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freshwater

Toward sustainable water use in the cotton supply chain

A comparative assessment of the water
footprint of agricultural practices in India



C&A Foundation



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www.waterfootprint.org

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C&A Foundation

C&A Foundation is a private foundation, affiliated with the global clothing retailer C&A. It is working to transform the apparel industry into a fair and sustainable industry that respects the rights of workers, improves livelihoods and the conserves the environment. It collaborates with key partners to achieve the best results and greatest long term impact. From farmers to factory workers, it helps build strong and resilient communities in all the countries we touch.

www.candafoundation.org



CottonConnect was created in 2009 through a collaboration between Textile Exchange, C&A, and the Shell Foundation. It is a pioneering company with a social purpose, delivering business benefits to retailers and brands by creating more sustainable cotton supply chains. CottonConnect works across many cotton sustainability initiatives and standards, with a team of farm experts on the ground in India, China, Pakistan and Peru. It provides tailored support and tools (such as its REEL Cotton programme) for brands and retailers to progress towards more transparent and sustainable supply chains.

www.cottonconnect.org

The results and findings of this report are based on scientific analysis done by Water Footprint Network. All the internal data from C&A and Cotton Connect are provided solely to be used in this report. The partners of the initiative consider it a living document that will be adapted to the circumstances based on new findings and concepts, future experiences and lessons learnt.

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Acronyms

BWS – Blue Water Scarcity

CC – CottonConnect

CWU – Crop Water Use

ET - Evapotranspiration

FAO – Food and Agriculture Organisation

FFB – Farmer Field Book

GMO – Genetically Modified Organisms

MP – Madhya Pradesh (Indian State)

REEL – Responsible Environment Enhanced Livelihoods

UT – University of Twente

WF – Water Footprint

WFA – Water Footprint Assessment

WFN – Water Footprint Network

Units

m³ – cubic metre

L - litre

ha – hectare (100m x 100m)

cm – centimetre

mm – millimetre

t – metric tonne (1000kg)

kg – kilogramme

g - gramme

Executive summary

The textile industry touches everyone's lives through clothing, fabrics and other products, yet it also has a significant impact on the world's resources. Its production relies heavily on water, from raw materials production to the industrial processing stages.

Leading clothing retailer, C&A, aims to transform its supply chain so it can source apparel that is fairly and sustainably produced. It has formed a strategic partnership with the Water Footprint Network to deepen its understanding of water use and pollution in its supply chain. Because it uses a significant quantity of cotton, C&A is focusing on sustainable water use in its cotton supply chain as part of its efforts to reduce its environmental impacts.

The water footprint is an indicator of freshwater use that looks at both direct and indirect water use for any kind of productive activity, e.g., growing cotton, for the products consumed by an individual or group of individuals, or for the activities within a geographic area. It accounts for both water consumption and pollution over each phase of the production process and value chain, and includes three components.

- **The blue water footprint** is the amount of fresh surface or groundwater used to grow a crop or produce goods or services. It is the amount of water evaporated, incorporated into the product or returned to a different location or in a different time period from where it was withdrawn.
- **The green water footprint** is the total rainfall or soil moisture used to grow plants. It is relevant for products that include agricultural crops and wood and other forestry inputs; where it refers to the quantity of water either evapotranspired by plants or incorporated into the harvested crop, or both.
- **The grey water footprint** is a measure of pollution. It is expressed as the volume of water required to assimilate the pollutant load to meet ambient water quality standards. The pollutant that requires the largest assimilation volume is referred to as the critical pollutant and is used to calculate the grey water footprint; if there are both surface and groundwater discharges, the grey water footprint for each discharge is calculated separately.

By measuring the water footprint – and finding out where and when it lands – C&A can see the impact of its water use and take steps to reduce that impact.

The Study: Previous studies by Water Footprint Network identified two areas as supply chain hotspots for the water footprint: water consumption and pollution of raw materials production and the garment processing stage of cotton textile. This current study aims to develop a deeper understanding of water use in the production of cotton in India, one of the world's primary cotton farming areas and a country that experiences water scarcity and degraded water quality. It supports C&A's aims to reduce the water footprint of cotton to levels at or below sustainability benchmarks and to contribute to the overall improvement of water scarcity and pollution in relevant river basins.

Water Footprint Network investigated the link between the water footprint and the various agricultural practices used in cotton cultivation in three states of India during the 2012 – 2013 growing seasons. The practices were conventional, REEL Cotton and organic farming from a sample of 1,144 farms selected across Madhya Pradesh, Maharashtra and Gujarat, India. The main difference between these farming practices relates to chemical inputs. REEL farms are stricter in the use of synthetic chemical pesticides and fertilisers than conventional farms, and organic farms are the strictest on chemical inputs and use more compost, urea, neem oil and organic seeds.

Two aspects of water use were considered:

- the overall pressure on water resources, e.g., the water consumed or polluted per hectare or year, which must be understood in the context of local water availability; and
- the efficiency with which the water is being used, which is related to the productivity of the water, e.g., tonnes of cotton produced for the volume of water consumed or polluted.

This study establishes the relationship between cotton agricultural practices and technologies and the use of water and includes the following steps:

1. Calculating the green, blue and grey water footprint of cotton cultivation using the data collected from representative farms located in the three Indian states of Gujarat, Maharashtra and Madhya Pradesh;
2. Establishing the relationship between cotton agricultural practices and technologies and the green, blue and grey water footprint; and
3. Analysing the potential for water footprint reduction through the transition from one farming practice to another and developing water efficiency benchmarks or targets for reduction.

The findings support previous assessments done by Water Footprint Network; however, this assessment provides a far more detailed analysis, based on farm field data. The best performers of

these farms can shed light on the potential for water footprint reduction and the specific practices that can lead to a more sustainable supply chain.

Findings: Whilst farm performance varies and the results illuminate a number of recommendations for C&A, the overall outcome is that organic farming is the top practice to consider for a long-term strategy – if yields can be increased and farmer income needs met. The report also provides evidence that, in the interim, farms under the REEL Cotton programme are performing well in terms of reduced water pollution, when compared to conventional farming, and have the highest yields overall.

- **Green water footprint:** Cotton production on the farms included in this study is primarily rainfed, resulting in a relatively larger green than blue water footprint per tonne of cotton. REEL farms had the lowest green water footprint, indicating that the land under cultivation is being used more productively. Each hectare of land is producing more cotton.
- **Blue water footprint:** Of the farms sampled in Madhya Pradesh, 96% were irrigated; however, irrigation was only 6% of the total water consumed in growing the crop. Gujarat is the second highest user of irrigation systems across the three practices, with 89% of farms irrigating in 2013; irrigation provided 9% of the total evapotranspiration. Maharashtra is the least reliant on irrigation, with only 30% of the farms irrigating. The average blue water footprint on farms using drip irrigation is 382 m³/ha, whilst those using furrow averaged 427 m³/ha, a difference of 12% in the blue water footprint.
- **Grey water footprint:** The grey water footprint of cotton, when including pesticides, clearly demarcates the three agricultural practices. Conventional agriculture pollutes more than REEL and organic farms are the best performers. Conventional farms of Gujarat generated an average grey water footprint 22 times higher than the state's organic farms per tonne of cotton. Conventional farms of Maharashtra generated a grey water footprint 122 times higher than the state's organic farms. The average grey water footprint per hectare ranges from 496,657 cubic metres in Madhya Pradesh to 4,386 cubic metres in Gujarat. Replicating the good performance of farmers in Gujarat at all the farms in this study would reduce the grey water footprint (pollution) by 88%.
- **Yields:** The cotton yields of the farms included in this study range from a low of 1.06 tonnes/ha for organic cotton in Maharashtra to a high of 3.49 tonnes/ha for REEL farms in the same state. The best performance in terms of yield came from rainfed REEL farms in

Maharashtra followed closely by REEL farms in Gujarat that were irrigated. REEL farms had three times as much yield as the organic farms. This can be due in part to the seeds used on organic farms, which must be organic and may be lower producing seeds than those used on REEL or conventional farms. REEL farms also out-performed the conventional farms with 1.5 times as much yield.

- **Resource efficiency:** When comparing cotton yields to the water consumed or polluted, farming is more resource efficient in Gujarat than in the other two states, whether it is conventional, REEL or organic. The better performance in terms of yield and water footprint of conventional, REEL and organic farms in Gujarat reflects the higher levels of access to resources such as government support, training in best practices, technology, etc. REEL farms in both Gujarat and Maharashtra are resource efficient due to their high yields; organic farms are resource efficient due to less toxic inputs. Increasing the yields on organic farms will move organic farms into the position of best performers.

This study confirms that there are significant water footprint savings possible with changes at the farm level. It is also evident that there are significant variations in performance between farms, even those located in the same areas. The findings clearly indicate that farmers who receive information, training and financial resources perform better. C&A, and other clothing retailers, can use the results of this study to advocate for the agricultural practices used by farmers to be those with the lowest green, blue and grey water footprint, both in terms of the overall pressure on freshwater resources, i.e., the water consumed or polluted throughout the growing season, and the efficiency, i.e., the water consumed to produce a tonne of cotton.

Recommendations: A range of strategic actions can be used to achieve a more sustainable supply chain, from awareness raising to farmer training, from investments in knowledge and technologies at the farm level to joining forces to transform the sector, from establishing policies that secure long term sustainability to disclosing the current state and the pathway to be taken to the desired future condition. In summary, strategic actions are:

- Advocate the impressive results achieved in reducing water pollution levels from organic farming to employees and customers as a way to build support for the transition to sustainable cotton for C&A and other retailers;
- Improve agricultural practices at the farm level such that the green, blue and grey water footprint are reduced and strengthen supportive mechanisms for building farmer capacity, for providing accurate and timely information and for expanding expert knowledge in Water Footprint Assessment and its applications;

- Understand the local context in select priority catchments and contribute to actions that will improve local water conditions;
- Engage with standards organisations, PPPs, river basin organisations and other collective actions to accelerate improvements in the sustainability of cotton production and the local water conditions;
- Encourage coherent and effective regulations, laws and policies that will support progress toward sustainable, efficient and equitable water use and management;
- Support the development of informed communities committed to sustainable cotton through water stewardship, and
- Be open and transparent about the water stewardship journey – where you are now, what you are doing, what you have learned and where you are headed.

This Water Footprint Assessment of cotton farms in India was made possible through funds from C&A Foundation. Given the significant impact the sector has on the world's water resources, C&A's efforts to improve its environmental, social and economic sustainability are to be applauded. The insights this report provides and the strategic actions and investments it recommends will contribute to transforming the sustainability of the textile sector. Along the way, lessons will be learned and an iterative approach to deepening understanding, such that resources are directed in the most beneficial way, should be used. As these changes in cotton farming are implemented in production sites around the world, the cotton supply chain will become more sustainable.

1 Introduction



Organic cotton boll, Vellitiruppur, Erode, Tamilnadu.
Source: Indiawaterportal.org (July, 2012)

1.1 Context

Companies worldwide are recognising that water is an essential ingredient in their business operations and the lack of access to sufficient water quantities and/or degraded water quality is posing a material risk to a growing number of companies. Concern about water is highlighted by a survey of companies conducted by the World Economic Forum in 2015, which identified water crises as the top systemic risk to the global economy in terms of potential impact. In 2016, 40% of those surveyed deemed water crises to be the risk to be most worried about over the next 10 years. A survey of its members by the World Business Council for Sustainable Development indicates that some 70% of its corporate members identify water as a material theme (Vionnet, 2015).

Textiles touch everyone's lives through clothing, fabrics and other products, yet the sector not only has an impact on people's lifestyles, it also has a significant impact on the world's

resources. Its production relies heavily on water, from raw materials to the industrial processing stages. Rising competition for water is already impacting the textile and other sectors and water constraints will increasingly challenge “business as usual”. It is critical for the sector’s long-term viability - and for the health of ecosystems and communities - to understand how water is used at every step of the supply chain and to prioritise actions that will ensure it is used as sustainably as possible.

Half a billion people in the world face severe water scarcity all year round, whilst 4 billion people live under conditions of severe water scarcity at least one month of the year. Nearly half of those people live in India and China.

(Mekonnen and Hoekstra, 2016)

1.1 Cotton and water

Cotton is the most important natural fibre used in the textile sector worldwide. Global consumption of cotton is expected to be 105.5 million bales in 2016/17 (Johnson et al., 2016).

Cotton production takes place in over one hundred countries but has traditionally been concentrated in a few. Over the last three decades, the four leading producing countries have accounted for an increasing share of world production. China, India, the United States and Pakistan accounted for 48% of world production in 1970/71 and 75% in 2009/10. In particular, increases in production in China and India resulted in an increased share of Asia in world production from 35% in 1980/81 to 65% in 2009/10 (Oerklion, 2010).

Currently around 70% of the world's cotton is grown in India, China, USA and Pakistan, with over one quarter of cotton production occurring in India (USDA, 2016). Many of the areas in which cotton is grown are water scarce.

Cotton consumption is responsible for as much as 2.6% of global water use (Hoekstra and Chapagain, 2008). From field to end product, cotton passes through a number of distinct

production stages in different locations and with different impacts on water resources in the countries where it is grown and processed. There are two major stages in the production chain: the agricultural stage (growing the cotton) and the industrial stage (processing of seed cotton into final cotton products).

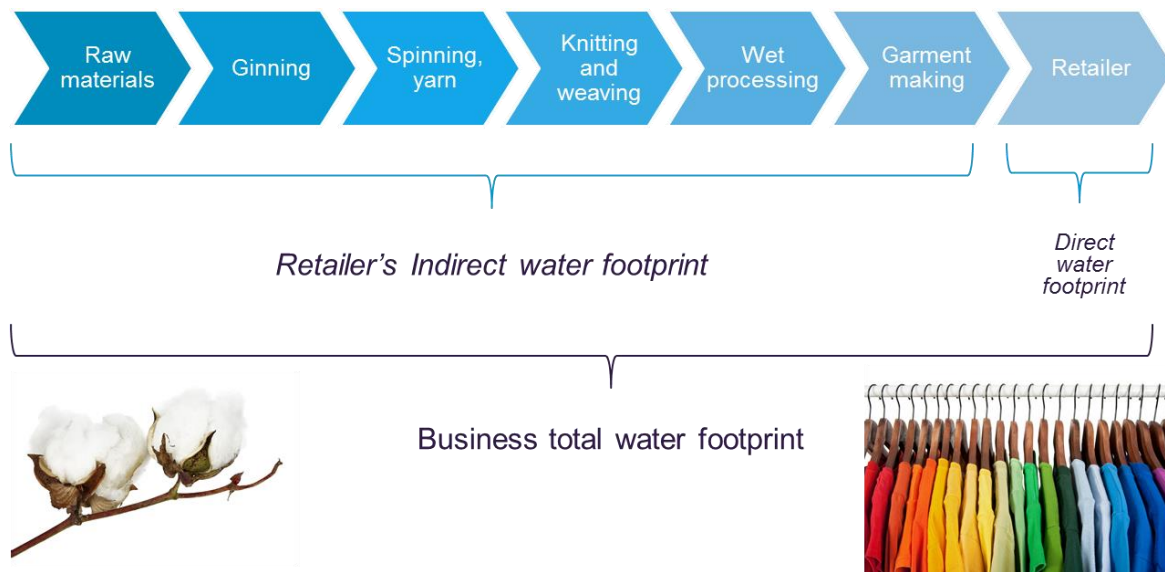


Figure 1 - Water footprint along a retailer's supply chain

To understand the impact of textile on global water resources we measure the water footprint, which can illuminate the story of water throughout (Figure 1) the supply chain. These insights can be used as a credible basis for strategic plans and actions that will advance water stewardship by encouraging, supporting and facilitating efforts that ensure sustainable production and processing in the textile supply chain.

On average, it takes almost 10,000 litres of water (Figure 2) to produce one kilogram of cotton fabric (Mekonnen and Hoekstra, 2010; 2011), meaning it takes about 8,000 litres for a pair of cotton jeans, equivalent to 50 bathtubs of water.

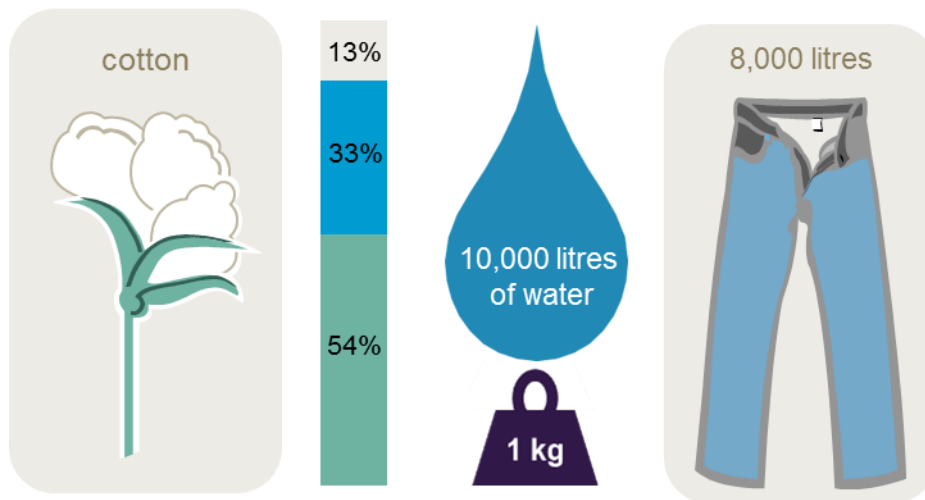


Figure 2 – Water footprint of a pair of jeans based on global averages

The global water footprint of cotton products is estimated at 233 billion cubic metres per year (Mekonnen and Hoekstra, 2010), which is an average of 33m³/year per capita, equivalent to an average of 238 bathtubs of water per person per year.

Table 1 – Water footprint of cotton by component

Water footprint components		
33%	Blue water footprint	The volume of water used or irrigation from surface or groundwater during cotton farming
54%	Green water footprint	The volume of rain - or soil moisture - consumed by plants during the growing period
13%	Grey water footprint (Nitrogen)	The volume of fresh water polluted as a result of cotton production

Based on Mekonnen and Hoekstra's 2011 global study (Table 1), 33% of cotton's water use is the blue water footprint, 54% is the green water footprint and 13% is the grey water footprint associated with Nitrogen pollution.

1.2 C&A's strategy for sustainable sourcing

The Water Footprint Network through its strategic partnership with C&A, has been supporting the company in developing a deep understanding of water consumption and pollution of raw materials production and garment processing stage; as these two areas have been identified as hotspots in previous work. Through quantifying the water footprint of raw materials and processing, assessing the sustainability of these water footprints and recommending strategic response options which will reduce the water footprint or make it more sustainable, the Water Footprint Network is helping C&A reach its sustainable sourcing targets. Two studies have been completed: 'C&A's Water Footprint Strategy: Cotton Clothing Supply Chain' (Franke and Mathews, 2013a) and 'Grey Water Footprint Indicator of Water Pollution in the Production of Organic vs. Conventional Cotton in India' (Franke and Mathews, 2013b).

The first study identified the unsustainable 'hotspots' in C&A's supply chain with respect to cotton agriculture and the textile washing-dyeing-finishing phase. The global water footprint database, WaterStat¹, was used to estimate C&A Europe's water footprint for cotton cultivation in 2011 as 3.6 billion cubic metres (Franke and Mathews, 2013a). 63% (Figure 3) of this was blue water footprint, 24% was green water footprint and 13% was grey water footprint from Nitrogen-based fertilisers.

