InnoCotton GROW

InoCottonGROW: Innovative impulses reducing the water footprint of the global cotton-textile industry towards the UN Sustainable Development Goals

Reducing the water footprint of the global cotton-textile industry towards the UN Sustainable Development Goals

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ABSTRACT

InoCottonGROW aims at contributing to sustainable water use along the entire cotton-textile value chain „from cotton field to hanger". In case studies in Pakistan, a major supplier of German textile demand, our goal is to advance the water footprint (WF) concept to become a meaningful regional steering instrument for national decision makers in managing scarce water resources and for German consumers in making informed choices when purchasing textiles.

In cooperation with Pakistani partners, an inventory analysis of current water consumption and levels of pollution are conducted using multiple methods (M1-M7) in cotton farming and textile industry. The WF approach is extended to a region-specific impact assessment to quantify the impact the cotton-textile industry has on water scarcity, human health, ecosystems, and freshwater resources. Five demonstration projects (D1-D5) assess technical options for WF reduction. Strategies towards a more flexible irrigation scheduling and controlled deficit irrigation allow to increase water productivity, efficient textile machinery and resource-efficient dyestuff reduce water use, and wastewater treatment options improve effluent water quality. While each option is urgently important, from a WF perspective, the installation of functioning wastewater treatment has a main impact on reducing cotton-textiles' WF.

Five scenarios of how the cotton-textile industry can contribute towards achieving the UN-Sustainable Development Goals (SDGs) are discussed. By producing documentary videos, an internet-based WF tool, and assessing integration of the WF concept into textile labels, the project aims at raising the awareness of internationally operating brands, retailers, and German consumers for sustainable consumption. A 12 min video documentary is available on **https://www.inocottongrow.net/**

Figure 1: Anaerobic textile wastewater treatment produces biogas for water heating (© FiW)

INTRODUCTION

Pakistan is the world's fourth-largest producer of cotton. German demand for water-intensive cotton textiles (jeans, T-shirts, towels, and many others) has a major impact on water scarcity and water pollution in the mostly Asian manufacturing countries, where population growth and climate change further exacerbate the water-related challenges. The irrigation of cotton plants as well as dyeing and finishing processes in textile production require large quantities of water. In addition, rivers, soil, and groundwater are polluted by salinization, application of pesticides and fertilizers, and the discharge of untreated textile wastewater. The Indus basin in Pakistan sustains one of the world´s largest irrigation systems. Water is diverted by a hierarchy of 56.000 km of irrigation canals from mains, branch, and distributaries to watercourses for field application. Cotton is grown in Kharif season from April/May to October, with Monsoon rain in July to September. Allocation of irrigation water among farmers is organized by certain formal and informal rules known as the Warabandi system, in which water is allocated proportional to each field size in a strict rotation. Leaking canals, low field application efficiency and water theft results in a head-tail problem leaving the farmer at the tail-end to depend on often saline groundwater that is 15 to 20 times more expensive than canal water due to drilling and pumping costs – mainly cotton farmers since cotton is a comparably drought- and salt-resistant crop. In textile manufacturing, textile finishing is by far the most water-intensive process. Most textile mills operate own groundwater wells for freshwater supply. Only few have functioning wastewater treatment plants installed, and even if installed, activated sludge treatment processes are hardly operated due to high energy costs. Mainly untreated wastewater is thus discharged via open, partly unlined central drains into the river Ravi and Chenab. Percolation of untreated wastewater contaminates downstream ecosystems, groundwater pumped for irrigation, and drinking water supplies.

METHODS

The Lower Chenab Canal (LCC) is the main study area (15,700 km^2, irrigation water entitlement approx. 8 billion m^3/year, 12 million inhabitants). A combination of methods is applied in WF inventory analysis and impact assessment, including (M1) satellite remote sensing, (M2) field experiments and crop-irrigation modelling, (M3) hydrologic and (M4) hydraulic modelling, (M5) survey on the institutional framework of water use in cotton farming, as well as (M6) textile company audits, and (M7) laboratory and full-scale dyeing trails in textile finishing. Five demonstration projects illustrate strategies for WF reduction: (D1) flexible irrigation strategies to increase irrigation water productivity, (D2) water-saving textile machineries, (D3) resource-efficient dyestuffs, (D4) textile wastewater treatment by anaerobic treatment of highly polluted wastewater of desizing, (D5) pollutant analysis and regulatory enforcement of wastewater effluent standards.

INTERIM RESULTS AND DISCUSSION

Water Footprint as a Regional Steering Indicator

Regional water consumption of cotton was calculated based on hydrological modelling results (M3 below). In the irrigation subdivision Tarkhani, for example, the green water amounts to 1,681 L and blue water to 2,415 L/kg raw cotton, which is approx. 50% (for green water) and 30% (for blue water) higher than previous literature data for Punjab (Mekonnen & Hoekstra 2011), which do not consider regional patterns in crop evapotranspiration.

