REDUCING THE WATER FOOTPRINT OF THE GLOBAL COTTON-TEXTILE INDUSTRY TOWARDS THE UN-SDGs

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MID-TERM CONFERENCE AT UNIVERSITY OF AGRICULTURE, FAISALABAD
COOPERATION PARTNERS
# COTTON-TEXTILE VALUE CHAIN

<table>
<thead>
<tr>
<th>Population</th>
<th>Germany</th>
<th>Pakistan</th>
</tr>
</thead>
<tbody>
<tr>
<td>Population</td>
<td>82 million</td>
<td>208 million</td>
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<thead>
<tr>
<th>Cotton Production</th>
<th>-</th>
<th>1.8 million tons</th>
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<thead>
<tr>
<th>People employed in Cotton Textile-Retailing Value Chain</th>
<th>94‘000</th>
<th>&gt; 25 million</th>
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<thead>
<tr>
<th>Import of Textiles and Clothing</th>
<th>42 Billion EUR (1.3 Billion EUR directly from Pakistan)</th>
<th>-</th>
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<tr>
<th>Turnover of Textile Retailing Business</th>
<th>63 Billion EUR</th>
<th>-</th>
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<table>
<thead>
<tr>
<th>Target</th>
<th>Germany</th>
<th>Pakistan</th>
</tr>
</thead>
<tbody>
<tr>
<td>6.1.1 Population using safely managed drinking water</td>
<td>99.2 %</td>
<td>35.6 %</td>
</tr>
<tr>
<td>6.3.2 River water bodies with good ambient water quality</td>
<td>35.1 %</td>
<td>No data</td>
</tr>
<tr>
<td>6.4.2 Level of water stress</td>
<td>41.5 %</td>
<td>102.5 %</td>
</tr>
<tr>
<td>3.9.2 Mortality due to unsafe water and sanitation per 100,000 population</td>
<td>0.6</td>
<td>19.6</td>
</tr>
<tr>
<td>2.1.1 Prevalence of undernourishment</td>
<td>&lt;2.5%</td>
<td>19.9%</td>
</tr>
</tbody>
</table>
WASTEWATER TREATMENT AND WATER QUALITY

Due to public pressure, brands are increasingly demanding their producers to comply with environmental standards.
PROJECT GOALS

1. Make the water footprint a meaningful steering indicator for decision-makers, retailers & consumers
2. How water-intensive is the Cotton-Textile Value Chain really? From inventory analysis to impact assessment in Punjab
3. How to improve: Five demonstration projects
4. Scenarios: consistent options for intervention given the current economic and institutional framework
5. Contribution towards UN-Sustainable Development Goals
6. Support German retailers & consumers in sustainable consumption
## WATER FOOTPRINT AS A STEERING INDICATOR

<table>
<thead>
<tr>
<th>Water Footprint Methodology</th>
<th>Policy Scenarios</th>
<th>Contributing to UN-SDGs</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Inventory Analysis</strong></td>
<td><strong>Impact Assessment: Cause-Effect Chains</strong></td>
<td><strong>Options for WF Reduction</strong></td>
</tr>
<tr>
<td><strong>Human Health</strong></td>
<td>Water Scarcity</td>
<td><strong>Demonstrations:</strong></td>
</tr>
<tr>
<td></td>
<td>Water Pollution</td>
<td>1. Advanced irrigation techniques &amp; scheduling</td>
</tr>
<tr>
<td><strong>Ecosystem Damage</strong></td>
<td>Water Scarcity</td>
<td>2. Textile machinery</td>
</tr>
<tr>
<td></td>
<td>Water Pollution</td>
<td>3. Advanced dyestuff</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4. Wastewater treatment</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5. Monitoring and pollution control</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
## IMPACT ASSESSMENT: CAUSE-EFFECT CHAINS

<table>
<thead>
<tr>
<th>Human Health</th>
<th>Water Scarcity</th>
<th>Water Pollution</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(CE1) Impact of water scarcity on loss of yield and malnutrition</td>
<td>(CE2) Impact of water pollution on drinking water quality</td>
</tr>
<tr>
<td>Ecosystem Damage</td>
<td>(CE3) Impact of water scarcity on damage to freshwater ecosystems</td>
<td>(CE4) Impact on river water quality and toxicity to aquatic ecosystems</td>
</tr>
</tbody>
</table>

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(M1) SATELLITE REMOTE SENSING


- MODIS NDVI: 250 m resolution
- Sentinel 1 & 2: 20 m resolution
- Ground truthing: 1400 locations
- Both unsupervised and machine learning techniques

Cotton in Punjab province:
2.35 ± 0.21 million ha
(47% of cultivated irrigated land)