¹ <http://waterfootprint.org/en/resources/water-footprint-statistics/>

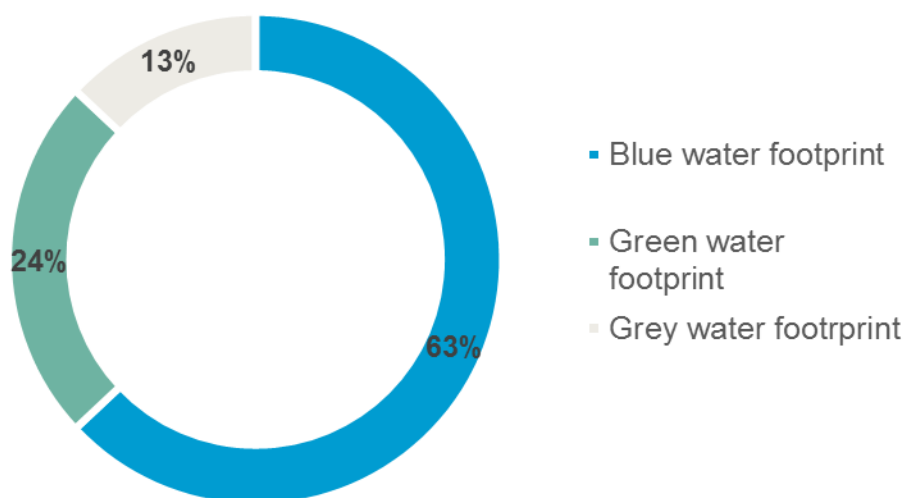


Figure 3 - C&A Europe's global water footprint for cotton sourced in 2011

The study found that C&A had a blue water footprint in India of greater than 500 million m³/year, due to the amount of cotton fibre C&A sources from India.

*60% of C&A's blue water footprint lies in India
39% of this lands in the Indus River basin,
which is a hotspot for water scarcity and pollution.*

Severe blue water scarcity occurs when the blue water footprint for the river basin is two times larger than the blue water available – in this case environmental flow requirements are not met and degradation of aquatic life and ecosystem services can be expected.

The second study, published in 2013, compared the grey water footprint of growing organic and conventional cotton across 480 farms in India. The results showed that conventional cotton production creates as much as five times more water pollution than organic farming, mainly because of the use of synthetic pesticides and, thereby, puts greater pressure on local water resources. This study was the first of its kind to document the grey water footprint reduction opportunities in cotton farming through changes in farming practices. The results point to how C&A and others could help farmers reduce the pollution load coming from cotton agriculture and lessen its impact on freshwater resources.

In the comparison of conventional cotton farming to organic, the 2013 study shows that conventional cotton farming is five times more polluting than organic

These two studies form the basis for the second phase of the partnership between C&A and Water Footprint Network: 'Building Capacity in the Apparel Sector on reducing and managing the Water Footprint: C&A Water Footprint Strategy 2013 – 2015'.

This report presents the results of the Water Footprint Assessment of agricultural practices used in cotton production on farms in India. To ensure that C&A's water strategy is based on the best information, this study used data collected from individual farms in cotton producing states in India. The aim of the study is identifying how to reduce the water footprint of cotton agriculture through the transformation of agricultural practices, thereby improving the sustainability of the cotton supply chain.

By working with suppliers to improve agricultural practices, the textile sector is well positioned to make a significant positive impact on global water use, secure the future of the sector and benefit humanity and the environment.

The results presented here can be pivotal for C&A to reach its target for sustainable sourcing of cotton and in directing its investments toward the most promising improvements that will increase the sustainability of the cotton supply chain.

1.3 Project goals & scope

Through its global supply chain, C&A has both a dependency upon the availability and quality of water and an impact on those water resources. The water footprint is one of the family of environmental footprints that help us understand how our production and consumption choices impact on natural resources. The quantities of water, fertilisers and pesticides required for cotton production, together with the fact that most cotton is grown in water scarce and polluted areas suggests that for the long-term viability of C&A and other textile companies – and the health of ecosystems and communities – it is critical to understand how water is used in the production of apparel and other textile goods.

*“By 2020, 100% of the total cotton we use will be more sustainable.
We will also act upon circular economy and closed-loop product design.”*

C&A

By measuring the water footprint – and finding out where and when it lands – C&A can see the impact of its water use and take steps to reduce that impact. The results of this study will be instrumental in developing guidance on which practices should be further developed and implemented by C&A and its suppliers (cotton farmers) to reduce to sustainable levels and better manage their water footprint.

Farm level data was collected by CottonConnect, a social enterprise that helps farmers improve agricultural practices. Approximately 700 farms were sampled in the 2013-2014 season (referred to 2013 growing season in this report) and 450 farms were sampled (from Gujarat and Maharashtra states only) in the 2012-2013 season (referred to 2012 growing season in this report). The farms grew cotton using one of three different agricultural practices: organic farming; conventional farming; or REEL farming. The main difference between these farming practices (Table 2) relates to chemical inputs. REEL farms are stricter in the use of synthetic chemical pesticides and fertilisers than conventional farms, and organic farms are the strictest on chemical inputs and use more compost, urea, neem and organic seeds.

Reductions in the consumption and pollution of water resources in the cotton supply chain will lead to greater water security for the textile sector and is necessary for water use to be sustainable, efficient and equitable.

The Water Footprint Assessment methodology (Hoekstra et al., 2011), developed by Water Footprint Network, is used in this study to assess which agricultural practices contribute to more sustainable water use and which actions will effectively reduce C&A's water footprint related to its cotton supply chain.

Table 2 – Comparison of three agricultural practices

Conventional	REEL Cotton Programme	Organic
<p>Conventional farming is the standard practice that is used extensively, employing a combination of mostly synthetic agrochemicals for pest control and fertilisers and has the least restrictions in terms of the chemicals used. While quantities of sustainably produced cotton are increasing, approximately 90% of all cotton is grown conventionally (Textile Exchange, 2014).</p> <p>Conventional cotton uses about 16% of the world's insecticides and 7% of pesticides, while grown on 2.5% of arable land (ICAC, 2010). 73% of global cotton harvest comes from irrigated land (WWF, 1999). Conventional farming can look different from farm to farm and in different geographies as there are no guiding principles compared to the other practices. Spraying of chemicals is often done on an extensive scale on all plants, timed according to a prescriptive schedule. Although there are many conventional farmers that use good agricultural practices such as less chemical and water usage, they are not certified or verified as being more sustainable. Conventional farming can be rainfed or irrigated².</p>	<p>REEL³ (Responsible Livelihood Enhanced Environment) Cotton programme is a farmer capacity building programme, delivering training throughout the cotton season. It addresses soil, water and pest management, as well as decent work practices, focusing on:</p> <ol style="list-style-type: none"> 1. Environmental sustainability: Reduction of toxic chemical inputs, increased water efficiency, improved soil health and biodiversity, intercropping and using natural/ organic fertilisers and pesticides; 2. Socio-economic sustainability: Increasing the productivity of farmers by reducing input costs and increasing yields, thereby improving their profitability and their livelihoods. Awareness on decent work practices; including health and safety and importance of education, working towards eliminating child labour (as defined in ILO convention 138 and 182). <p>The programme also offers farmer finance and business management training, gender empowerment, supply chain mapping, supply chain conventions and procurement support to brands and retailers.</p>	<p>Organic farming is a form of agriculture that uses techniques such as crop rotation, compost, and biological pest control, leading to improved ecosystem and soil health (MoIC, 2005). Organic farming also makes use of fertilisers and pesticides, including herbicides, insecticides and fungicides, so long as they are derived naturally and within the guidelines of the organic certification. Organic production forbids the use of any synthetic inputs and the organic inputs tend to be more readily assimilated by the natural ecosystem. Farms must ensure these standards for two to three years before being eligible for organic status and must maintain these standards to comply with the certificate.</p> <p>Almost 150,000 farmers are certified organic globally (Textile Exchange, 2014).</p>

² Comments from CottonConnect

³ Provided by CottonConnect

2 Method and Data



Cotton harvest, Vellitiruppur, Erode, Tamilnadu.
Source: Indiawaterportal.org (July, 2012)

2.1 Method

This study follows the methodology for Water Footprint Assessment described in *Water Footprint Assessment Manual: Setting the Global Standard*⁴ as developed by Water Footprint Network (Hoekstra et al., 2011).

⁴ For additional details on Water Footprint Assessment, please refer to the Water Footprint Assessment Manual (Hoekstra et al., 2011).

2.1.1 Water footprint

The water footprint is an indicator of freshwater use that looks at both direct and indirect water use for any kind of productive activity, e.g., growing cotton, for the products consumed by an individual or group of individuals, or for the activities within a geographic area. It accounts for both water consumption and pollution over each phase of the production process and value chain, and includes three components.

- The **blue water footprint** is the amount of fresh surface or groundwater used to grow a crop or produce goods or services. It is the amount of water evaporated, incorporated into the product or returned to a different location or in a different time period from where it was withdrawn.
- The **green water footprint** is the total rainfall or soil moisture used to grow plants. It is relevant for products that include agricultural crops and wood and other forestry inputs; where it refers to the quantity of water either evapotranspired by plants or incorporated into the harvested crop, or both.
- The **grey water footprint** is a measure of pollution. It is expressed as the volume of water required to assimilate the pollutant load to meet ambient water quality standards. The pollutant that requires the largest assimilation volume is referred to as the critical pollutant and is used to calculate the grey water footprint; if there are both surface and groundwater discharges, the grey water footprint for each discharge is calculated separately.

2.1.2 Water Footprint Assessment

Water Footprint Assessment (Figure 4) is a process that answers questions of interest such as:

- How large is the water footprint and what proportion is green, blue and grey;
- Is the water footprint sustainable and, if not;
- Which response strategies will improve its sustainability?

Water Footprint Assessment includes four phases:

- **Setting goals and scope:** Identifying the objectives and scope of the assessment, including geographical/temporal and process/supply chain boundaries;
- **Water footprint accounting:** Calculating the operational (“direct”) and supply chain (“indirect”) water footprint, for both quantity and quality;

- **Water footprint sustainability assessment:** Assessing the water footprint against environmental, social and economic criteria; and
- **Water footprint response formulation:** Selecting strategic actions to reduce the water footprint or improve its sustainability.

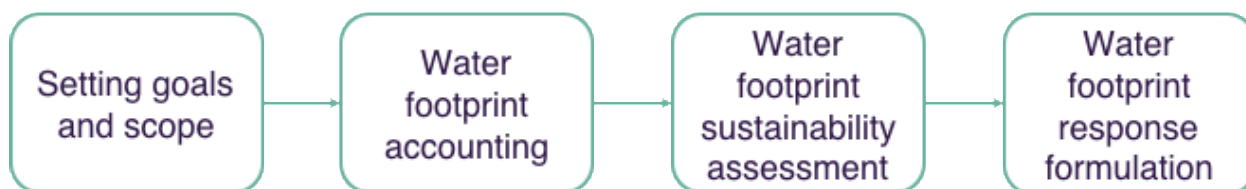


Figure 4 – Four phases of Water Footprint Assessment

Water Footprint Assessment sheds light on a company's dependence upon freshwater resources and helps a company identify unsustainable water uses, both in terms of water quantity and quality.

Water Footprint Assessment places the water footprint within the context of local water conditions.

This study includes the following steps:

- Calculating the green, blue and grey water footprint of cotton cultivation using the data collected from representative farms located in the three Indian states of Gujarat, Maharashtra and Madhya Pradesh;
- Establishing the relationship between cotton agricultural practices and technologies and the green, blue and grey water footprint; and
- Analysing the potential for water footprint reduction through the transition from one practice to another and developing water efficiency benchmarks or targets for reduction.

The study establishes the relationship between cotton agricultural practices and technologies and the use of water. A powerful methodology for identifying and evaluating these relations, Water Footprint Assessment proposes improvement strategies and is an effective tool in achieving a company's corporate sustainability goals. It provides a holistic understanding of the size and sustainability of the water footprint.

By analysing the potential for water footprint reductions through the transition from one farming practice to another, Water Footprint Assessment can form the basis for water efficiency benchmarks or targets for reduction and assist C&A in developing priority actions for improving the sustainability of its cotton sourcing.

2.1.3 Green and blue water footprint accounting

To calculate the green and blue water footprints, it is necessary to know how much water is consumed – through evapotranspiration – by the plants during the entire growing season. This is further broken down into the amount that is from rainfall stored as soil moisture (green water footprint) and how much is from irrigation (blue water footprint). The type of plant, climate, soil characteristics and irrigation methods, amounts and schedules all contribute to determining the crop water use.

A model is used, in this case, AquaCrop, to calculate the daily water balance due to environmental factors, such as meteorology and soil characteristics, in combination with irrigation schedules, whilst the plant grows. AquaCrop was selected for calculating the green and blue water footprints because it is well tested and can be customised. It includes a crop growth module (estimating yield, which allows for comparison with the actual farm yield), can be run for large datasets and is able to handle specific irrigation schedules and environmental factors per farm.

To set up and run the model, data collected from the farms by CottonConnect were used. These data were supplemented with data from literature as recommended by the Food and Agriculture Organisation (FAO) for use in AquaCrop, such as the cotton crop characteristics and expected growing season (Raes et al., 2010). The Global Soil Database (FAO et al., 2012), along with data from CottonConnect, was used in determining soil types and their associated soil water characteristics. Initial soil moisture was determined by default values based on the soil type, region and climate. CROPWAT, another crop water use model, was used to provide the initial evapotranspiration needed by AquaCrop. The results from AquaCrop were validated over several iterative model runs and through comparison with CROPWAT and the actual field level data. Based on these findings, various assumptions were made to extend the parameters to our case study across the three Indian states.

The output of AquaCrop is the daily evapotranspiration from the farm field, which is aggregated over the growing season to give the total in cubic metres per hectare (m^3/ha).

The (proportional) contribution of irrigation vs. precipitation (in the model) determines the blue and green water footprint respectively.

This result can also be used to calculate the water footprint per year (m^3/y) or the water footprint per tonne of cotton produced (m^3/t).

2.1.4 Grey water footprint accounting

The grey water footprint is calculated by considering the pollutant load from fertilisers, pesticides and other chemicals relative to the maximum allowable concentration and natural background concentration of the pollutant in question. Estimation of the loads of pollutants from non-point sources, e.g. from cotton and other crop farming, to receiving water bodies is difficult due to the complexity of pollutant fate and transport processes through the soil until finally reaching water bodies. Given the data available, the Tier 1 approach, as suggested in Hoekstra et al. (2011), and ‘The Grey Water Footprint Accounting Guidelines’ (Franke et al., 2013) was used. Variables such as residence time, decay constants and soil properties were considered in determining the leaching-runoff fraction, which affects the load and subsequent grey water footprint. The maximum allowable concentrations for each chemical were determined based on the most stringent ambient water quality standards of the European Union (EU) (EC, 2009), Canadian (CCME, 1999) and United States Environmental Protection Agency (US EPA, 1994) in line with previous work with C&A (Franke and Mathews, 2013a, b).

Data collected from farmers included the fertilisers and pesticides used and the application of these inputs over the growing season. The fertiliser and pesticide names and concentrations of active ingredients (Figure 5) were cross-referenced to confirm that accurate information was used in the calculation of the grey water footprint.

The grey water footprint was calculated for each pollutant; the pollutant with the largest grey water footprint is the critical pollutant and determines the farm’s total grey water footprint.

The other pollutants with a lower grey water footprint are assimilated in that same water volume. In the case of fertilisers, the Nitrogen and Phosphorus contents (in percentage) are considered the main pollutants to calculate the grey water footprint. In the case of pesticides, the percentage of active ingredient(s) and their relative toxicity are deterministic for the grey water footprint.

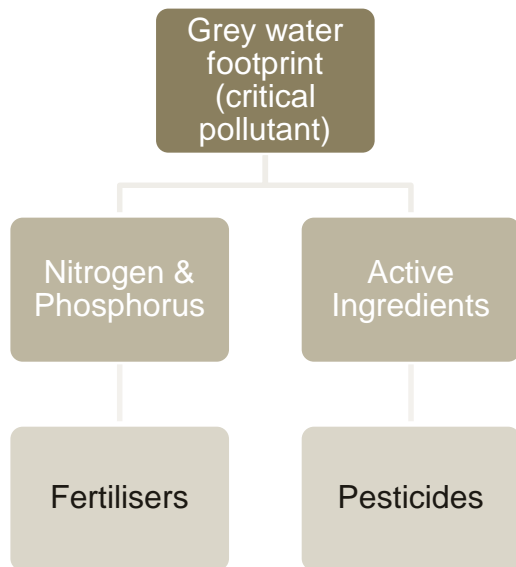


Figure 5 – Step-wise grey water footprint calculation from fertilisers and pesticides to critical pollutant

2.2 Data

Data from 702 cotton farms applying conventional, organic and REEL agricultural practices were sampled in the 2013 growing season, also referred to as 'seasonal data'. The aim was to have an even distribution across the three states and three practices but practical limitations resulted in an uneven distribution (Table 3) with a larger number of conventional farms than REEL or organic and more farms overall from Gujarat. In Madhya Pradesh, no farms participated in the REEL Cotton programme. Madhya Pradesh is a large producer of organic cotton; however these were not included in the study. This means that the analysis and results need to be interpreted carefully, yet does not invalidate their value as there are a sufficient number of farms across a large enough area with differing local conditions to compare the results from this analysis.

Table 3 – Number of farmers included in data collection: 2013 growing season

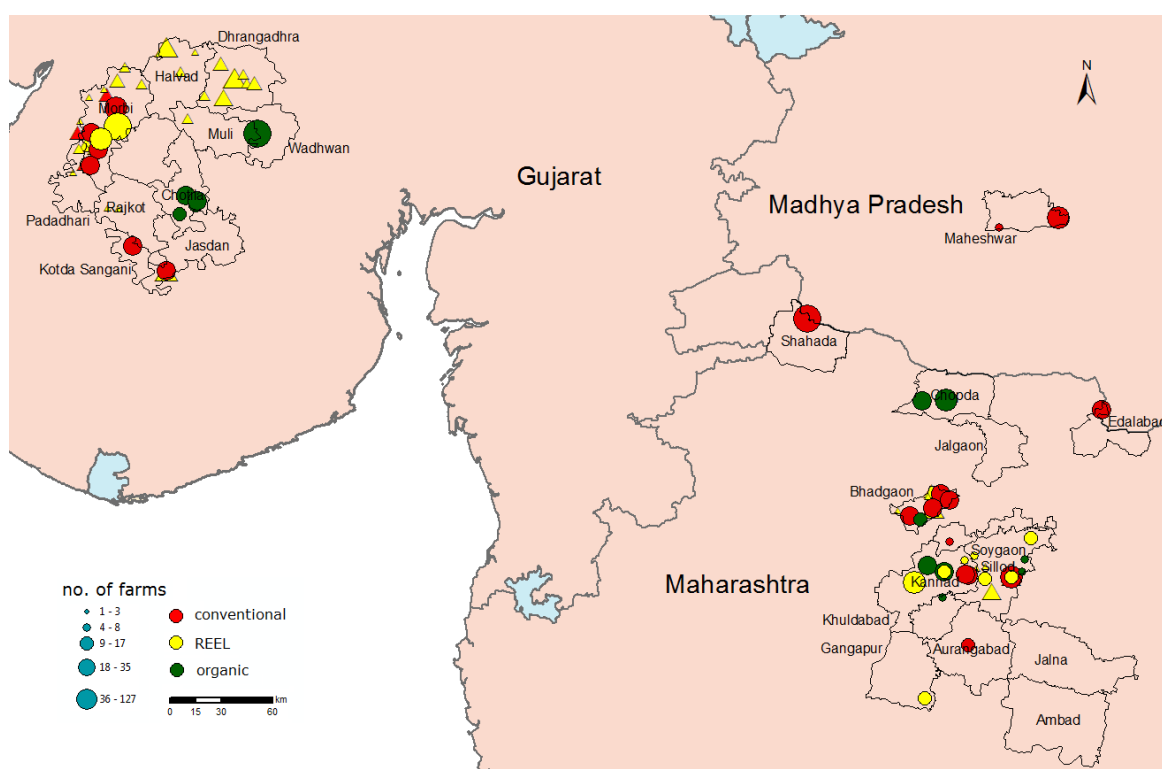
Agricultural Practice & State	Madhya Pradesh	Gujarat	Maharashtra	Total
Conventional	100	90	100	290
REEL	n/a	160	49	209
Organic	n/a	101	102	203
Total	100	351	251	702

CottonConnect also provided data for an additional 450 farms (Table 4) from the 2012 growing season.