A regional Water Scarcity Footprint (WSF) was calculated based on the WAVE+ model (Berger et al. 2018). In Tarkhani, the WSF amounts 2,261 L deprived/kg cotton. The Grey WF was calculated for cotton farming (based on nitrate leaching from fertilizer application) and textile production (based on COD and other wastewater parameters). For the cotton cultivation, Grey WF varies between 1,035 and 4,582 L/kg raw cotton depending on the calculation method (leaching factor, water quality threshold). For the textile production, Grey WF amounts to 1,108 L/kg textile with BOD5 being the most penalizing pollution. For regional impact assessment, four cause-effect chains are considered: (I1) impact of irrigation water use on water scarcity, loss of yield, costs for groundwater pumping, income loss and malnutrition, (I2) impact of irrigation water use on reduced water flow and damage to aquatic ecosystems, (I3) impact of water pollution on human health, and (I4) toxicity to aquatic ecosystems.

Inventory Analysis

(M1) In satellite remote sensing, both unsupervised and machine-learning classification approaches are utilized for land use land cover mapping using MODIS NDVI data at 250 m and Sentinel 1 & 2 data at 20 m spatial resolutions. All major crops of spring (Rabi) and monsoonal autumn (Kharif) cropping seasons including cotton, wheat, rice, and sugarcane are classified from 2005 to 2017. In this period, cotton was grown in Punjab province on 2.35 ± 0.21 million ha (47% of cultivated irrigated land). In LCC cotton is less dominant (15% of irrigated land), grown mainly in the tail end of the irrigation system. Accuracy assessment is performed by using multiple approaches including official crop inventory and own ground-truthing surveying 1,400 locations. Ongoing research estimates cotton yield, crop specific consumptive water use, and irrigation system efficiencies. Analysis and ground-truthing of a study site in Söke, Turkey is conducted for comparison.

(M2) The current practices and techniques in cotton irrigation are analyzed bottom-up from field to farm, watercourse, and distributary canal level in Mungi Disty. In the period mid-May till mid-November 2017, a gross irrigation amount of 370 mm was inflow to Mungi, in addition to 184 mm of effective rainfall. An irrigation scheduling model (FAO-AquaCrop) was used to estimate the crop water demand of cotton considering daily meteo data, soil, crop features, and an irrigation supply interval of 7 days (Warabandi fixed rotation) and an irrigation amount at field level of 358 mm (based on a technical irrigation efficiency of 50% and a groundwater reuse by pumping 90% of the irrigation losses. These simulations lead to a raw cotton yield in the range of 2.2 t/ha which matches yield level in Mungi. Changing the irrigation interval from 7 to a 14-day rotation leads to 40 mm less evaporation losses.

(M3) A hydrological model (SWAT) was set up for the LCC area. Focus was put on modelling the changes of evapotranspiration rates as a proxy for changes in future water demand caused by changing land use patterns, alternative crop management strategies, and climate change scenarios. Remote sensing and ground station evapotranspiration measurements were used to calibrate and validate the model. Results show that optimized irrigation techniques examined in M2 can help to reduce irrigation water demand in LCC area by up to 20%. Reducing water demand by crop shifting according to local climatic patterns and climate change scenarios are currently assessed.

(M4) Groundwater hydraulic head hydrographs of 588 wells suggest that groundwater levels are constant or even rising in the study area for the last decade. Trends of falling groundwater were observed in 33% of the wells, located partly in the tail end of the irrigation system. A groundwater flow model (FEFLOW), considering all major irrigation channels, was set up for the Rechna Doab including LCC. The model utilizes groundwater recharge data of M3, classified land use data of M1, and abstraction rates given by farmer interviews in M5. Budget analysis suggests that leakage from irrigation channels is the largest single contributor to the groundwater balance. A validation of the groundwater model using GRACE satellite data is ongoing.

(M5) A detailed analysis of water laws, rules in use, and everyday practices in the province of Punjab provides a conceptual framework for proposals to improve the water efficiency in irrigation. A survey conducted in 2018 with 150 farmers in three districts in Punjab confirms a deficit in the representation of farmers as well as in communication between different levels of organization. Furthermore, monitoring and sanctioning mechanisms are only marginally applied. Thus, harmonizing formal and informal rules and coordinating responsibilities between different hydraulic levels in Pakistan are most crucial for a sustainable irrigation management.