Basemap: OpenStreetMap
(M6) TEXTILE MILLS AND WASTEWATER IN LCC AREA

- 85 Textile processing mills in larger Faisalabad, approx. 10 with installed wastewater treatment
- Central Drains
(M5) COTTON FARMERS IN WARABANDI SYSTEM
FACE-TO-FACE INTERVIEWS WITH 152 + 69 FARMERS

<table>
<thead>
<tr>
<th></th>
<th>Average</th>
<th>(Range)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>42</td>
<td>(19 - 80)</td>
</tr>
<tr>
<td>Schooling</td>
<td>10 years</td>
<td>(0 – 19)</td>
</tr>
<tr>
<td>Land ownership</td>
<td>2 ha</td>
<td>(0 – 40 ha)</td>
</tr>
<tr>
<td>Net income</td>
<td>1768 €/a</td>
<td>(177 - 42440 €/a)</td>
</tr>
<tr>
<td>Water shortage</td>
<td>70% experience water shortages (mainly April/May and winter)</td>
<td></td>
</tr>
<tr>
<td>Water theft</td>
<td>26% complain when upstream farmers use more water than allowed in Warabandi system</td>
<td></td>
</tr>
<tr>
<td>Raw Cotton Yield</td>
<td>2499 kg/ha ± 1500 kg/ha</td>
<td></td>
</tr>
<tr>
<td>Groundwater abstraction in Kharif</td>
<td>184 mm ± 27 mm</td>
<td></td>
</tr>
</tbody>
</table>

Zimmermann et al. (2018) and Usman et al. (2017)
(M3) HYDROLOGIC SWAT MODEL IN LCC AREA
CROP IRRIGATION IN KHARIF SEASON (MEAN 2004-2013)

Precipitation
381 mm

ET_{act}
550 mm

Precipitation
374 mm

ET_{act}
782 mm

Punjab Irrigation Department:
Canal Entitlement
320 mm

Net irrigation demand
406 mm

Depletion of soil moisture: 15 mm

GW pumping
36 mm

Percolation
135 mm

GW pumping
199 mm

Percolation
97 mm

Net irrigation demand
519 mm

Depletion of soil moisture: 82 mm

Canal and Field Application Losses

Becker et al. (2019)
(M3) DEMAND FOR COTTON IRRIGATION

Irrigation Rate [mm]

Apr | May | Jun | Jul | Aug | Sep | Oct

- Canal Water Entitlement by Punjab Irrigation
- Additional Irrigation Demand (Groundwater Abstraction)
HYDRAULIC GROUNDWATER MODEL (FEFLOW)
GROUNDWATER DEPLETION?
(TRENDS 2005 – 2015)

Water table trend [cm/season]
- Raising (75 to 15 cm)
- Raising (15 cm to 0 cm)
- Constant
- Falling (0 to 15 cm)
- Falling (15 to 75 cm)
(M4) GROUNDWATER QUALITY

Groundwater Quality:
Electrical Conductivity [µS/cm]

- 0 - 750
- 750 - 1500
- 1500 - 2250
- 2250 - 3000
- 3000 - 5000
- 5000 - 21750

Schelter et al. (2019)
(M7) WATER USE OF EXHAUST DYEING MACHINERY
THIES iMASTER OPERATED IN PAKISTAN (N=7-9)

Freericks, THIES (2018)
(M6) WASTEWATER OF TEXTILE PROCESSING PLANTS
RESULTS OF 9 COMPANY SURVEYS

Box-Plot of Wastewater Compositions (n=9)
Pakistan National Emission Standard
Zero Discharge of Hazardous Chemicals (ZDHC) - Foundational
Five Demonstration Projects: How to improve
## (D1) IMPROVED WATER PRODUCTIVITY

<table>
<thead>
<tr>
<th>Method</th>
<th>Yield [t/ha]</th>
<th>Efficiency</th>
<th>Productivity [kg raw cotton / m³ gross irrigation]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Furrow full irrigation</td>
<td>2.95</td>
<td>64%</td>
<td>0.48</td>
</tr>
<tr>
<td>Drip irrigation</td>
<td>3.25</td>
<td>90%</td>
<td>0.68</td>
</tr>
<tr>
<td>Furrow 10% deficit</td>
<td>2.64</td>
<td>71%</td>
<td>0.48</td>
</tr>
<tr>
<td>Furrow 20% deficit</td>
<td>2.35</td>
<td>80%</td>
<td>0.48</td>
</tr>
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</table>

Irrigation experiments with UAF at WMRC

Area supplied by the Mungi Distributary Canal

Tischbein (2018)
(M2) FLEXIBLE IRRIGATION SCHEDULING IN MUNGI

Options evaluation by FAO-AquaCrop Model

Inflow to Mungi
9 May to 11 Nov 2017: 370 mm

Effective precipitation
184 mm

ET<sub>act</sub>
600 mm

Furrow, 7-d Warabandi

Raw cotton yield: 2.2 t/ha
Net irrigation: 352 mm
Gross productivity: 0.51 kg/m<sup>3</sup>