Table 4 – Number of farms included in data collection: 2012 growing season

Agricultural Practice & State	Gujarat	Maharashtra	Total
Conventional	29	22	51
REEL	261	130	391
Total	290	152	442

The farms were located (Figure 6) in the states of Gujarat, Maharashtra, and Madhya Pradesh. These three states are home to the majority of C&A's cotton supply: 75% for conventional and 85% for organic cotton. In addition, these states produce more than 40% of India's total conventional cotton and more than 60% of India's total organic cotton (Franke and Mathew, 2013b).



Note: The triangles indicate farms from 2012, the circles represent the farms from the 2013 season. The size of each symbol determines the number of farms sampled in that village or taluka.

Figure 6 – Detail of farm locations

In general, the conventional farmers in this study have been farming cotton for many years and have medium to high access to resources such as government support, technology, irrigation facilities, etc. However, farmers in Gujarat overall have access to more resources and use more technology compared to farmers in Madhya Pradesh and Maharashtra. REEL farmers in Gujarat and Maharashtra have both had 2-3 years of training. In the organic farms included in this study, Gujarat farms have been organic for 8-10 years whilst Maharashtra organic farms have been in the conversion phase for 1-2 years (where they will be certified organic after 2-3 years of being in conversion). The organic farms have lower levels of access to resources and it is common for farms that are in the conversion phase to have low yields, as the yields often drop during the first few years compared to conventional farming.

There are overlaps in locations between the growing seasons, although the sample size is larger and location of farms is more widespread in the seasonal data. In general, each type of farm is amongst a cluster of similar farms; for example, organic farms are proximal to each other. Only a few villages have a mix of organic and REEL or conventional and REEL farms.

There are no organic farms near conventional farms. This is logical because organic farms require a buffer from conventional farms in order to avoid contamination.

The total area under cultivation (Table 5) for the 702 farms was 2,142 hectares.

Table 5 – Area under cultivation

Agricultural Practice	Farm Area (hectares)			Total
	Madhya Pradesh	Gujarat	Maharashtra	
				-
Conventional	192	482	241	915
REEL	n/a	782	108	890
Organic	n/a	193	143	337
State Totals	192	1457	493	2,142

Farmers were surveyed by CottonConnect's farm team at various times during the growing season and again during picking and harvesting and the data collected was recorded in Farmer Field Books. CottonConnect also assisted in verifying data and filling gaps in information.

The Farmer Field Book captures details about the farmers, such as name, location, age and level of education, as well as details of the land they farmed, such as farm size, cotton yield, soil type, irrigation schedule and irrigation method, climate and meteorological data, fertiliser and pesticide application and the concentrations of their active ingredients. Specific irrigation, fertiliser and pesticide schedules, along with the yield delivered at the end of each picking, were recorded. Meteorological data and soil information was provided in parallel to the FFB, and this formed the basis for the modelling of the green and blue water footprint. The soil type was further verified using FAO soil maps. Information on tillage practices, such as mulching, was not available.

3 Results



Separating the lint from the boll, Vellitiruppur, Erode, Tamilnadu.
Source: Indiawaterportal.org (July, 2012)

3.1 Water footprint perspectives

The data collected from the farms are analysed from two perspectives:

- Geographic water footprint, which indicates the pressure the farms are putting on water resources;
- Production water footprint, which indicates the efficiency, or productivity, of the water use.

Together they help us understand the volumes of water consumed through the production of cotton and allow us to compare different agricultural practices.

When considering the water footprint from a geographic perspective, it is measured in volumes of water per unit of area or period of time. This is helpful in understanding the contribution that a farm, or a group of farms or all water using activities in a catchment, for example, is making to

the local water issues of water scarcity or water pollution. Only a certain amount of water can be consumed (blue water footprint) from a specific water resource, whether surface or groundwater, beyond which there is blue water scarcity that can impact on local communities, economic development and ecosystems. It is also important in terms of water pollution. If the grey water footprint is too large, water quality standards will be violated. Water quality can be improved by reducing the grey water footprint per hectare.

The geographic water footprint provides insight into the potential for specific agricultural practices to contribute to an increase or decrease of water scarcity and declining water quality.

When the water footprint is measured in volumes of water per unit of production, we understand how efficiently water is being used, i.e., are we producing as much as we can with the water that we are using? This becomes important when considering the total amount of production needed e.g., the tonnes of cotton needed by C&A to keep clothing in its stores. The production water footprint can be used to identify which agricultural practices result in the greatest amount of cotton per unit of water.

*Both arable land and water are limited. Reducing the green, blue and grey water footprint per tonne of cotton uses these scarce resources wisely.
Maximizing efficiency of both land and water is a requisite part of a sustainable sourcing strategy*

The interplay between the water footprint from the geographic and production perspectives provides the information necessary to evaluate how best to produce the amount of cotton needed with environmental sustainability and resource efficiency.

3.2 Water footprint of cotton cultivation: geographic perspective

3.2.1 Green and blue water footprint

For the green and blue water footprint, the primary factors contributing to variations between farms are plant characteristics, climate (see Appendix II), planting/harvest schedules (i.e., number of growing days), and other environmental variables such as soil characteristics, as well as human factors such as farm management practices, including irrigation. Combined, these translate into the total evapotranspiration for the farm. The evapotranspiration is then differentiated by the source of the water (Table 6), either moisture stored in the soil from rainfall (green water footprint) or irrigation from surface or groundwater (blue water footprint).

To understand the pressure cotton production is putting on freshwater resources, the water footprint is viewed in relation to the area under cultivation i.e., we assess how much water is used in the production of cotton relative to an area of land. Table 6 shows the average green and blue water footprint of cotton for the farms in this study. The variations between states generally reflects climatic and other geo-physical characteristics as well as socio-economic differences between the three states. For example, there are greater public investments in farmer training in Gujarat and more awareness of best practices, access to irrigation equipment, etc., than in the other two states. The variations across practices within a state are more related to agricultural practices including seed types, cropping systems, etc.

Table 6 – Average green & blue water footprint: 2013 growing season

Agricultural Practice	Average Green Water Footprint (m ³ /ha)			Average Blue Water Footprint (m ³ /ha)		
	Madhya Pradesh	Gujarat	Maharashtra	Madhya Pradesh	Gujarat	Maharashtra
Conventional	5,985	5,381	5,177	372	464	13
REEL	n/a	5,652	5,374	n/a	381	0
Organic	n/a	5,340	5,891	n/a	372	289
State Average	5,985	5,493	5,506	372	400	123

Note: Averages also include farms that do not irrigate - the averages are calculated using the sum of the water footprint of each group of farms divided by each farm group's total acreage.

The results deviate remarkably from global statistics (In general, across India, 70 – 80% of cotton farms are rainfed, with only 20 – 30% using irrigation. Cotton farms in Gujarat and Madhya Pradesh are more likely to use irrigation than cotton farms in Maharashtra.

Table 7) and demonstrate the value of local data collection to refine global assumptions. Compared to the data collected from farms in the current study, Mekonnen and Hoekstra (2011) overestimated the amount of irrigation used, thereby resulting in higher blue water footprints and a lower proportion of green water footprint than the results from the farm data. In general, across India, 70 – 80% of cotton farms are rainfed, with only 20 – 30% using irrigation. Cotton farms in Gujarat and Madhya Pradesh are more likely to use irrigation than cotton farms in Maharashtra.

Table 7 – State average green and blue water footprint: 1996-2005

Average Green Water Footprint (m ³ /ha)			Average Blue Water Footprint (m ³ /ha)		
Madhya Pradesh	Gujarat	Maharashtra	Madhya Pradesh	Gujarat	Maharashtra
5,314	4,761	4,883	1,449	761	550

Note: Only conventional farming practices were modelled in the global study by Mekonnen and Hoekstra

Of the farms sampled in Madhya Pradesh, 96% were irrigated; however the resulting blue water footprint (per hectare) was smaller than in Gujarat due to the higher amounts of rainfall received in Madhya Pradesh; irrigation was only 6% of the total water consumed in growing the crop. From the farms sampled, Gujarat is the second highest user of irrigation systems across the three practices, with 89% of farms irrigating in 2013; irrigation provided 9% of the total evapotranspiration. This reflects the comparatively hotter and drier climate in Gujarat. Gujarat receives a lot of rain in the monsoon but it is heavily focused between June and October. Maharashtra is the least reliant on irrigation, with only 30% of the farms irrigating. Irrigation was used primarily on organic farms, which had access to irrigation systems. Maharashtra experiences similar weather throughout the year as Gujarat; however it is cooler and wetter on average with rains not only in the monsoon season.

With irrigation supplying only 2% to 9% of the total water needed for growing cotton, farms which are using irrigation are doing so to supplement rainfall, either to plant their crops earlier or to maintain soil moisture during dry periods.

Whilst the farms included in this study are not fully representative of the range of farms that C&A sources from worldwide, these results are a first step toward quantifying the total pressure that C&A's cotton supply chain is putting on freshwater resources, based on data collected from farms.

On average, >90% of the evapotranspiration on the farms studied is provided by green water i.e., most of the water consumed by cotton came from rainfall.

The annual green and blue water footprint (Table 8) show us the cumulative impact of all the farms combined together. The annual water footprint reflects the water footprint per hectare over the entire growing season for all the hectares under cultivation. Here the annual water footprint is shown for each state; this approach can also be used to assess the cumulative water footprint of cotton in a specific catchment or river basin, or for cotton using a groundwater aquifer for irrigation water.

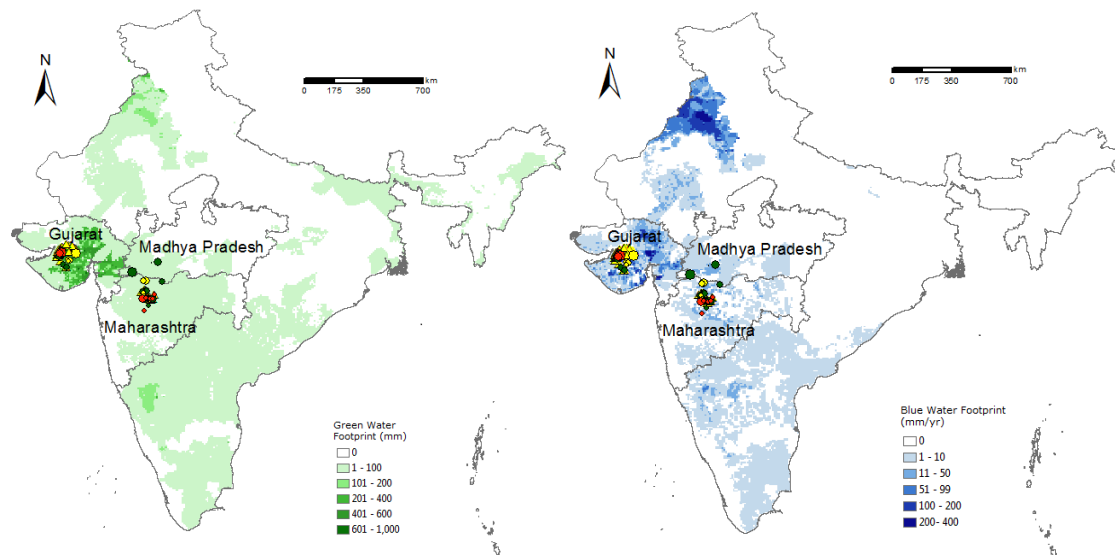
Table 8 – Total annual green & blue water footprint: 2013 growing season

Agricultural Practice	Green Water Footprint (m ³ /y)			Blue Water Footprint (m ³ /y)		
	Madhya Pradesh	Gujarat	Maharashtra	Madhya Pradesh	Gujarat	Maharashtra
Conventional	1,150,201	2,605,830	1,253,474	72,142	192,849	3,355
REEL	n/a	4,400,499	579,025	n/a	311,057	0
Organic	n/a	1,031,430	846,206	n/a	71,024	39,083
State Totals	1,150,201	8,037,759	2,678,706	72,142	574,930	42,438

Viewing the water footprint from this perspective can highlight the locations where cotton cultivation is making the largest contribution to unsustainable levels of water use. Even when the individual farms are not making large contributions to blue water scarcity, the cotton sector as a whole may need to work toward water footprint reduction.

Whilst irrigation may only contribute 6% of the total water used in cotton cultivation on the farms in Gujarat, with 89% of the farms using irrigation, the cumulative blue water footprint for the 351 farms from Gujarat is 574,930 cubic metres.

Cotton cultivation (Figure 7) is widespread in India. The green water footprint shows where cotton is grown, whilst the blue water footprint indicates the level of dependence on irrigation.



Note: Green and blue water footprint of cotton in India from global study with farm locations overlaid.

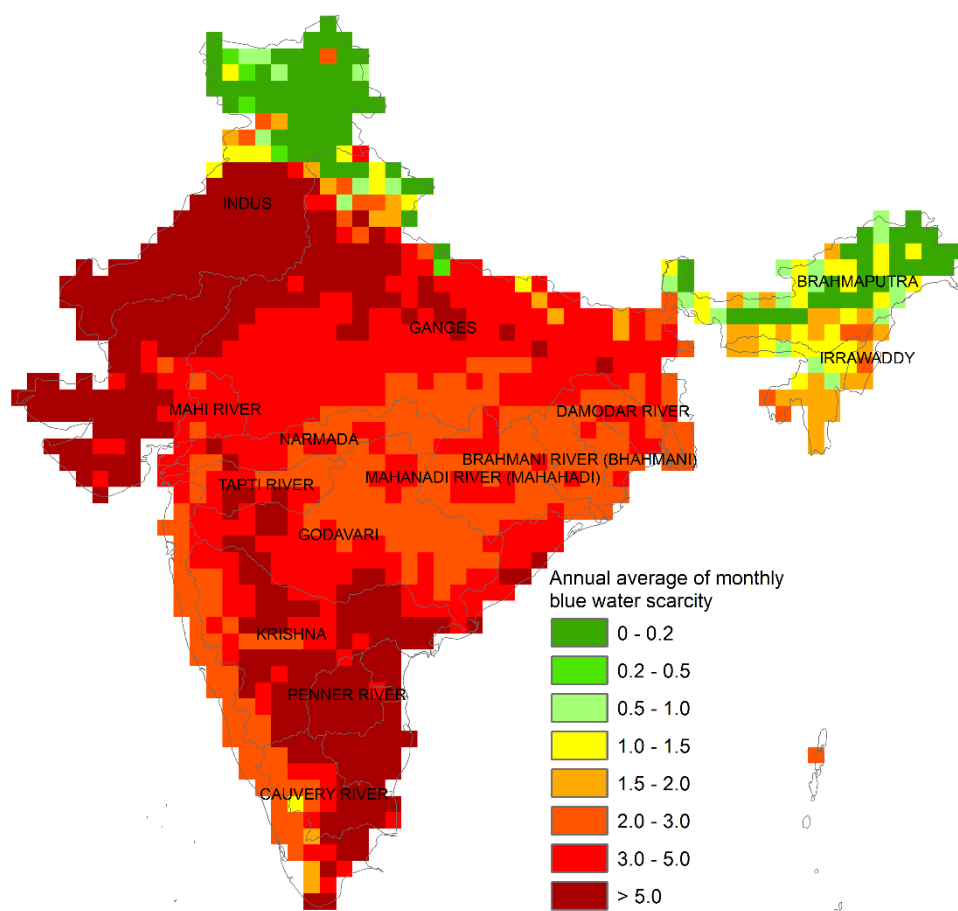
Source: Mekonnen and Hoekstra (2010)

Figure 7 – Green and blue water footprint of cotton

Gujarat stands out for the intensity of cotton production, and its related green and blue water footprints. Gujarat farms are well represented in this study, giving us a more detailed view of farming practices and their related water footprints.

Considering only the farms in this study, the combined green and blue water footprints are more than 12.5 million m³/y.

The farm data further refine our understanding of the pressure that cotton agriculture is putting on freshwater resources and C&A's contribution to the overall green and blue water footprint in these three states. This becomes important when considering the levels of blue water scarcity (Figure 8) in the basins where the farms are located.



Source: Mekonnen and Hoekstra (2016)

Figure 8 - Annual average of monthly blue water scarcity in India

Blue water scarcity is a result of the cumulative impact of the blue water footprint of cotton cultivation, as well as all other activities that contribute to the overall blue water footprint in a catchment. In areas where blue water scarcity is greater than one – yellow, orange and red areas in the map – environmental flow requirements are not met, which can lead to degradation of natural ecosystems, loss of valuable ecosystems services and negative impacts on subsistence uses, e.g., access to drinking and other household water, loss of fisheries, etc. The farms in this study are located in river basins which have high levels of blue water scarcity.

*Gujarat, Madhya Pradesh and Maharashtra are water scarce.
Cotton grown in these states is environmentally unsustainable.*

3.2.2 Grey Water Footprint

The grey water footprint is the volume of water that must be present in the receiving freshwater body for ambient water quality standards to be met for the critical pollutant. If enough water is available to assimilate the critical pollutant, the other pollutants are addressed. The grey water footprint measures the amount of the available assimilation capacity used by an individual farmer to maintain water quality standards. This differs from dilution of pollutants to meet a specified concentration whereby the volume of water in which a pollutant is diluted can be increased to meet the specified concentration. With the grey water footprint, the load of pollutants is being measured and this loading cannot be altered by increasing the amount of water it is diluted in. The grey water footprint is more reflective of a farmer's contribution to water quality degradation and can be used to understand the cumulative impact of all polluters affecting a freshwater body.

The grey water footprint (Table 9) varies much more dramatically across the different agricultural practices than the green and blue water footprint. This reflects the level of toxicity of the pesticides used, or the overuse of nutrients. In this case, average grey water footprint for all farms in each practice and state are shown.

Table 9 – Average water footprint per hectare: 2013 growing season

Agricultural Practice	Average Grey Water Footprint (m ³ /ha)		
	Madhya Pradesh	Gujarat	Maharashtra
Conventional	496,657	9,108	88,698
REEL	n/a	3,845	29,432
Organic	n/a	204	384
State Average	496,657	4,386	39,504

Different pesticides are used in each of the states in part due to the type of pest infestations arising in different locations. Selection of agro-chemicals used by conventional and REEL farms can be influenced by what is available locally or in the case of conventional farms, what is recommended by agro-chemical dealers.

The grey water footprint of cotton, when including pesticides, clearly demarcates the three agricultural practices. Conventional agriculture pollutes more than REEL and organic farms are the best performers. Therefore, a substantial reduction of pressure on water resources could result from a change in agricultural practices, in particular, in pest management.

