustainability Assessment

International regulations + further goals

Standards classified by legitimacy

e.g.: Minimum water supply to sustain ecosystems’ functions (ref. Watercourse Convention, CBD, Ramsar Convention)

Literature review

Measuring

Quantitative indicators
  • Domestic water use
  • Environmental Flow Requirements

Geodata

Assessment

Hot Spots & Cold Spots

Scenario Modeling

Scenario analysis

Change of sustainability

Governance analysis

Recommendations

• Crop management
• Protection of vulnerable habitats
From global to regional to global again

ViWA results we will show:

• Example of simulations of 291 global 1 km simulations of agricultural management options carried out using approx. 5 mio CPU-hours on the High Performance Computing system SuperMUC

• Example of Sentinel satellite data and model analysis in Saxony and Germany

• Example of water-food nexus analysis in the Danube pilot catchment with special emphasis on impact of irrigation
Global high-resolution ensembles: Example Maize LAI

- = Maize
- = standard
- = rainfed
- = 30 arcsec ~1km
- = 1 h

290 more movies could follow

01/10/2016
Regional: The Danube Basin subset: Maize LAI

- = Maize
- = standard
- = rainfed
- = 30 arcsec ~1km
- = 1 h

Leaf Area Index

15/04/2017
Regional: The Danube Basin subset: Maize Yield

Yield (t/ha)

Evapotranspiration, soil moisture, water stress etc. are also available globally
Regional: The Danube Basin subset: Maize Yield

Evapotranspiration, soil moisture, water stress etc. are also available globally.
Simulated Yield [t/ha]

Statistics 2017: 9.65 t/ha

- 2017: Average 9.45 t/ha
- 2018: Average 4.65 t/ha

Simulated WUE [kg/m³ ET]

- Sentinel-2 tile of July 3rd 2018 with a subset showing one selected maize pixel and its LAI developments

Chemnitz

Leipzig

Meißen
Winter Wheat: predicted Yields of Drought Year 2018

Yield Anomaly Prediction on the States Level

Yield Anomaly 2018:
Sentinel-2/PROMET prediction 2018

Yield Anomaly 2018:
-35% -25% -15% -5% 5%

Yield Anomaly 2018:
preliminary official
statistics
2018

Yield Anomaly 2018:
-15%
preliminary official
statistics
2018

Yield Anomaly 2018:
-35%
Simulated aver. ann. Irrigation Demand 2015-2017

- **Surface water?**
  - Extract irrigation water from closest extraction point in the river network

- **Groundwater?**
  - Extract irrigation water from the groundwater underneath the pixel

<table>
<thead>
<tr>
<th>Irrigation Water [mm/year]</th>
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<tr>
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<tr>
<td>90</td>
</tr>
<tr>
<td>180</td>
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</tbody>
</table>
Simulated aver. annual Irrigation Demand 2015-2017

Surface water?
Extract irrigation water from closest extraction point in the river network

Groundwater?
Extract irrigation water from the groundwater underneath the pixel

Marginal Profit of Maize Irrigation  
Danube Basin 2001-2010

$\Delta$ Yield (t/ha) = $4.1286 \ln(x) - 16.911$

$R^2 = 0.9354$

Marginal Profit (€/hectare/mm/season)
River: 66%  
Storage: 33%

**Sustainability Indicators e.g.:**
**Environmental Flow Requirements (EFR)** – water that needs to flow from each pixel in the rivers and lakes to ensure healthy aquatic ecosystems
EFR = 60% of mean Discharge (high sustainability)
Irrigation from groundwater? Towards global groundwater models

Integrated results

Irrigating maize would mean to the Danube:

- WUE increase from 1.8 to 2.7 kg/m³
- ~30 Million t more maize harvested
- +5.3 Billion m³ water transpired by maize
- ~5 Billion € plus in revenue
- Ecology (EFR, Groundwater etc.)?

• New **(efficient) approach** to establish regional scale groundwater models worldwide.

• Groundwater abstractions may decrease regional groundwater levels by a few meters (0.5 – 5 m), but the **regional GW response might be observable only after long time.**
WUE of Agriculture in the Danube (2015-17)

WUE of Agriculture in the Danube (2015-17)

= Realistic crop mix
= Realistic
= Rainfed

Water use efficiency [kg/m³]
Back to the Global Picture: Hot- and Cold-Spots of WUE

- Maize
- Realistic
- Rainfed
Back to the Global Picture: Hot- and Cold-Spots of WUE

- Maize
- Realistic
- Irrigated

Water use efficiency [kg/m³]
ViWA – next steps:

• Fully develop DART-Water to include virtual water value in global trade, couple with PROMET, develop and explore scenarios to foster global improvements in agricultural WUE

• Integrate Sentinel satellite observations and ensemble simulations to complete the WUE monitoring system

• Further develop Danube case (hydropower, thermal power, industry, households) and develop and use sound indicators for sustainable water use in the Danube Basin

• Extend approach to the Zambesi Basin
By comparing modelled vegetation growth with Sentinel Earth Observation data the most realistic scenario can be determined among the simulations contained in the ensemble.

LAI simulated for different scenarios on each pixel
Local: Dynamic Yield-Estimation - Filderstadt 2018

Winter Wheat Pixels

Temporal Development of observed Leaf Area Index (LAI)

- 7.92 t/ha
- 10.25 t/ha
- 4.88 t/ha

Sentinel 2A, 14.02.2018

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