Depletion of soil moisture: 64 mm

GW pumping
167 mm

Percolation:
185 mm

GW replenishment:
18 mm

Tischbein (2018)
(D2/D3) WATER-EFFICIENCY IN EXHAUST DYEING

From 69 to 52-62 L/kg for black shade dyeing by THIES online process control and down to 38 L/kg by CHT advanced dyestuff 4SUCCESS

Freericks, THIES (2018)
(D4) ANAEROBIC TREATMENT OF DESIZING WASTEWATER

63% COD reduction plus biogas production 0.33 m³/kg COD
(D4) ANAEROBIC TREATMENT OF DESIZING WASTEWATER

63% COD reduction plus biogas production 0.33 m³/kg COD

Full Aerobic Effluent Treatment Plant for Mixed Textile Wastewater

Aerobic Effluent Treatment Plant after Anaerobic Pretreatment of Desizing Wastewater

Biogas production: +60 PKR/m³ wastewater

Saved energy: +20 PKR/m³

Operation and Maintenance: -30 PKR/m³

Baumann et al. (2018)
POLICY SCENARIOS FOR REDUCING THE WATER FOOTPRINT TOWARDS ACHIEVING UN-SDGs
GREEN AND BLUE WATER CONSUMPTION

Water consumption in cotton farming (production weighted average):

- 2318 L blue/kg raw cotton
- 1723 L green/kg raw cotton

higher than previous literature data for Punjab (Mekonnen & Hoekstra, 2011)

1898 L blue water/kg
1122 L green water/kg

Finogenova et al. (2018)
WATER SCARCITY ASSESSMENT

Cotton growing season

Finogenova et al. (2018)
WATER SCARCITY FOOTPRINT (WSF)

Water Scarcity Footprint (WSF) (production weighted average):

2269 L deprived/kg raw cotton

above results obtained using water scarcity factors on a country and/or watershed level (Berger et al., 2014, 2018)

1594 L deprived/kg raw cotton

Finogenova et al. (2018)
GREY WATER FOOTPRINT

Cotton Farming
• Calculation based on $\text{NO}_3^-$ leaching from fertilizers (depend on threshold, leaching rate, and calculation method applied)
• Pesticide toxicity: impact assessment on human health and ecosystems under way

Textile Wastewater
• Calculation based on most penalizing water quality parameters (BOD or COD)
• Heavy metals toxicity: impact assessment under way

Product Environmental Footprint (PEF)
Water Footprint Network (WFN)
Zero Discharge of Hazardous Chemicals, foundational (ZDHC-f)
National Environmental Quality Standards of Pakistan (NEQS)
## POLICY SCENARIO: “S2 MANY PENNIES MAKE A DOLLAR”

<table>
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<tr>
<th>Options for intervention</th>
<th>WF</th>
<th>UN-SDGs Indicators</th>
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<tr>
<td><strong>Cotton</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Promotion of flexible irrigation scheduling within Warabandi system</td>
<td></td>
<td>6.4.2 (+) 2.1.1 (+)</td>
</tr>
<tr>
<td>• Promotion of advanced irrigation techniques (e.g., drip)</td>
<td></td>
<td>2.3.1 (+)</td>
</tr>
<tr>
<td><strong>Textile</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Promotion of water-efficient machinery in textile processing</td>
<td></td>
<td>7.b.1 (+)</td>
</tr>
<tr>
<td>• Promotion of advanced dyestuff and process chemicals</td>
<td></td>
<td>6.4.1 (+) 12.4.1 (+)</td>
</tr>
<tr>
<td><strong>Wastewater</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Installation and operation of effluent WWTPs in all large- and medium-size textile finishing plants</td>
<td></td>
<td>6.1.1 (+) 6.3.1 (+) 3.9.3 (+) 7.3.1 (-)</td>
</tr>
</tbody>
</table>
PRELIMINARY CONCLUSION & NEXT STEPS

1. WF as a Steering Indicator
   • Installation of **functioning wastewater treatment** has a main impact on reducing grey water footprint
   • For **achieving UN-SDGs**, other measures are also important

2. Workshops, Trainings, and Roadmap IWRM
   • **Punjab irrigation reform**: Institutional gaps in water allocation prevail. Monitoring and sanctioning hardly exist
   • **Environmental authorities** are currently not in a position to assure compliance with existing wastewater standards

3. Awareness Raising: Brands, Retailers, and Consumers
   • Internet-based WF tool
   • Integration of the WF concept into **textile labels**?
   • **12-min Documentary Video** available on YouTube
The project is funded by the Federal Ministry of Education and Research (BMBF) within the framework of the funding measure “Water as a Global Resource (GRoW)”

www.inocottongrow.net