Including pesticides in the calculation of the grey water footprint demonstrates the tremendous levels of water pollution coming from these chemicals. This is further elaborated when looking at the grey water footprint across the entire growing season. The 100 farms (Table 10) in Madhya Pradesh cultivating 192 hectares of cotton, have an annual grey water footprint of over 95 million cubic metres.

Table 10 - Average annual grey water footprint: 2013 growing season

Agricultural Practice	Grey Water Footprint (m ³ /y)		
	Madhya Pradesh	Gujarat	Maharashtra
Conventional	95,473,624	4,390,202	21,394,126
REEL	n/a	3,005,503	3,192,146
Organic	n/a	39,518	54,865
State Average	95,473,624	7,435,224	24,641,136

In Madhya Pradesh and Maharashtra, the grey water footprint is over 90% of the total water footprint (green, blue and grey water footprint combined). On the opposite end of the spectrum, the grey water footprint for organic farms in Gujarat is only 3% of the total and overall for Gujarat the grey water footprint is less than 50% of the total.

This study shows that improved agricultural practices can greatly enhance water quality.

Replicating the good performance of farmers in Gujarat at all the farms in this study would reduce the grey water footprint by 88%.

The grey water footprint of each farm is determined by the specific pesticides and fertilisers (Figure 9) that are used and how they are applied throughout the growing season. The active

ingredients of each product used, and its level of toxicity, as reflected in its corresponding water quality standard, influence the volume of water needed to maintain water quality.

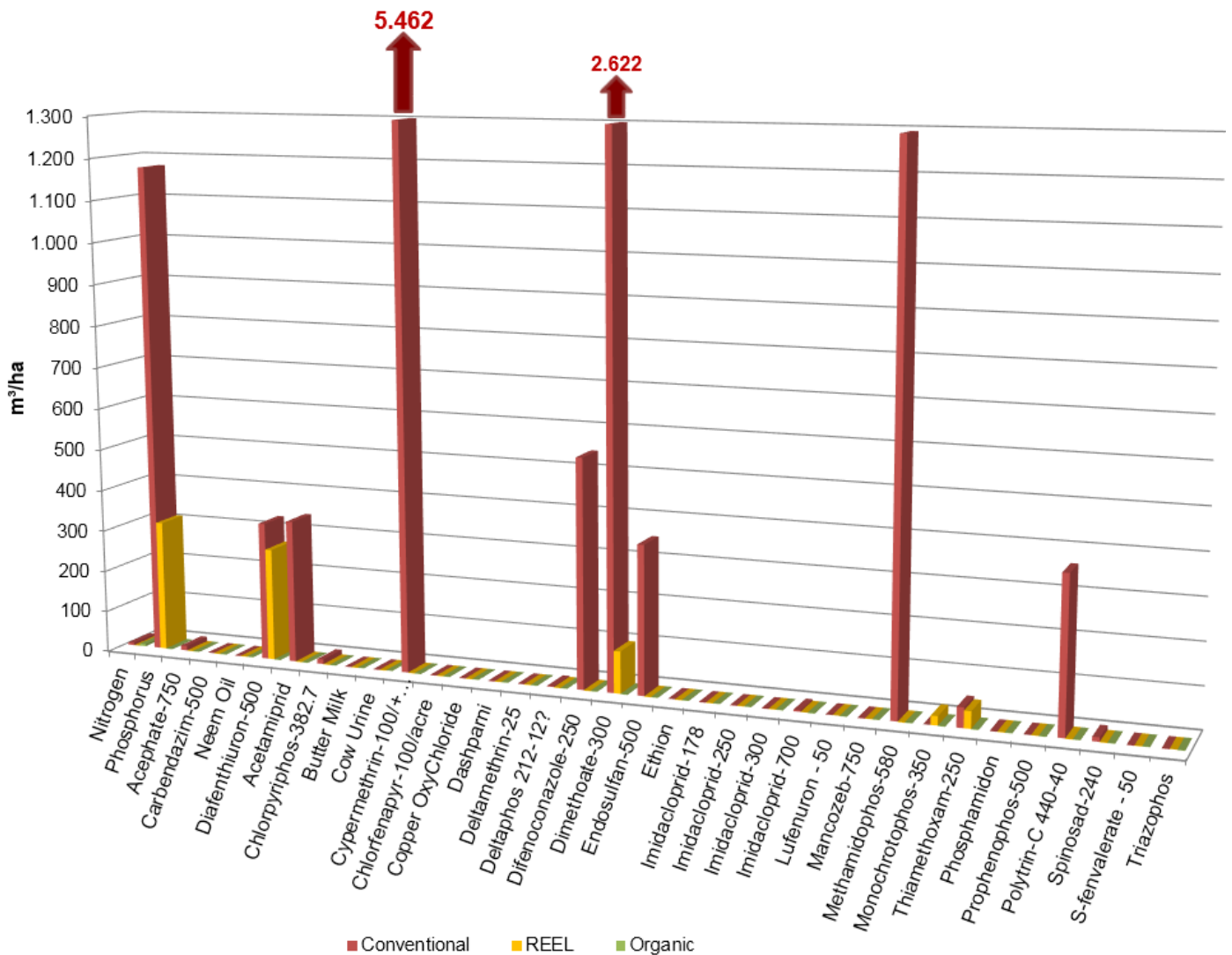


Figure 9 – Grey water footprint of critical pollutants: 2013 growing season

Most farms use more than one pesticide, depending on the pests needing to be controlled and may add both Nitrogen and Phosphorus to provide necessary nutrients to the plants. The pesticide, or fertiliser, with the largest grey water footprint, is the critical pollutant for the farm, i.e., the one that dictates the grey water footprint for the farm.

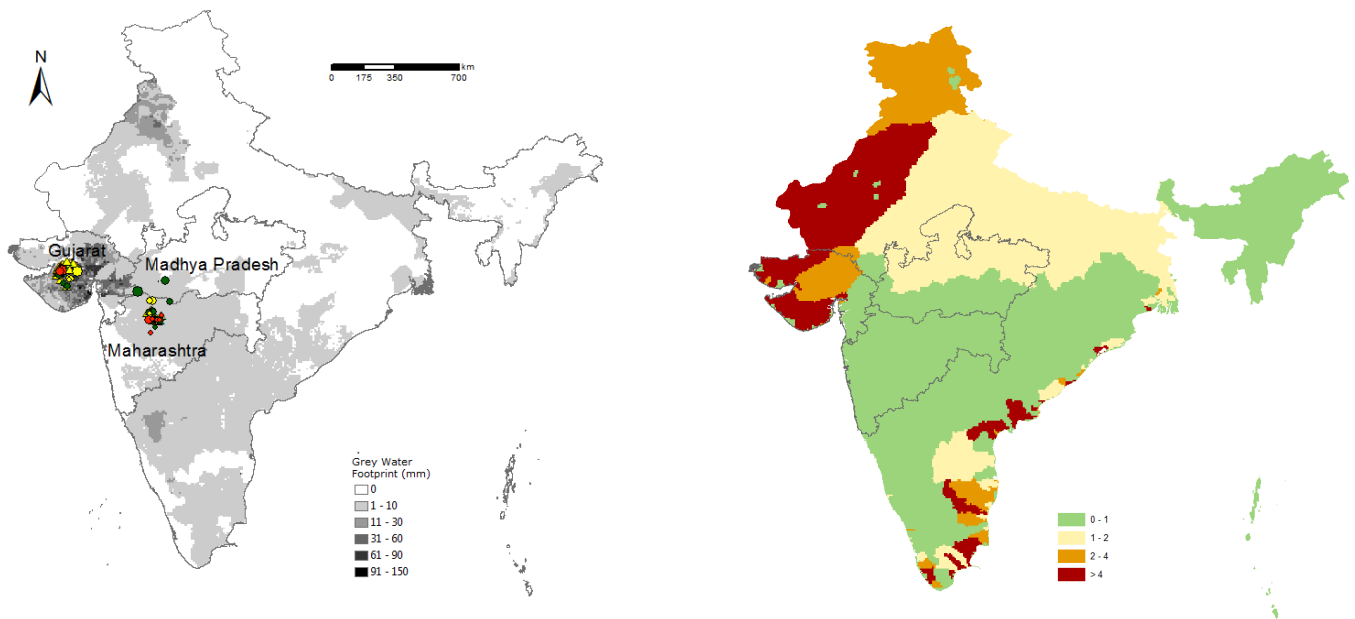
These results, derived from data collected directly from farms, again deviate significantly from the grey water footprint modelled in the global study. In large part this is due to the global study only taking into account pollution related to Nitrogen, whereas in this study pesticides were considered in addition to nutrients.

Table 11 – Grey water footprint in the three states according to the global study

State	Average Grey WF of Nitrogen (m ³ /t)
Gujarat	1087
Maharashtra	875
Madhya Pradesh	801
Global	440

Source: Mekonnen & Hoekstra, 2013

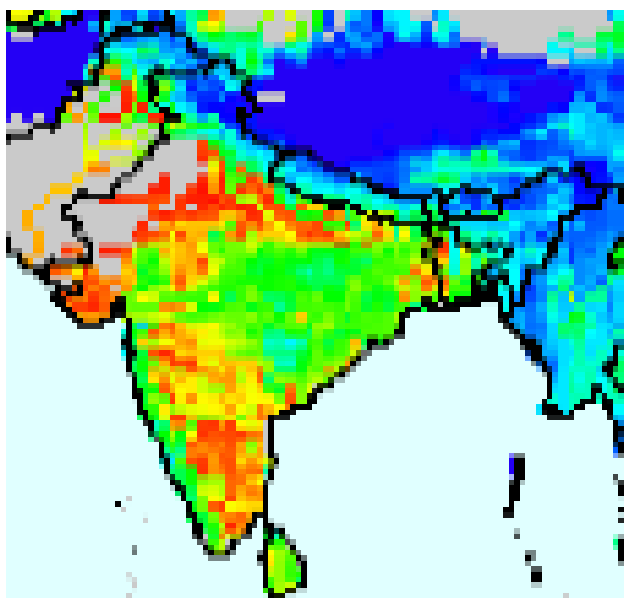
The grey water footprint related to Nitrogen (map on left) and the water pollution levels (map on right) for the corresponding river basins (Figure 10) indicate that nutrient pollution is significant to severe in Gujarat. Water pollution levels above 1 – yellow, orange and red areas – indicate that water quality standards for Nitrogen are not being met. Excessive nutrients can cause eutrophication, which can negatively impact both aquatic life and human health.



Note: Grey water footprint of cotton related to Nitrogen with farm locations overlaid (left).
Source: Mekonnen and Hoekstra (2010)

Figure 10 - Grey water footprint of cotton and river basin water pollution levels related to Nitrogen in India

Water pollution levels for pesticides have not been mapped as there is not sufficient data available on a global scale to calculate these. As a proxy, pesticide loading as assessed by Vörösmarty et al., (2010) can be used to give an indication of this impact on freshwater bodies. The impact is assessed relative to other locations, globally. Pesticide loading (Figure 11) is indicated as a water quality issue of concern for Gujarat and surrounding areas.



Note: Pesticide loading from Global Threats to Human Water Security and River Biodiversity project. Scale shows the impact of pesticide loading relative to other locations in the world.
Source: Vörösmarty et al. (2010)

Figure 11 – Pesticide loading

3.3 Water footprint of cotton cultivation: production perspective

3.3.1 Overview of the production water footprint

When considering the water footprint from the production perspective, the primary concern is the efficiency of water use, i.e., the volume of water consumed, or assimilation capacity used, per unit of production. Our main interest here is the water footprint per tonne of cotton produced. This is arrived at by understanding the water footprint per hectare of cotton cultivation and the yield in terms of the tonnes of cotton per hectare. The total production of cotton (Table 12) on the farms included in this study was 5,136 tonnes.

Table 12 – Production in tonnes of cotton: 2013 growing season

Agricultural Practice	Cotton Production (tonnes)			Practice Average
	Madhya Pradesh	Gujarat	Maharashtra	
Conventional	286	1,110	484	1,880
REEL	n/a	2,504	379	2,882
Organic	n/a	222	152	374
State Totals	286	3,836	1,014	5,136

The yield of the farms included in this study ranges from a low of 1.06 tonnes/ha for organic cotton in Maharashtra to a high of 3.49 tonnes/ha for REEL farms in the same state. The yields (Table 13) vary between the states, with Madhya Pradesh having the lowest average yield. This low yield can be a reflection of poor soil health, lower water retention in the soil and less access to training on best practices, technology, etc. More noteworthy is the variation in yield between the agricultural practices, with the REEL farms having three times as much yield as the organic farms. This can be due in part to the seeds used on organic farms, which must be organic and may be lower producing seeds than those used on REEL or conventional farms. REEL farms also out-performed the conventional farms with 1.5 times as much yield.

Table 13 - Yield per state and practice: 2013 growing season

Agricultural Practice	Yield (tonnes/ha)			Average
	Madhya Pradesh	Gujarat	Maharashtra	
Conventional	1.49	2.30	2.01	2.05
REEL	n/a	3.20	3.49	3.24
Organic	n/a	1.15	1.06	1.11
State Average	1.49	2.63	2.06	

This variation in yield directly impacts the water footprint when measured relative to tonnes of production; higher yield indicates that the water consumed or assimilation capacity used is more productive, i.e. there is greater resource efficiency. This also results in a lower production water footprint.

Madhya Pradesh, with its low yield, had the highest green water footprint per tonne of production for conventional farming (Figure 12). Organic farms have the highest green water

footprint, reflecting the low yield from these farms, whilst REEL farms have the lowest green water footprint due to the high yields on those farms.

The lower green water footprint on REEL farms indicates that the land under cultivation is being used more productively. Each hectare of land is producing more cotton.

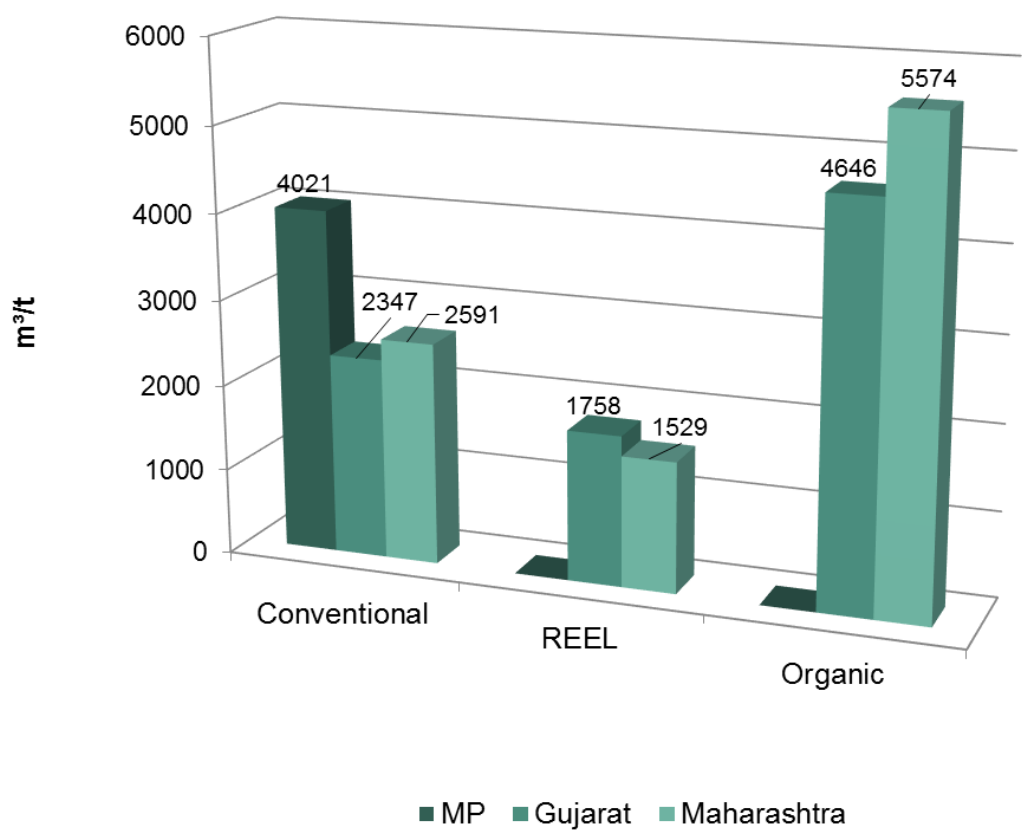


Figure 12 – Average green water footprint per tonne of cotton: 2013 growing season

The organic farms of Gujarat had the largest blue water footprint per tonne of cotton (Figure 13) produced due to their low yield. In contrast, Maharashtra was the least reliant on irrigation, with the smallest blue water footprint of the three states for conventional farming and no irrigation

used on the REEL farms. The largest blue water footprint per tonne of production in Maharashtra was again on the organic farms, due to the comparatively lower yield on these farms.

The REEL farms in Gujarat are using more irrigation water per hectare (361 m³/ha) than organic farms (289 m³/ha) in Maharashtra, yet have a lower blue water footprint per tonne of production. Increased yields through a range of agricultural practices increases the efficiency of water use.

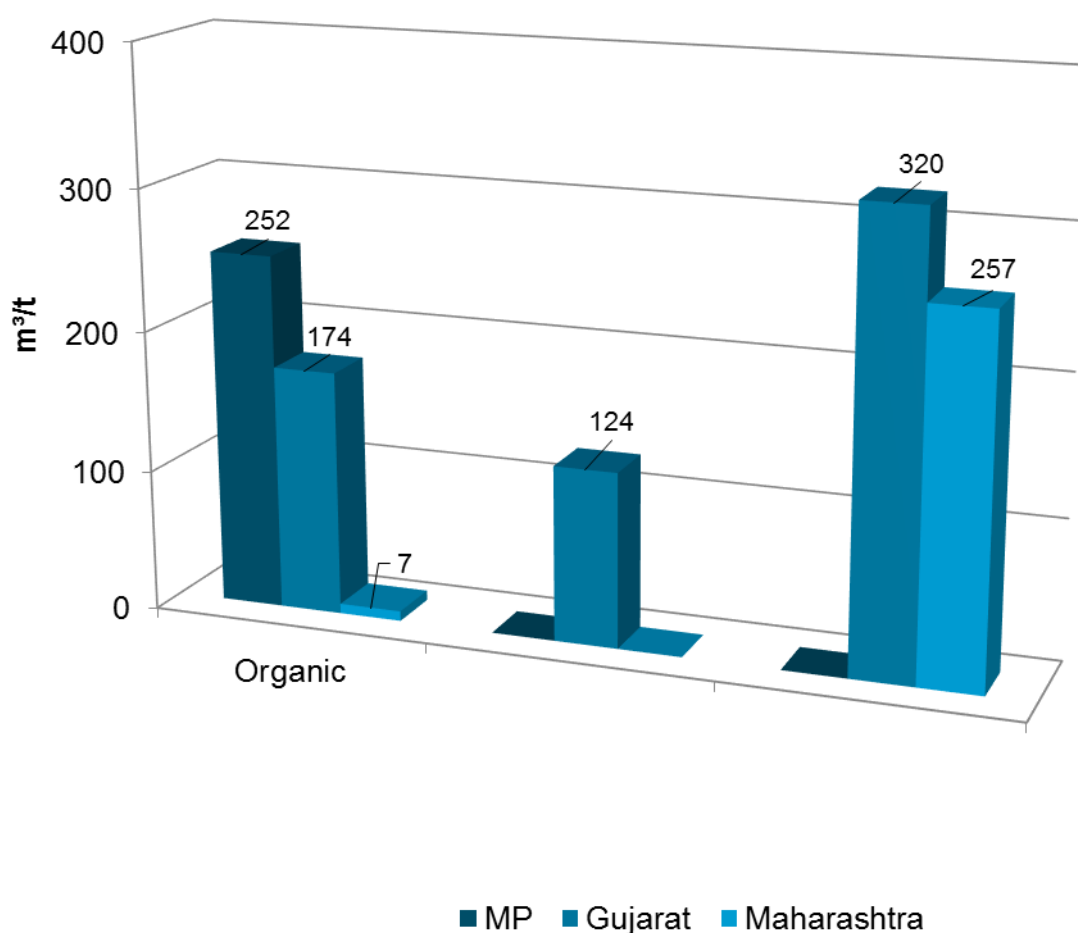


Figure 13 – Average blue water footprint per tonne of cotton: 2013 growing season

The variation in the grey water footprint seen in the previous section is repeated here, with an overall trend of decreasing volumes from conventional practice to REEL and organic.