(M6) Company surveys identified some 85 textile finishing plants in the Greater Faisalabad area, discharging approx. 100 million m^3/year of mainly untreated wastewater via central drains into the rivers Ravi and Chenab. To our information less than ten of these 80 finishing plants maintain activated sludge effluent treatment plants in steady operation.

(M7) The dyestuff chemicals employed, machine types and ages, but also operators´ experience determine the water use and wastewater production in textile finishing. Online log recordings of exhaust dyeing machinery operated in Pakistani companies revealed that dyeing light color shades currently uses 29 to 36 L/kg, dark color 35 to 50 L/kg and extra dark up to 69 L/kg. Laboratory and full-scale black dyeing trials of jersey fabric using advanced dyestuff and optimized processes in Germany show that up to 50% of water use reduction appears possible under certain conditions. Testing methods to assess color hue, strength, and color fastness to washing, rubbing, light and perspiration assured that in most cases product quality was not impaired.

Demonstration Projects

(D1) Improved scheduling strategies and advanced handling of irrigation techniques enabling a higher efficiency, effectiveness, and productivity of irrigation water and salt management are derived and tested at the University of Agriculture Faisalabad (UAF) WMRC test site and considered under real conditions in Mungi Disty. Field experiments consider different irrigation methods (furrow, raised-bed, drip) as well as full and deficit strategies. Experiments show that full irrigation by a drip system enables a yield of 3.25 t/ha raw cotton with an application efficiency of 83% and water productivity of 0.68 kg raw cotton per m^3 gross water input. Furrow irrigation was applied without deficit, and 10% and 20% deficit (related to evapotranspiration). Yields of 2.95, 2.64, and 2.35 t/ha raw cotton and efficiencies at full level of 64%, 71%, and 80% showed that in deficit irrigation lower gross water input (higher efficiency) compensated lower yields. Therefore, water productivity was rather constant at approx. 0.48 kg raw cotton per m^3 gross water input.

(D2/D3) At a textile finishing plant in Lahore, installation of a Thies DyeControl in existing iMaster exhaust dyeing machinery for online opacity measurements of the liquor to optimize rinsing time and number of rinsing baths resulted in a decrease of water use for black shade dyeing from 69 to 52-62 L/kg textile. Overall, a reduction of 10 to 15% of water use for textile finishing seems feasible by installing water efficient textile machinery. Introducing efficient dyestuff have not yet been conducted at any of the Pakistani cooperation partners, suggesting that companies are not yet fully convinced to pay higher prices for dyestuff despite the undisputed water and energy savings demonstrated within laboratory and full-scale demonstrations in Germany.

(D4) A pilot-scale anaerobic treatment of desizing wastewater has been planned, build, shipped, commissioned, tested, and optimized at Kohinoor Mills Ltd. textile factory south of Lahore to demonstrate the effectiveness of anaerobic pretreatment of heavily organically polluted wastewater of the desizing process. During pilot-plant operation a COD reduction of approx. 55.7% was achieved, while biogas at a specific methane yield of 0.25 m^3/kg COD was produced. A highlight was burning the produced biogas to boil a pot of tea in front of the factory employees to proof that wastewater can produce energy (Figure 2). A cost-benefit analysis that was conducted suggests that a projected full-scale anaerobic plant is financially viable given Pakistani energy prices, although payback period of ≥ 16 years is long.

(D5) Multi-parameter groundwater sensors installed at UAF test site monitor percolation under agricultural fields. The process of providing analytical instruments to Punjab authorities indicate that authorities are currently not in a position to routinely measure and thus control existing textile effluent standards. International brands and retailers are the key drivers increasingly mandating improvements of those textile manufacturers which produce for western markets.

CONCLUSIONS & OUTLOOK

InoCottonGROW identified several technically feasible measures to increase the efficiency and productivity of water consumption and to reduce water pollution along the cotton-textile value chain. Combining individual measures to different policy scenarios, including (S1) making the most of the current system, (S2) many pennies make a dollar, (S3) think big, (S4) regional shifting of water or crops, (S5) quality instead of quantity, are compared to a baseline scenario to investigate how implementation of these measures could contribute to achieving selected UN-Sustainable Development Goal targets in Pakistan. The baseline scenario is currently under development considering population growth, climate change, and land use change projections.

Workshops with Pakistani farmers' organisations, textile companies, water boards, and authorities are conducted to discuss policy options for implementation. In May 2018, Pakistani decision makers were invited to Lippeverband in cooperation with the Gesellschaft für Internationale Zusammenarbeit (GIZ) for a knowledge exchange on Integrated Water Resource Management, which is still fragmented in Punjab. A Mid-Term Conference with 100 participants, scientific presentations, training sessions, and policy seminar took place at University of Agriculture Faisalabad in January 2019.

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