The conventional farms of Gujarat generated an average grey water footprint 22 times higher than the state's organic farms, and in Maharashtra the conventional farms' grey water footprint was 122 times higher than the state's organic farms. If yields would increase, the grey water footprint per tonne of organic cotton would have an even stronger comparative advantage over REEL and conventional farms.

In addition, the average grey water footprint (Figure 14) of the conventional farms in Gujarat is 3 times greater than the REEL farms from the same state. The average grey water footprint of the conventional farms in Madhya Pradesh state is extraordinarily large - 333,766 m³/tonne. This large grey water footprint results from the use of highly toxic pesticides and the deleterious impact they have on water quality. Farms in Gujarat are the best performers across all three practices.

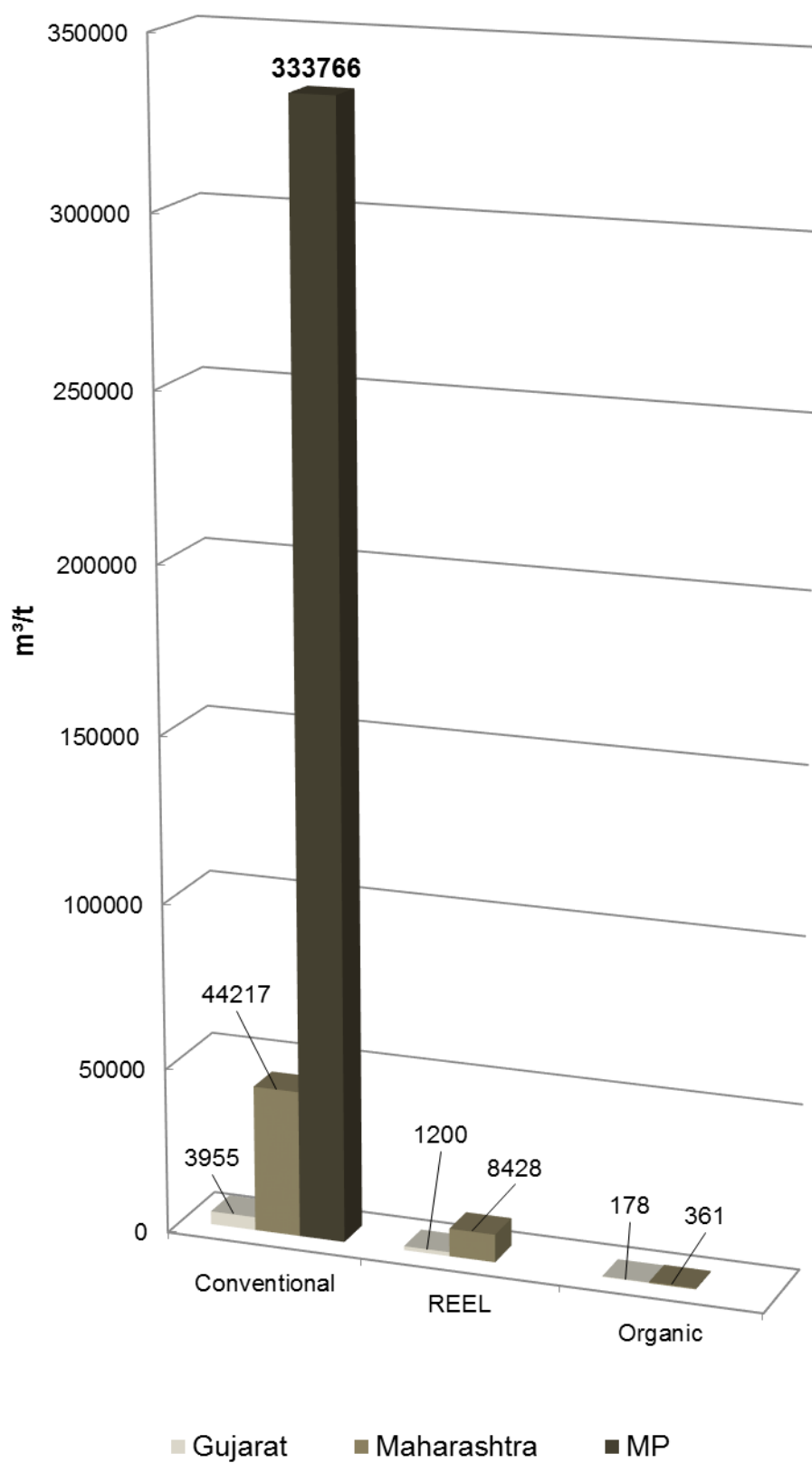


Figure 14 – Average grey water footprint per tonne of cotton: 2013 growing season

The total combined green, blue and grey water footprint (Figure 15) gives an indication of how much pressure a specific activity puts on freshwater resources, both in terms of quantity and quality. The total water footprint follows much the same pattern of the grey water footprint across the three practices and three states. This further highlights the dominant role of pesticides and their resultant grey water footprint in the production of cotton.

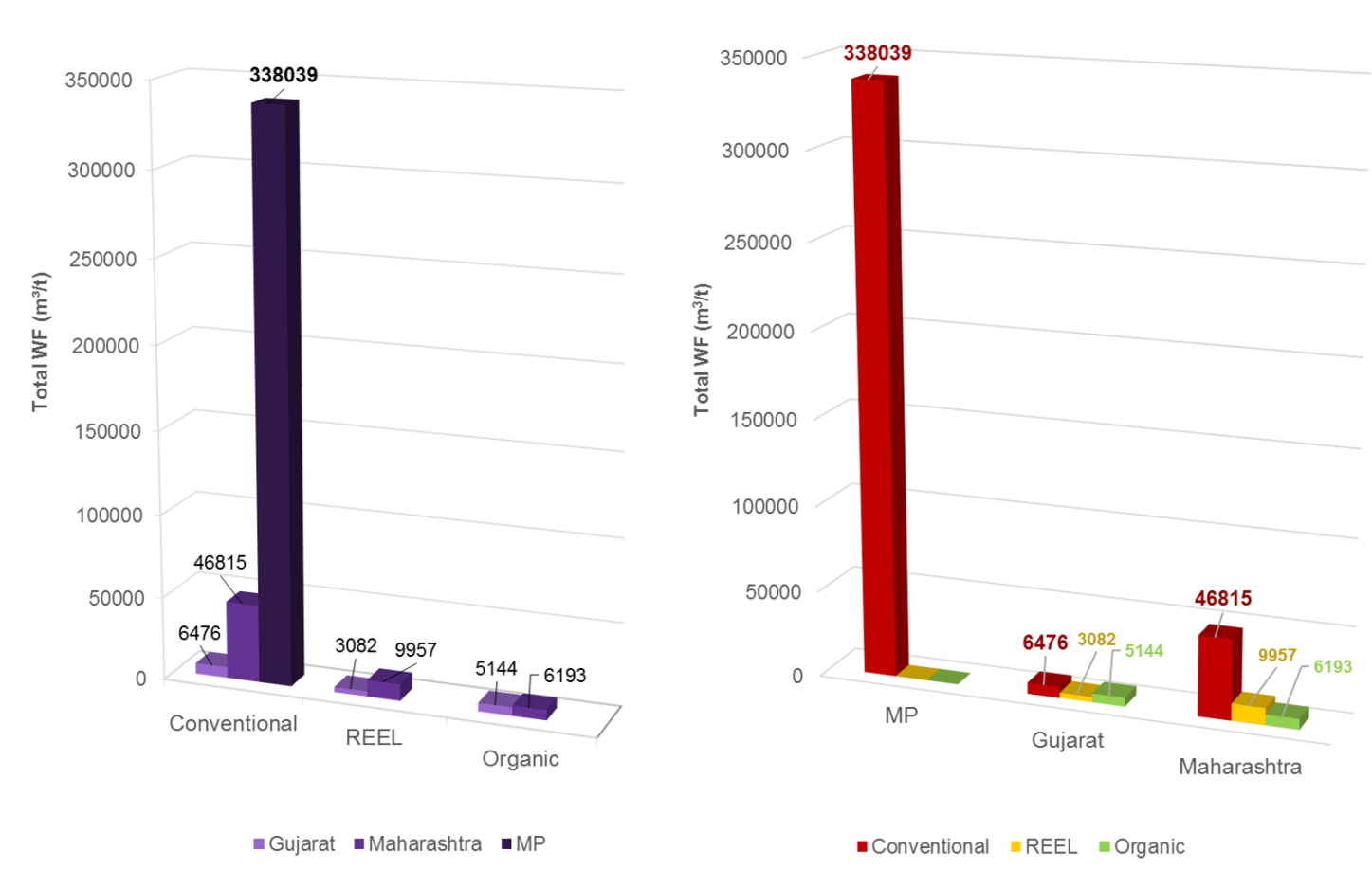


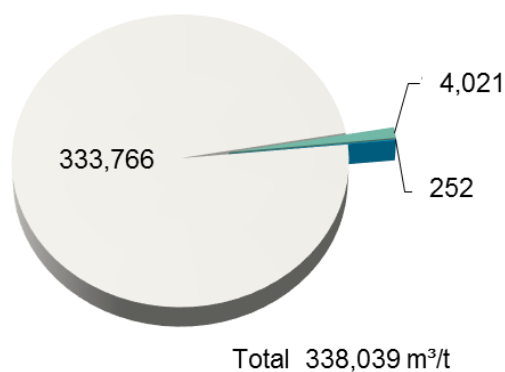
Figure 15 – Average total water footprint of cotton per practice and per state: 2013 growing season

The total water footprint in m³/tonne compares the relative resource efficiency of each agricultural practice across the three states.

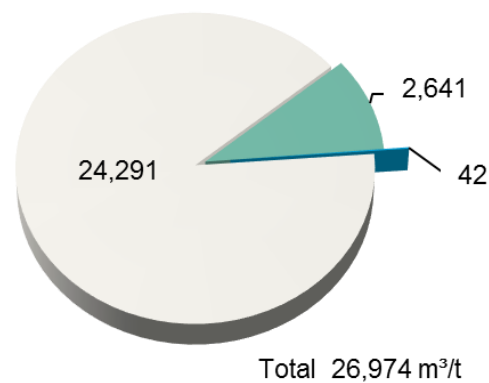
Farming is more resource efficient in Gujarat than the other two states, whether it is conventional, REEL or organic. REEL farms are resource efficient due to their high yields; organic farms are resource efficient due to less toxic inputs.

Combining the three agricultural practices (Figure 16) within each state, provides further insight into the variations in cotton production between states. Only conventional farms were sampled in Madhya Pradesh and the overall dominance of the grey water footprint is clear. The yield was also quite low, 1.49 tonnes per hectare, which also increases the size of the production water footprint in comparison to Gujarat (2.63 tonnes/ha) and Maharashtra (2.06 tonnes/ha).

Madhya Pradesh WF (m³/t)



Maharashtra WF (m³/t)



Gujarat WF (m³/t)

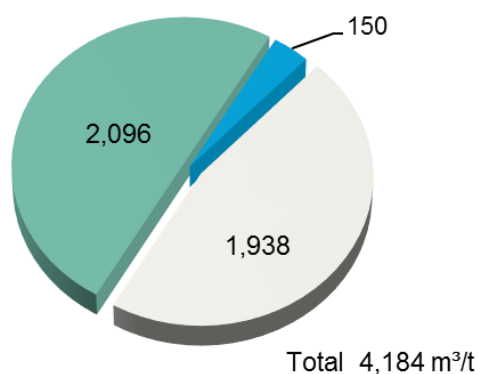


Figure 16 – Average green, blue and grey water footprint per tonne of cotton: 2013 growing season

As seen in the geographic assessment, cotton production on the farms included in this study is primarily rainfed, resulting in a relatively larger green than blue water footprint. The Maharashtra farms have very little impact on blue water resource per tonne of cotton produced. In Gujarat, the impacts of cotton production on water quantity (scarcity) and water quality (pollution levels) is relatively balanced.

Focusing on improving yields in organic farming would drastically reduce the total water footprint. It would result in organic having the lowest overall water footprint of all the farming methods studied.

3.3.2 Water footprint of cotton agriculture at farm level

The average water footprints presented above provide a generalised overview of the three agricultural practices in the three states and are useful to identify key trends and comparisons. A closer look at individual farms deepens the understanding of each of the practices, highlights the variations between farms and the ranges within each of the practices. This demonstrates the variability in efficiency, i.e. volume of water consumed per tonne of cotton produced from farm to farm. Most of this variation is linked to the productivity of each state, which is controlled by several human factors but also to environmental differences, i.e., climate and soil.

3.3.2.1 Water footprint of conventional cotton

Madhya Pradesh conventional farms have the highest average green water footprint (Figure 17) at 4021 m³/tonne, in part due to the low yield from these farms. Maharashtra farms have the lowest green water footprint per hectare but with its higher yield, Gujarat farms have the lowest green water footprint of the three states at 2,347 m³/tonne.

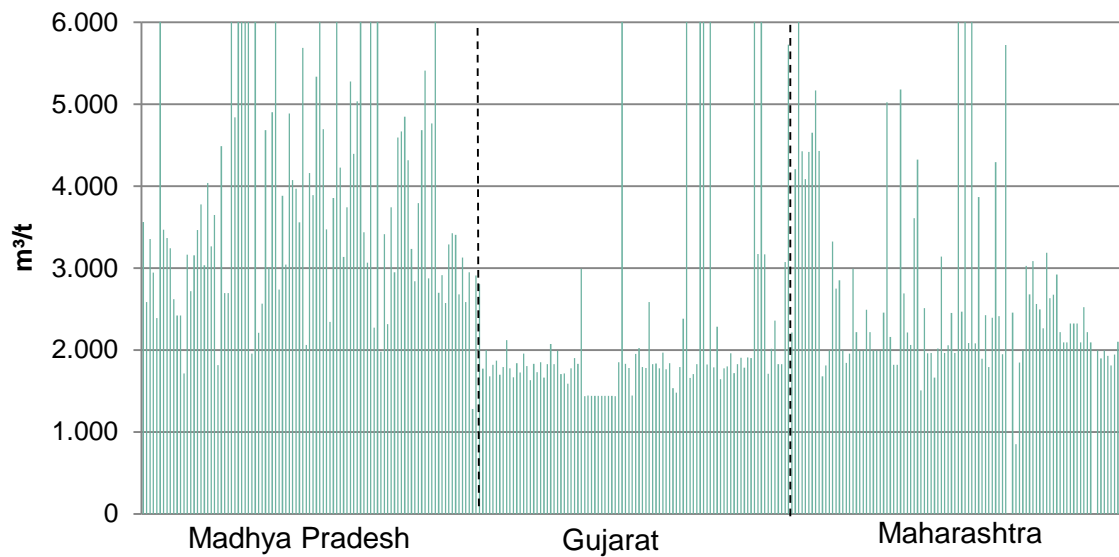
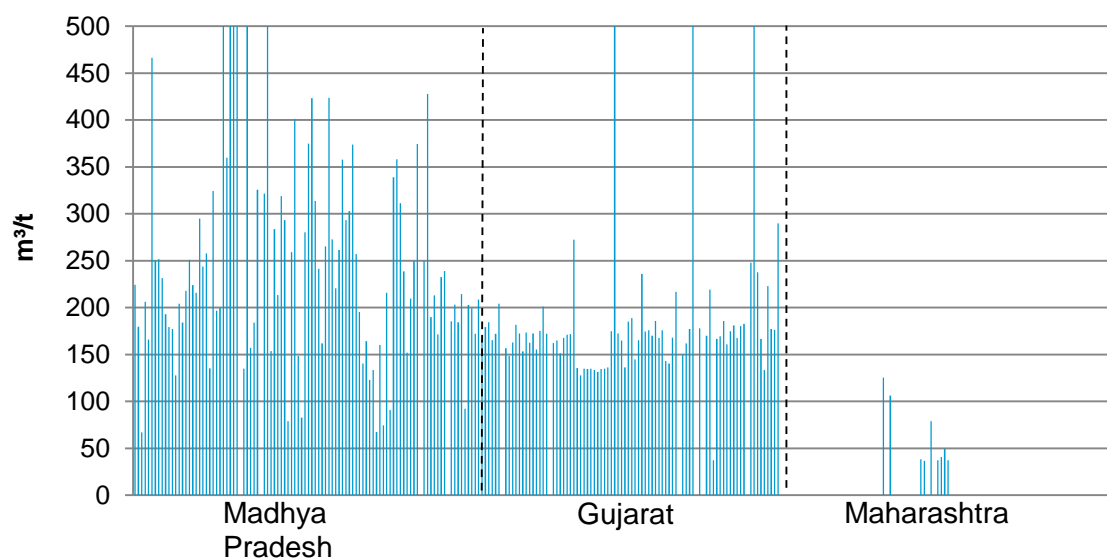


Figure 17 – Green water footprint of individual conventional cotton farms

Very few conventional farms (Figure 18) in Maharashtra used irrigation. Whilst Madhya Pradesh farms used less irrigation water per hectare ($372 \text{ m}^3/\text{ha}$) than the Gujarat farms ($464 \text{ m}^3/\text{ha}$), the blue water footprint per tonne was higher on these farms, again due to the lower yield. There is also greater variation in the blue water footprint between farms in Madhya Pradesh.



Note: The non-occurrence of a blue water footprint indicates a purely rainfed system, as can be seen for the majority of conventional farms in Maharashtra. There are a handful of farms whose values are much higher than the rest – these have been truncated by the scale beyond 500 m³/tonne, and are the result of very low yields in individual cases, or inaccurate data in the FFB.

Figure 18 - Blue water footprint of individual conventional cotton farms

The grey water footprint, shown using a logarithmic scale, varies dramatically (Figure 19) with averages from 3,955 m³/tonne for Gujarat, 44,217 m³/tonne for Maharashtra and 333,766 m³/tonne for Madhya Pradesh.

There are significant variations between farms within each state; whilst the average for the state indicates an overall level of performance, in each state there are farms with lower grey water footprints, indicating better performance.

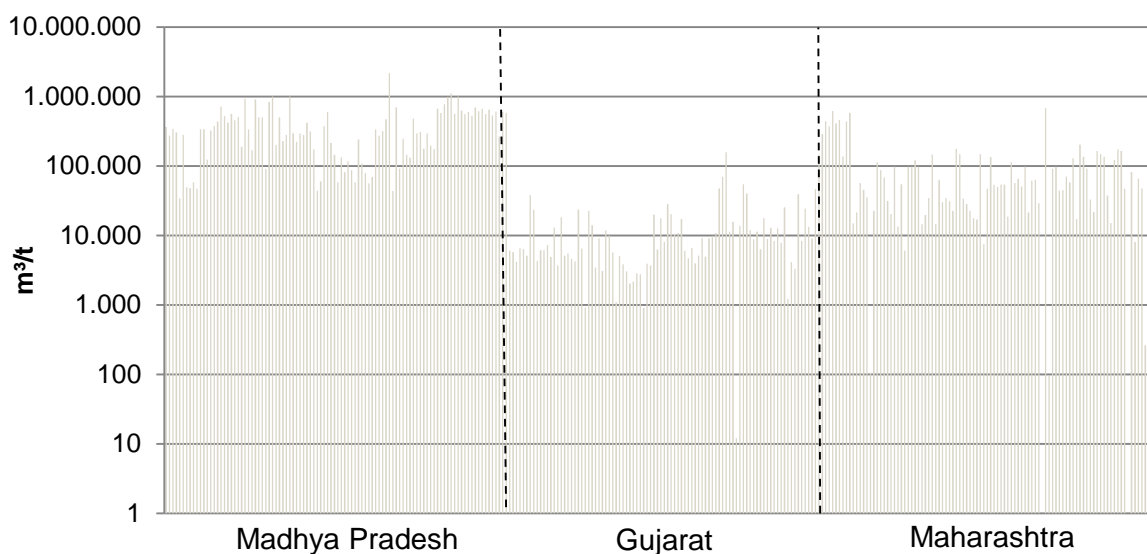


Figure 19 – Grey water footprint of individual conventional cotton farms

The grey water footprint for each farm is determined by the critical pollutant, i.e., the pollutant (Table 14) that results in the highest grey water footprint.

The critical pollutant may be the most toxic of the chemicals used or it may be that more of the chemical was applied. When nutrients – Nitrogen and Phosphorus – appear as critical pollutants, this is an indication of over fertilisation.

Cypermethrin was the critical pollutant for 61 farms, averaging a grey water footprint of 492,666 m³/tonne. Cypermethrin is commonly used on conventional cotton farms to address Bollworm, Jassid and thrips. This is followed closely by Methamidophos-580, which was the critical pollutant on 9 farms and has a grey water footprint of 439,622 m³/tonne. Methamidophos-580 is not as commonly used as it is classed as a highly hazardous pesticide, which has been banned in some countries but not yet in India. It is used to control chewing, mining and sucking insects. Alternatives to these two pesticides exist, including natural bio-pesticides. Phosphorus-based fertilisers were also very impactful; they were the critical pollutant on 112 farms, averaging 91,933 m³/tonne.

Table 14 - Critical pollutants for conventional cotton farms: 2013 growing season

Critical Pollutant	No. of Farms	Average Grey Water Footprint (m³/tonne)
Cypermethrin-100/250	61/2	492,666
Methamidophos-580	9	439,622
Polytrin-C 440-40	5	137,945
Difenoconazole-250	7	111,453
Dimethoate-300	40	95,562
Phosphorus	112	91,933
Acetamiprid	1	39,271
Diafenthiuron-500	33	39,150
Thiamethoxam-250	19	4,377

The conventional farms from the 2012 growing season have a lower grey water footprint (Table 15) than those in 2013. Monochrotophos was the most frequent critical pollutant on 30 conventional farms in the 2012 growing season.

Table 15 - Critical Pollutants for conventional farms: 2012 growing season

Critical Pollutant	No. of Farms	Average Grey Water Footprint (m³/tonne)
Deltamethrin	1	191,270
Acephate	5	157,259
Chlorpyrifos	5	113,869
Monochrotophos	30	111,635
Diafenthiuron	3	47,826
Prophenophos	5	24,241
Triazophos	1	19,802
Imidacloprid 700	1	14,193

3.3.3 Water footprint of REEL cotton

The green water footprint for REEL farms (Figure 20) in Maharashtra averages 1,529 m³/tonne, whilst Gujarat averages 1,758 m³/tonne in comparison to 2,591 m³/tonne and 2,347 m³/tonne for conventional farms, respectively.

The lower green water footprint of REEL farms reflects the higher yield on these farms and, therefore, greater resource efficiency; less land and water are used to produce each tonne of cotton.

Gujarat shows more variability in the green water footprint, either due to poor yields or inaccuracies in the data. Several of the farms in Maharashtra are more water efficient (lower green water footprint), without compensating with irrigation.

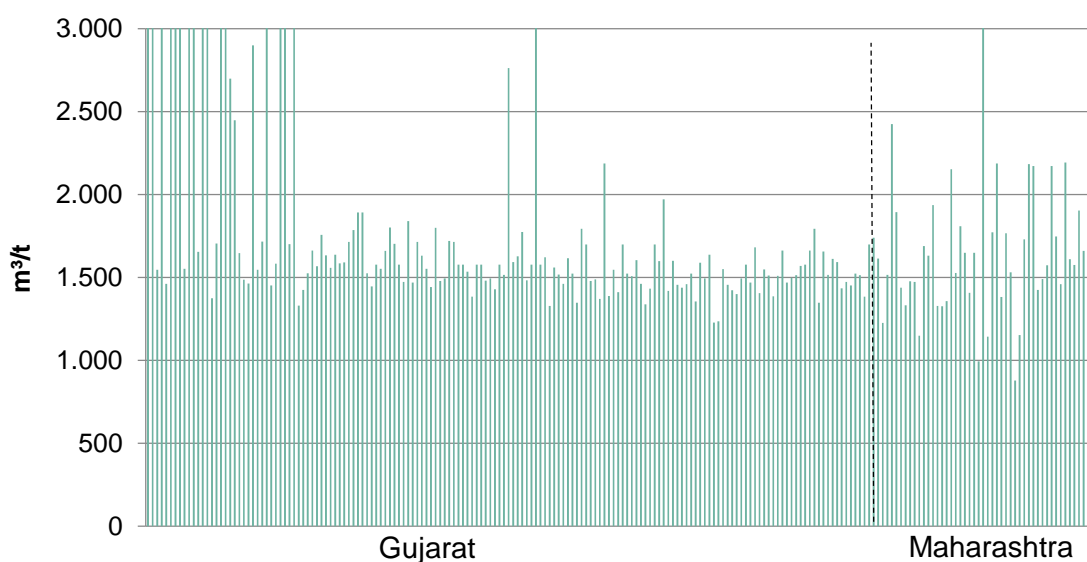


Figure 20 – Green water footprint for individual REEL farms

No REEL farms (Figure 21) in Maharashtra used irrigation. Whilst, nearly all REEL farmers in Gujarat irrigated their land. With the high yield on the REEL farms, the blue water footprint per tonne of cotton averages 124 m³/tonne.

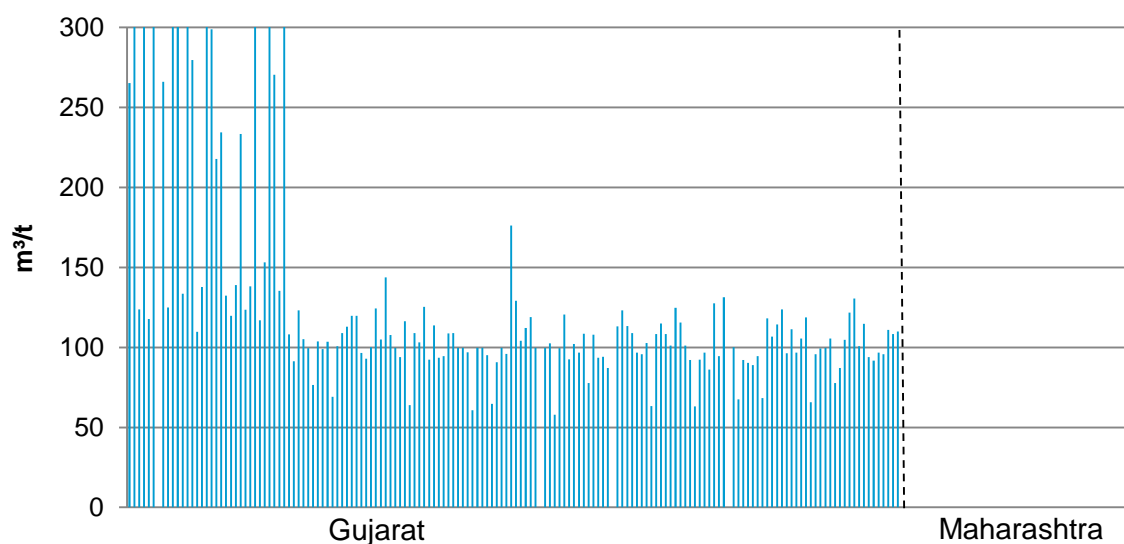


Figure 21 - Blue water footprint for individual REEL farms

The average grey water footprint for REEL farms (Figure 22) is significantly lower than the conventional farms, with an average of 1,200 m³/tonne. The grey water footprint in Maharashtra for REEL farms averages 8,428 m³/tonne, which is 7 times higher than REEL farms in Gujarat.

The high yields of REEL farms in Maharashtra (3.49 m³/ha) is produced without irrigation, hence no blue water footprint but they have a higher grey water footprint than REEL farms in Gujarat.

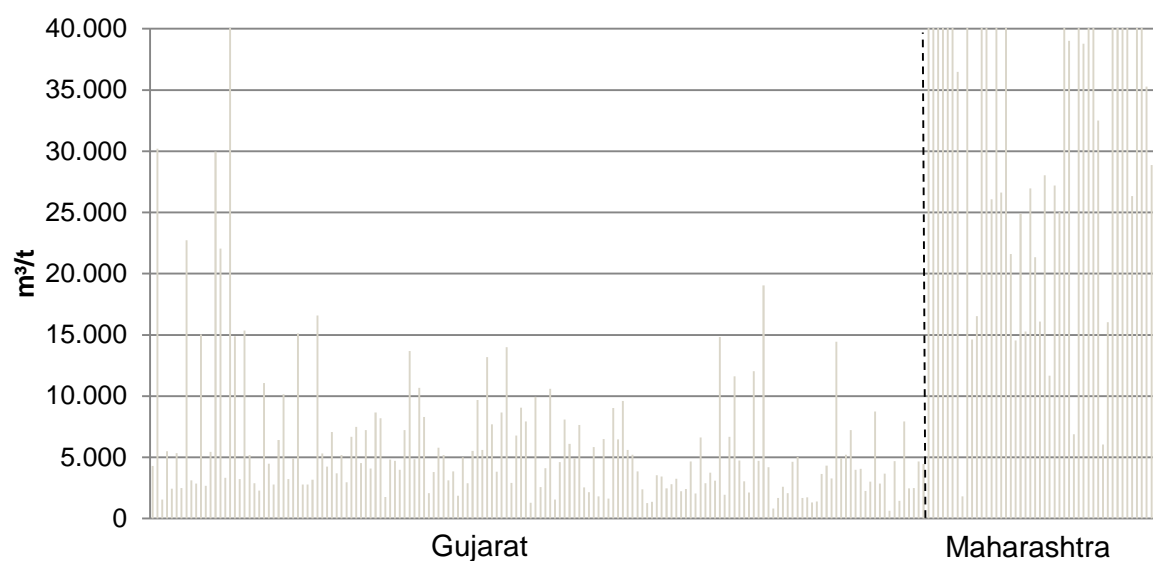


Figure 22 – Grey water footprint for individual REEL farms

The average grey water footprint for REEL farms in Maharashtra is about half of the conventional grey water footprint in that state, yet it is still three times higher than the conventional average grey water footprint in Gujarat. This is due to the pesticide Diafenthiuron-500, which can be seen amongst the critical pollutants (Table 16) that determine the grey water footprint.

Table 16 – Critical pollutants for REEL farms: 2013 growing season

Critical Pollutant	No. of Farms	Average Grey Water Footprint (m³/tonne)
Diafenthiuron-500	22	30,122
Phosphorus	123	16,976
Thiamethoxam-250	16	5,232
Dimethoate-300	48	4,875

Just as in the conventional farms, the REEL farms' grey water footprint is generally attributed to pesticides. It is important to note that the critical pollutant for 123 of the 209 farms resulted from Phosphorus-based fertilisers, averaging 16,976 m³/tonne.

Phosphorus is also an issue in the 2012 growing season; it is the critical pollutant (Table 17) for 25 farms. As was seen in the conventional farms from 2012, Monochrotophos was used most frequently. It is a chemical that treats a number of pests including mealybug, white fly, thrips, jassids and the red cotton bug, to name a few. It appeared as a critical pollutant on 291 farms, averaging 53,736 m³/tonne.

Table 17 – Critical pollutants of REEL farms: 2012 growing season

Critical Pollutant	No. of Farms	Average Grey Water Footprint (m³/tonne)
Deltamethrin	6	136,514
Chlorpyrifos	11	106,643
Phosphorus	25	69,870
Monochrotophos	291	53,736
Imidacloprid 700	3	46,695
Acephate w/w	33	42,471
Diafenthiuron	11	40,844
Spiromesifen	1	17,596
Prophenophos	10	15,744

3.3.4 Water footprint of organic cotton farming

The average green water footprint (Figure 23) of organic farms in Gujarat is 4,646 m³/tonne and 5,574 m³/tonne in Maharashtra. Looking across practices from conventional to REEL to organic practices, there is an evident progression towards more sustainable practices, which are resulting in lower total water footprints. However, in terms of efficiency, when looking at the green water footprint alone, organic cotton is the poorest amongst the three practices, due to the poor yields. The variability in the green water footprints between farms is indicative of the ranges of yield from these farms; those farms with a lower green water footprint have higher yields.

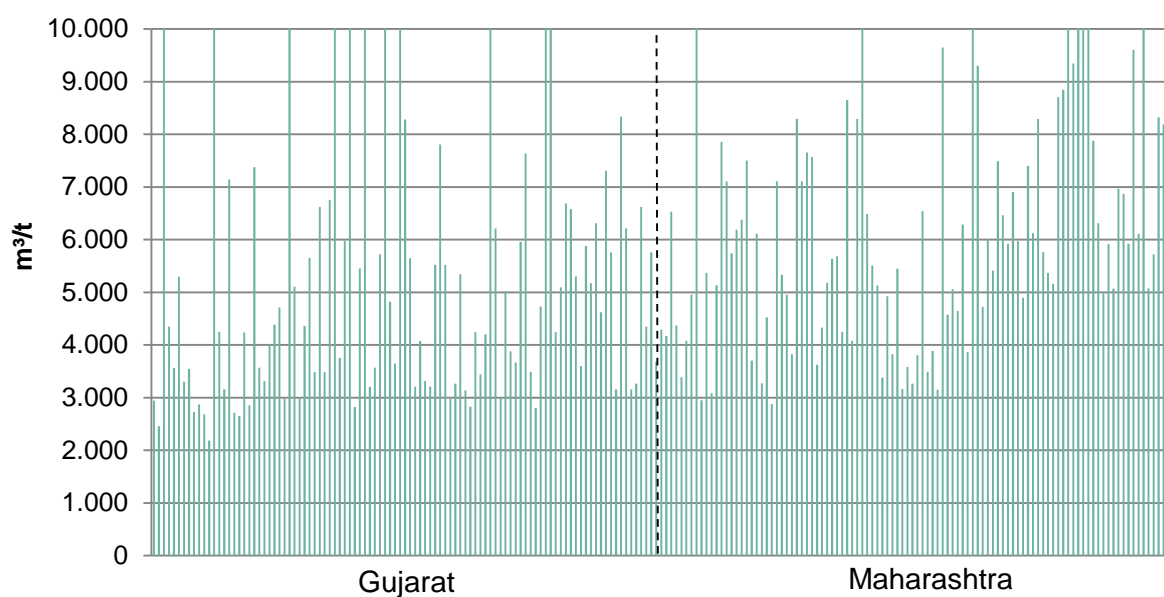


Figure 23 – Green water footprint for individual organic cotton farms

The average blue water footprint for organic farms (Figure 24) in Maharashtra is 257 m³/tonne, with about a quarter of the farms not irrigating at all. The average blue water footprint in Gujarat is 320 m³/tonne, with the majority of the farms using irrigation. This is more than twice the blue water footprint per tonne for REEL farms in Gujarat, which is reflective of the lower yield when compared to the REEL farms.

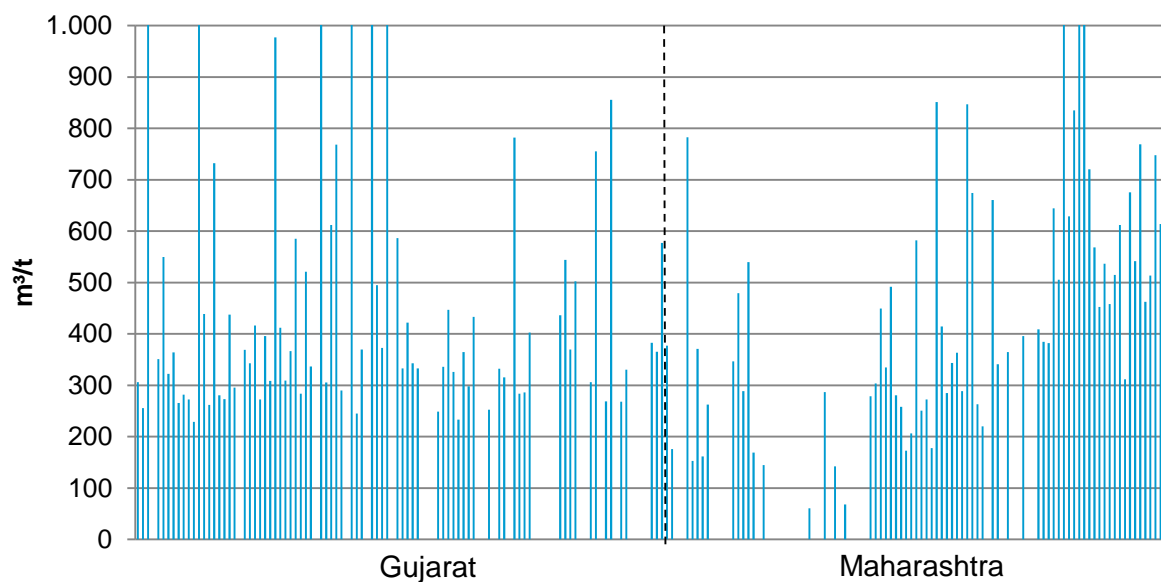


Figure 24 – Blue water footprint for individual organic cotton farms

The variability of the green and blue water footprint in organic farms is much greater than in REEL farms. This reflects the range of yields experienced in organic farming when compared to the REEL farms.

Organic farms have the greatest advantage over conventional and REEL farming in the grey water footprint; they have a substantially lower grey water footprint (Figure 25) when compared to the other practices. The organic farms of Gujarat have an average grey water footprint of 178 m³/tonne, whilst Maharashtra averages 361 m³/tonne.

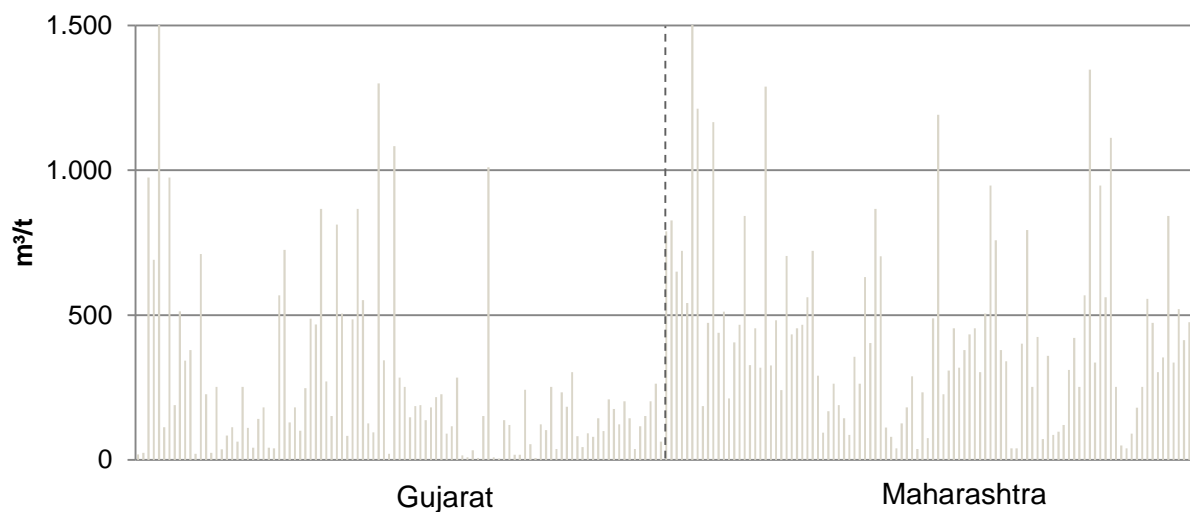


Figure 25 – Grey water footprint for individual organic cotton farms

The critical pollutants (Table 18) for the organic farms were fertilisers. Nitrogen was the critical pollutant on 176 farms and, whilst it resulted in a relatively small water footprint, it should still be noted due to the negative impacts Nitrogen runoff can have on freshwater ecosystems.

Table 18 – Critical pollutants for organic farms: 2013 growing season

Critical Pollutant	No. of organic farms	Average Grey Water Footprint (m³/tonne)
Nitrogen	176	353
Cow Urine	24	42
Buttermilk	3	6

3.4 Relationships between agricultural practices, water footprint and yield

3.4.1 Irrigation practices, blue water footprint and yield

Whilst the farms in this study are situated in a sub-tropical climate receiving plenty of rain in the form of monsoons, there can still be dry spells between rain events. This is when irrigation systems are put to use. There are many types of systems available yet the most common irrigation practice is furrow where the furrows between plants are flooded with water. However, it is not the most efficient. In furrow or sprinkler irrigation only about 70% of the water supplied effectively reaches the root zone, whilst the remainder is evaporated or lost in return flow⁵. The most efficient alternative is drip irrigation (Muhammad et al., 2010), a grid-like network of pipes and hoses that lay on the ground in furrows and supply water directly to the root zone of the plants in drops. Drip irrigation efficiency is closer to 90% (e.g. Brouwer et al., 1989).

Drip irrigation (Table 19) was used on farms included in this study but only on a small number of farms. The biggest barrier to its use is cost and installation and maintenance challenges when growing more than one crop. Drip irrigation was not associated with any particular farming practice.

Table 19 – Number of active vs. total drip irrigation systems: 2013 growing season

Drip Irrigation (active / total)	Madhya Pradesh	Gujarat	Maharashtra	Total
Conventional	19 / 19	-	7 / 53	26 / 72
REEL	-	5 / 5	0 / 29	5 / 34
Organic	-	4 / 4	9 / 9	13 / 13
Total	19 / 19	9 / 9	16 / 91	44 / 119

⁵ These efficiencies are consistent with the AquaCrop Reference Manual Annex (Raes et al., 2010) depending on irrigation method.

Many farms with drip irrigation systems only apply them to a part of their fields and others do not make use of them, even though they claim to have them, as can be seen from the number of active/total systems, especially in the state of Maharashtra. It appears the farmers of Maharashtra have made use of drip irrigation systems in the past; however, this seasonal data shows that a number of them have decided not to continue their use (often due to damage to the pipes), as evidenced by the low ratio of active systems. Meanwhile, Gujarat and Madhya Pradesh made full use of their drip irrigation systems, although on a low number of farms.

Table 20 – Blue water footprint of farms using drip irrigation: 2013 growing season

Blue Water Footprint (m³/ha)	Madhya Pradesh	Gujarat	Maharashtra	Average
Conventional	409	-	137	336
REEL	n/a	331	-	331
Organic	n/a	496	420	444
Average	409	474	296	382

When more efficient irrigation systems are applied, this may reduce the non-productive water use, i.e., the irrigation water (Table 20) that is used is taken up by the roots and transpired through the plants, not evaporated from the soil surface. Reduced evaporation from the soil will reduce the portion of the blue water footprint (m³/ha) coming from non-productive irrigation, i.e., evaporation instead of transpiration.

Table 21 – Blue water footprint of farms using furrow irrigation: 2013 growing season

Blue Water Footprint (m³/ha)	Madhya Pradesh	Gujarat	Maharashtra	Average
Conventional	383	498	188	383
REEL	n/a	388	-	388
Organic	n/a	501	401	454
Average	383	445	395	427

Comparing the blue water footprint for farms using drip irrigation with those using furrow irrigation indicates a general trend of a reduced blue water footprint on farms using drip irrigation, except for the organic farms in Maharashtra.

The average blue water footprint on farms using drip irrigation is 382 m³/ha, whilst those using furrow averaged 427 m³/ha, a difference of 12% in the blue water footprint.

Table 22 - Yield on farms with drip irrigation: 2013 growing season

Yield (tonnes/ha)	Madhya Pradesh	Gujarat	Maharashtra	Average
Conventional	1.71	-	2.37	1.89
REEL	n/a	2.08	-	2.08
Organic	n/a	1.47	0.85	1.04
Average	1.71	1.81	1.51	1.66

A comparison of the yields coming from the farms using drip (Table 22) versus furrow (Table 23) irrigation shows that, in all but organic farms in Gujarat, the farms using furrow irrigation had higher yields. However, one must be careful about generalising this conclusion as irrigation practices are just one contributing factor to improving yields and the sample size is very small.

Table 23 – Yield on farms with furrow irrigation: 2013 growing season

Yield (tonnes/ha)	Madhya Pradesh	Gujarat	Maharashtra	Average
Conventional	1.74	2.88	2.58	1.74
REEL	n/a	3.42	-	3.42
Organic	n/a	1.31	1.13	1.23
Average	1.74	2.79	1.18	2.37

When comparing yield (Table 24) on rainfed versus irrigated farms, irrigated farms (Table 25) in Madhya Pradesh had a higher yield – 1.74 tonnes/ha compared to 1.13 tonnes/ha on rainfed farms. In Gujarat also, the irrigated farms had a higher yield than rainfed farms.

Table 24 – Yield from rainfed farms: 2013 growing season

Yield (tonnes/ha)	Madhya Pradesh	Gujarat	Maharashtra	Average
Conventional	1.13	0.79	2.01	1.62
REEL	n/a	2.41	3.49	3.25
Organic	n/a	0.83	2.01	0.96
Average	1.13	1.09	2.29	1.89

The anomaly comes in Maharashtra where yield from rainfed farms exceeded those that were irrigated. This can be due to less pest infestations occurring on rainfed farms. Irrigated farms can have more susceptibility to pests.

The best performance in terms of yield came from rainfed REEL farms in Maharashtra followed closely by REEL farms in Gujarat that were irrigated.

Table 25 – Yield from irrigated farms: 2013 growing season

Yield (tonnes/ha)	Madhya Pradesh	Gujarat	Maharashtra	Average
Conventional	1.74	2.88	2.42	2.28
REEL	n/a	3.38	-	3.38
Organic	n/a	1.32	1.10	1.21
Average	1.74	2.76	1.24	2.31

Care must be taken when interpreting these results due to the small number of farms. The irrigation amounts reported in the Farmer Field Books were much larger than the results from AquaCrop. Farmers reported using ten times as much irrigation water – a total of 6,724,671 m³/y. Roughly 60% of the incoming precipitation and irrigation is lost to runoff. Much of this is attributed to the clay type soils. Clay soils have a very low hydraulic conductivity, poor drainage, high porosity and act as a confining layer, which makes it difficult for water to enter the soil matrix without ploughing the surface. Once water has entered the soil matrix; however, the clay layer expands like a sponge as it is highly porous and retains water relatively well, due to the water molecules adhering to the minute clay particles. This means that it is difficult for water to penetrate the root zone, which is where the plants have access to it and can make use of it productively.

3.4.2 Pesticide and fertiliser use, grey water footprint and yield

Pesticides and fertilisers are commonly used in an effort to increase crop yield by reducing the impacts of pests and improving crop nutrition. As shown in the previous section, the use of pesticides and fertilisers results in a grey water footprint; depending on the chemical used and its application, this grey water footprint can be quite large. To better understand this dynamic, the relationship between the grey water footprint and yield was plotted for each of the three practices per state.

3.4.2.1 Gujarat farms

In the case of Gujarat, the relationships between yield, grey water footprint and agricultural practice (Figure 26) are quite clear. In the lower left of the graph, the organic farms have yields of 0.2 – 2.2 tonnes/ha, with a grey water footprint from 4 – 100 m³/ha. The conventional farms are cantered around 3 tonnes/ha in two groups, one with a grey water footprint between 50 and 250 and another around 2,200 m³/ha. This reflects the use of different pesticides and the related levels of grey water footprint. The majority of the REEL farms range in yield from 3-4 tonnes/ha, with three groupings for the grey water footprint: less than 100 m³/ha, from 100 – 1000 m³/ha and above 1000 m³/ha.

The REEL farms with a grey water footprint less than 100 m³/ha are the best performers. They match the grey water footprint of organic farms but have twice the yield. Reducing the grey water footprint and maintaining yields as demonstrated on these farms will improve the sustainability of cotton production.

Whilst it is not possible to know without further testing if pesticides that result in a lower grey water footprint were substituted for those that result in a higher grey water footprint whether healthy crops and high yields would be maintained, the results from the REEL farms give a preliminary indication that it is possible to delink the use of toxic chemicals from yield.



Figure 26 – Grey water footprint versus yield in Gujarat: 2013 growing season

3.4.2.2 Maharashtra farms

In Maharashtra, the organic farms are in a cluster with yields between 0.25 and 2 tonnes/ha and corresponding grey water footprint ranging between 31 and 4500 m³/ha. Conventional farms have a wider distribution, with the majority of farms having a yield between 2.0 and 3.0 tonnes/ha and a grey water footprint between 10,000 and 100,000 m³/ha. The majority of REEL farms are clustered similarly to the conventional farms with regard to grey water footprint but with a higher yield between 3.0 and 4.0 tonnes/ha.

In all three practices, there are some farms (Figure 27) that are achieving yields that are characteristic of that agricultural practice with lower levels of grey water footprint. However, for all three practices, the largest groupings of farms have the higher grey water footprints associated with that practice. There is not as much distinction between the conventional and REEL farms in terms of grey water footprint, although the REEL farms have higher yields for the same levels of pollution.

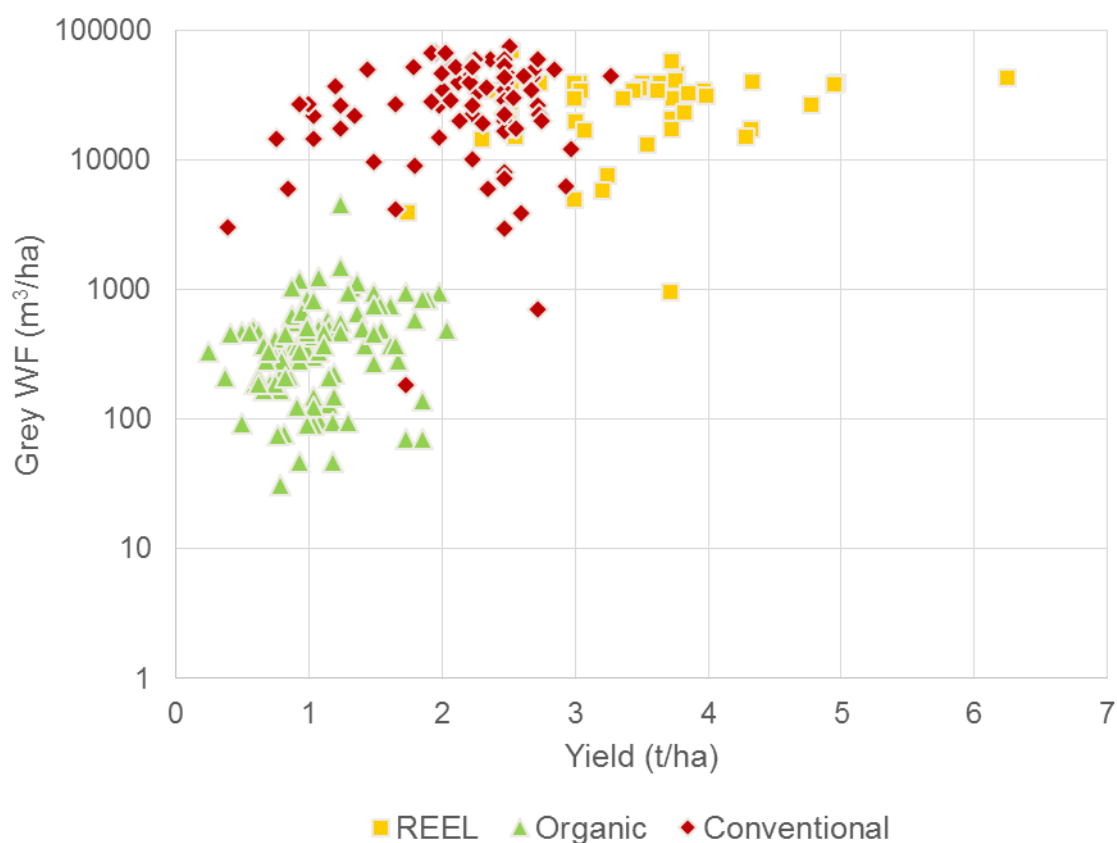


Figure 27 – Grey water footprint versus yield in Maharashtra: 2013 growing season

3.4.2.3 Madhya Pradesh farms

In Madhya Pradesh, the conventional farms (Figure 28) perform the poorest of the three states in this study, with a very high average grey water footprint, whilst achieving a moderate yield. Whilst there are a few farms with a smaller grey water footprint, the majority have the largest grey water footprint of all farms included in the study. The majority of farms yield 1.0 – 3.0 tonnes per hectare, with some farms achieving these yields with lower grey water footprints.

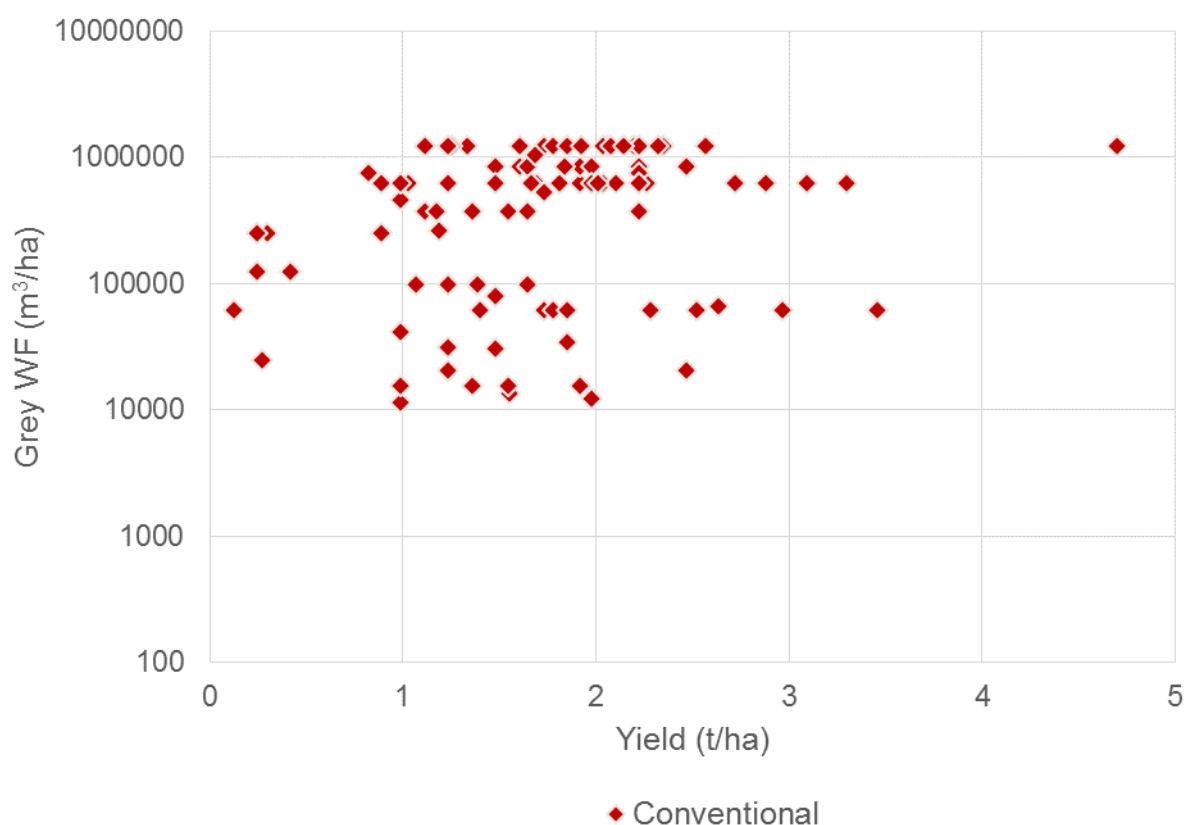


Figure 28 – Grey water footprint versus yield in Madhya Pradesh: 2015 growing season

Whilst some use of pest management and nutrient use to boost soil fertility will always be necessary, the analysis here clearly shows that high yields can be attained with less pollution.

Even within practices, there are significant differences in the choices of pesticide and fertiliser use.

And the inverse is also true, using pesticides and fertilisation schemes that produce a high grey water footprint may not payoff with higher yield.

When considering sustainable sourcing of cotton, it is essential to manage pests and soil fertility with lower grey water footprints. The farms in this study demonstrate that reduced environmental impacts and improved livelihoods through an increase in yields can be achieved.

3.4.3 Other relationships

Each farm is unique, both due to its intrinsic local and regional environmental characteristics but also because each farmer operates in his or her own way. Differences in water footprint per tonne were noted between farms. However, many achieved very similar results, which suggests a degree of knowledge sharing, or similar circumstances and available resources within a certain area. On the other hand, variability was observed even within the same village.

Other considerations that affect the outcomes at the farm level involve socio-economic factors and perhaps above all, level of experience and knowledge.

Farmers that are better trained, such as those in the REEL Cotton programme, are demonstrating a higher level of performance in yield whilst showing better performance in terms of pollution than conventional farms.

Therefore, whilst there are numerous environmental limitations, it is clear that specific human actions at the right time and scale can make a substantial impact on the water footprint.

3.5 Water footprint benchmarks

In addition to assessing the sustainability of cotton from the geographic perspective, where the water footprint is addressed in relation to the local context of blue water scarcity and water pollution levels, it is important to ensure that the water that is being used is as productive as possible. This study has highlighted the variation between farms and the levels of cotton produced for the amount of water consumed or polluted. Farms across the three agricultural

practices and the three states have had a range of green, blue and grey water footprints. The best performers of these farms can shed light on the potential for water footprint reduction and the specific practices that can lead to this.

*A strategy for sustainable sourcing should support continuous improvement.
The agricultural practices used by the farms with the lowest water footprints
can provide an example of what other farms can achieve.*

Global benchmarks have been developed to serve as reference levels towards which farmers can aim on a global scale (Mekonnen and Hoekstra, 2013). The benchmarks are based on the global dataset of water footprint values (Table 26) for the production of a specific crop, in this case for cotton.

*Benchmarks based on percentiles of performance elucidate what
can be reasonably expected from farmers and provide targets
for continuous improvement of agricultural practices.*

The 25th percentile, for example, can serve as a benchmark that then becomes a target for farms that are currently above this level. In this case, 25% of the cotton produced globally has a water footprint at or below this level. The remaining 75% of global production, by adopting agricultural practices that reduce the water footprint, can achieve this target level.

Table 26 – Global green, blue and grey water footprint distribution in percentiles.

Percentile	10 th	20 th	25 th	50 th	Global Average
Green + blue water footprint (m ³ /tonne)	1,666	1,821	1,898	2,880	3,589
Grey water footprint Nitrogen (m ³ /tonne)	0	63	175	469	440

Source: Mekonnen and Hoekstra (2014)

A larger number of farms and more years of data would be needed to develop regionally specific benchmarks. To give an indication of the water footprints of the best performers out of the 1,144 farms from the 2012 and 2013 growing seasons, the water footprints at the 10th, 20th,

25th and 50th percentiles are presented here. The 25th percentile represents the best performers when considering water use efficiency and can be used as a target for all farms to reach, in order to optimise water usage – ‘crop per drop’.

Table 27 – Green, blue and grey water footprint distribution: 2012 and 2013 growing season

Percentile	10th	20th	25th	50th	Local Average
Green + blue water footprint (m ³ /tonne)	1,446	1,621	1,692	2,163	3,383
Grey water footprint Pesticides (m ³ /tonne)	8	14	21	12,265	58,462
Grey water footprint Fertilisers (m ³ /tonne)	82	193	229	713	3,352

Comparison between the global benchmarks and the water footprints from the farms in this study shows a higher grey water footprint from Nitrogen fertilisers at these farms and a rapidly increasing grey water footprint related to pesticides.

3.5.1 Green + blue water footprint benchmarks

The green and blue water footprint have been added together and jointly assessed because this relates to the total evapotranspiration required for cotton production. The 25th percentile green+blue water footprint from the global study is 1,898 m³ per tonne. In this study, the 25th percentile is 1,692 m³ per tonne, which places these farms already in the top performers when considering the global green and blue water footprints.

3.5.2 Grey water footprint benchmark

Benchmarks for the grey water footprint are considered independently as they represent water quality pressures, not water quantity. The global study by Mekonnen and Hoekstra (2011) only assessed the grey water footprint of Nitrogen-based fertiliser and did not include the grey water footprint resulting from Phosphorus-based fertiliser, nor any pesticide. As such, there is no global average or benchmark for fertilisers and pesticides combined, only for Nitrogen-based fertilisers and their corresponding grey water footprint.

In this study, the grey water footprint has been assessed from the perspective of fertiliser, i.e., Nitrogen and Phosphorus, as well as pesticides. With regards to the grey water footprint for pesticides, the 25th percentile is 151 m³/tonne and for the grey water footprint of fertiliser only, it is 232 m³/tonne. The latter exceeds the global benchmark for Nitrogen although on some farms Phosphorus is the critical pollutant for the grey water footprint related to fertilisers. The rapidly increasing grey water footprint as evidenced by the local averages reflects the wide ranging values for the grey water footprint for farms in this study.

The farms with a water footprint higher than that generated by the top 25% of farms (i.e., the farms with the lowest water footprint per tonne of production) can aim for reducing their water footprint to the level of the top performers.

4 Response Formulation



Weeding a cotton field, Warangal District, Andhra Pradesh, South India.
Source: Jankle, taken on August 30, 2009

When considering a strategy for sustainable sourcing of cotton, two aspects of water use need to be addressed:

- the overall pressure on water resources; this must be understood in relation to local water resources; and
- the efficiency with which the water is being used, which is related to the productivity of the water, e.g., tonnes of cotton produced for the water consumed or polluted.

This report presents an in-depth analysis of cotton production across three states and three agricultural practices as a means for identifying key strategies to reduce the water footprint associated with cotton production and manage it sustainably.

The corporate water stewardship framework (Figure 29) provides a guideline for companies developing a business strategy related to water. It can be seen as a journey in which a company moves from addressing water in its direct operations stepwise, through to disclosure. It can also be used as a checklist for the components of a comprehensive cotton strategy.

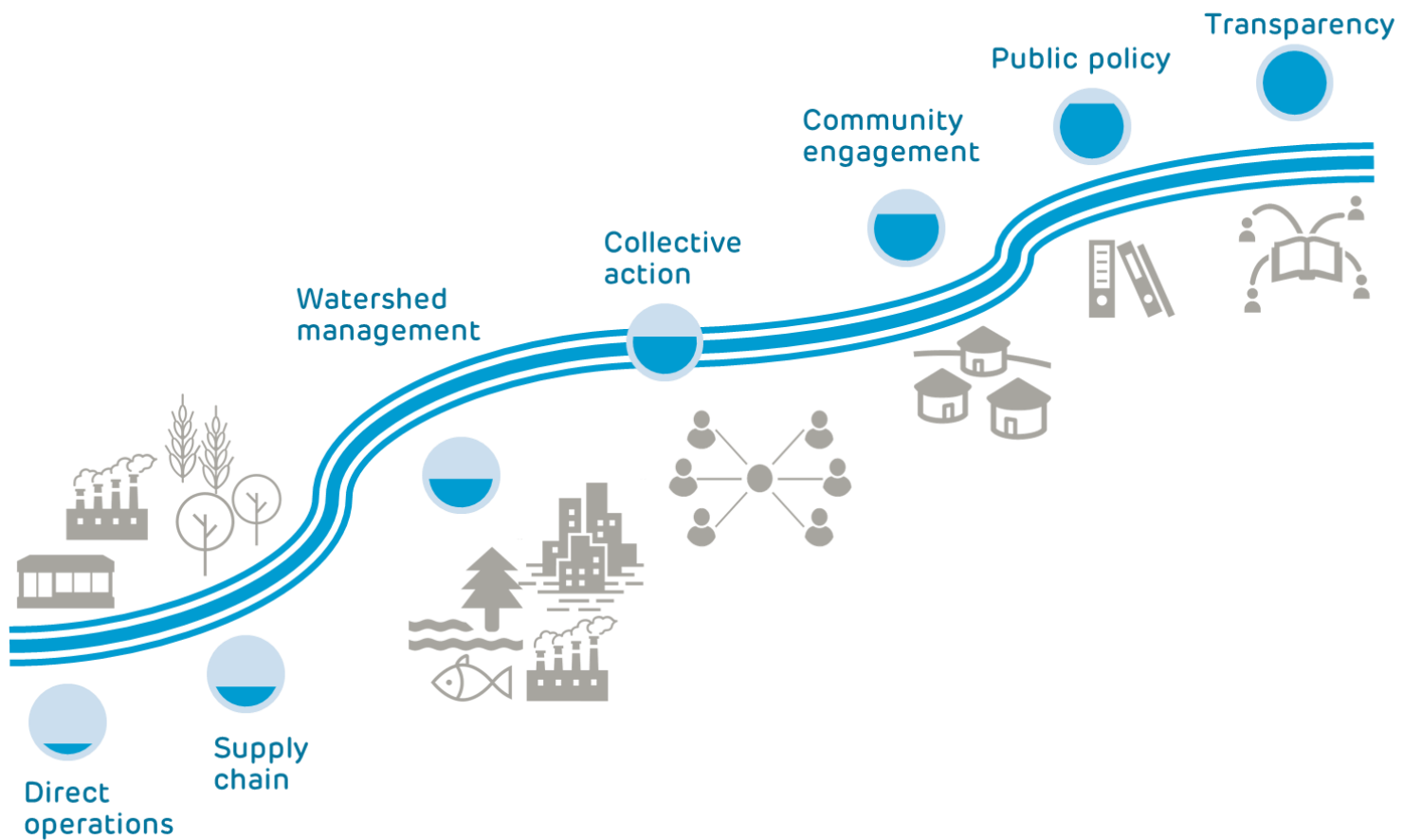


Figure 29 - Water Stewardship Journey, adapted from UN CEO Water Mandate

4.1 Recommended actions

With cotton clothing being the majority of sales by C&A, the company should address the ways in which cotton fibre is produced and how it impacts water and land resources. A range of strategic actions can be used, from awareness raising to farmer training, from investments in knowledge and technologies at the farm level to joining forces to transform the sector, from establishing policies that secure long term sustainability to disclosing the current state and the pathway to be taken to the desired future condition. This range of strategic actions can

contribute to C&A's water stewardship journey and to achieving sustainably produced cotton used in its products.

4.1.1 Direct operations

The water footprint of C&A's direct operations is small in comparison to the supply chain water footprint. It occurs primarily through lavatories and canteens in offices, retail stores and distribution centres. This water is supplied and treated through municipal services and regulated under the Water Framework Directive and other local regulations. However, C&A's employees and customers are a resource through which change on the ground can happen. Awareness raising that informs employees and customers about water sustainability issues where cotton clothing is produced, and the steps needed to produce cotton sustainably, can strengthen support for C&A's programmes in these areas. A recent survey indicated that water was the leading concern for C&A's customers; this interest should be harnessed for the betterment of cotton production, farmer's livelihoods, communities and the environment and the results communicated to customers.

C&A is already using the comparison between the grey water footprint from conventional versus organic cotton farming by Franke and Mathews (2013b), which showed a five times reduction in grey water footprint with organic cotton.

The current study further supports the benefits to water quality arising from moving from conventional to organic cotton with some conventional farms having a grey water footprint 40 to 60 times higher than organic farms.

This study also demonstrates that if less toxic chemicals are used, as was the case in Gujarat, across all three practices, it would be possible to reduce the total grey water footprint by 88% of 2013 levels for the same area of cotton production.

As customers understand the positive social, economic and environmental benefits of C&A's commitment to organic cotton, there will be more pressure on other brands to follow suit bringing a transformational, and pre-competitive, energy to the transition to a more sustainable cotton industry.

4.1.2 Supply chain

Considering that C&A globally sources significant quantities of cotton, C&A's global footprint on water resources from the cotton sold in its stores worldwide is considerable. This study confirms that there are significant water footprint savings possible with changes at the farm level. C&A's strategy for engagement with farmers should include:

- **Increasing yield:** If yields on organic farms were improved, this analysis shows that organic farming would have the lowest total water footprint of the three farming practices. Intercropping and nutrient management, including micronutrients are practices that can increase cotton yields. In addition, access to good quality, organic seeds can produce higher yields on organic farms.
- **Reducing non-productive evaporation:** the green and blue water footprint can be reduced through practices such as mulching, advanced irrigation technologies and deficit irrigation.
- **Selecting seed varieties:** seed selection and access to good quality seeds can improve success under local conditions. With organic seeds being a small proportion of cotton seeds, good quality organic seeds need to be developed and made available to farmers.
- **Eliminating use of high-toxicity pesticides:** the grey water footprint can be reduced by using bio-pesticides or less toxic agro-chemicals.
- **Reducing runoff and leaching of nutrients:** Nitrogen and Phosphorus leaching can be reduced through optimised application rates and timing and changes in irrigation, from furrow to drip.
- **Increasing use of biological controls:** natural pest control will reduce or eliminate the grey water footprint.
- **Increasing soil fertility:** limited or no tillage, organic inputs such as compost and crop rotation can improve soil structure and increase soil fertility, resulting in better yields and less nutrient leaching.

- **Optimising sowing timing:** appropriately timed planting relative to soil moisture and onset of the monsoon can increase yields.
- **Building farmer capacity:** farmers receiving specialised training in best practices such as those noted above and with access to technology out-perform other farmers for yield and water footprint per hectare. Access to credit and debt management as well as increased understanding of the benefits is critical for smallholder farmers to invest in new technologies.

4.1.2.1 Green water footprint reduction

The green water footprint in agriculture can be reduced by limiting non-productive evaporation and increasing yield. Reductions can be achieved by implementing various farming techniques and practices such as:

- Mulching and conservation tillage, thereby reducing evaporation from the soil surface.
- Mixed cultivation and intercropping, offering a variety of land cover, thereby reducing evaporative losses. This also improves biodiversity, (reducing the risk of singular pests whose numbers would remain unchecked in a mono-crop), nutrient cycling in the soil and resistance to disease.
- Good forecasting of the monsoon rains, through which all of India sets its schedule, is of utmost importance. Knowing the exact start of the monsoon will determine when the farmers will sow their seeds. If farmers plant early (pre-monsoon) they would have to make use of irrigation systems resulting in a longer growing period, which results in higher evapotranspiration. This could be offset by an increased yield, thus maintaining the green and blue water footprint when considered from the perspective of m^3/tonne . However, if yields are not proportionally higher, then this may lead to a higher green and blue water footprint per tonne of cotton. Poor rain forecasting can also put farmers at risk of losing their crop and their investment in buying seeds.

4.1.2.2 Blue water footprint reduction

As little as an average of 12% of the total irrigated volume (the value ranges from single digit percentages up to almost 50%) is being consumed by the crop ((Mekonnen and Hoekstra, 2010)). This percentage is related to the field level application efficiency of the irrigation technology used, which varies from 70-90% (Howell, 2003), e.g. furrow irrigation is less efficient than sprinkler or drip.

Irrigation can be optimised by:

- Increasing blue water availability by making use of rainwater harvesting. Rainwater harvesting captures water during the wet season and, when used during the dry season, reduces pressure on scarce surface and groundwater resources.
- Strategically timed irrigation during dry spells along with good pest and soil management leads to increased efficiency (through improved productivity).
- Improved weather forecasting to guide irrigation scheduling to meet the plant's water needs increases irrigation effectiveness. Deficit irrigation can further reduce the blue water footprint by limiting non-productive evaporation.

4.1.2.3 Grey water footprint reduction

The largest gains to be made in reducing the grey water footprint can be achieved through organic farming, nutrient management and through substituting chemicals that have a lower toxicity, thereby generating a smaller grey water footprint, whilst targeting the same pests.

- Pesticides that have a low water footprint should be used. Certainly, if the same pesticide is effective against a number of different pests, this is the most preferred chemical to apply or, if there is an organic alternative, this should be used. Organic pesticides can sometimes be more expensive and farmers may need to be trained on how to make natural pesticides.
- Application rates should be managed to maximise effectiveness whilst reducing the amounts that may runoff or leach to fresh water.
- Fertilisers should only be applied in amounts in line with plant and soil requirements to supplement any deficit in order to optimise productivity and reduce runoff or leaching into fresh water. Soil testing is required to accurately apply nutrients; farmers need to learn the benefits of investing in soil testing.
- Excessive irrigation, or irrigation technologies such as furrow, can increase the risk of leaching of pollutants and lead to saltation and toxic build-up in soils.

In addition to improving agricultural practices of farmers, C&A can engage with the Central Institute for Cotton Research (CICR) and other institutes and agricultural extension services that are providing guidance and training to farmers about the relationships between specific agricultural practices and their related water footprint. This will help provide supportive mechanisms for the transition throughout the cotton agriculture sector to more sustainable production.

Table 28 summarises the strategies for farmers to reduce their green, blue, grey and total water footprints.

Table 28 – Summary of response options for cotton producers

	Measures	Details and Effects	References
Green	Mulching: <ul style="list-style-type: none"> - Synthetic (black poly-ethylene) is most effective but costly. - Organic/geotextile mulches more appropriate for Indian farmers 	Most effective in the early crop growth stages. Irrespective of crop variety, poly mulching improved yield (up to 43% for BT and 26% for non-BT cotton). In wet months, organic mulch just as effective as black poly mulch in reducing ET. Water use efficiency improved by 83%.	Tolk et al., 1999; Nalayini, 2007; CICR, 2008; Kumar and Dey, 2011
	Intercropping: <ul style="list-style-type: none"> - Cotton followed by wheat with groundnut intercrop - Green gram, black gram and soybean were identified as suitable intercrops for varieties grown in wider spacing (90 cm) and hybrids. 	<p>Seed cotton yield can potentially be increased significantly even on shallow soils. Adding groundnut increased yield by 0.58 t/ha.</p> <p>Green gram with cotton enhanced ratio of yield of cotton to water applied by 22%, whilst black gram lead to an increase of 19% compared to the control system of solely cotton</p>	<p>CICR, 2008, 2011a, 2011b, 2015;</p> <p>Singh et al., 2009;</p>
	Precision Forecasting & Planting: <ul style="list-style-type: none"> - Improved forecasting of monsoon allows farmers to optimise timing of planting 	Delayed sowing after 15 July results in drastic reduction in productivity (up to 40–50%). Most relevant for rainfed farms in order to optimise productivity.	<p>CICR, 2005;</p> <p>Ravindran, 2000</p>

	Measures	Details and Effects	References
Blue	Irrigation Strategy: <ul style="list-style-type: none"> - Bridge dry spells and provide irrigation at sowing time if monsoon is delayed, possibly from a previously installed rainwater harvesting system to increase productivity - Reduction of blue water use through deficit irrigation 	Consumptive water footprint per unit of crop reduces in order from rainfed practice to supplemental irrigation, to full irrigation and further until deficit irrigation. In other studies, 60% of full irrigation (i.e. deficit irrigation) resulted in 14% higher yield per unit of water applied than full irrigation treatment. Water use efficiency improvements on the order of 15-60% are feasible through deficit or supplemental irrigation practice	Zhang, 2003; Aggarwal et al., 2008; English, 1990; Gundlur et al., 2013
	Irrigation Technology: <ul style="list-style-type: none"> - Rainwater harvesting - Switching to (subsurface) drip irrigation (from furrow or sprinkler) 	Rainwater harvesting optimises the use of green water and increases the availability of blue water. Drip irrigation reduced consumptive (blue + green) water footprint by 35%. It also increased yield by 18%. Water use efficiency increased by 60% on average in comparison with furrow-irrigated cotton. Drip irrigation also increased seed cotton yield by 21% and 30% over furrow and sprinkler irrigation, respectively.	Bhattarai et al., 2005; Ibragimov et al., 2007; Hodgson et al., 1990; Cetin and Bilgel, 2002

	Measures	Details and Effects	References
Grey	Organic Pesticides: - Prioritise organic pesticides (e.g. Neem Oil) with low toxicity and high efficacy against multiple target pests.	Grey water footprint reduces significantly from conventional to REEL to organic practices	
	Nutrient Management: - Synchronise NPK (fertiliser and micronutrients) supply with crop demand - Apply only as much as needed based also on soil quality	Can result in higher seed cotton yield and at the same time lead to reduction of total amount of nutrients applied, thereby reducing the pollutant load. Yield is enhanced in cereals in the range of 0.3 to 0.6 t/ha through addition of micronutrients. The response of micronutrients in food crops and vegetables is highly pronounced. Under micronutrient deficient situations, the application of major nutrients alone is not as effective. Similar trends can be expected for cotton.	CICR, 2008; MOFF, 2006; Ministry of Agriculture of India, 2012
	Fertigation: - Application of nutrients can best be optimized when combined with irrigation - Subsurface drip deficit irrigation	Nitrogen leaches 5 times more in furrow irrigation than subsurface drip irrigation. Leaching becomes absent in deficit irrigation. Phosphorus loss from furrow was greater than for the wetter subsurface drip treatments. No Phosphorus loss was recorded from drier subsurface drip irrigation rates. Reduction of Nitrogen requirements on the order of 30-50% was reported for drip fertigation application without yield reduction. This will similarly lower the fertiliser-based grey water footprint.	CICR, 2007
	Increase biodiversity: - Introducing natural biological controls to limit pest populations	Beneficial natural control agents prevent the need for additional pesticides, which drastically lowers the pollutant load.	MOFF, 2006

	Measures	Details and Effects	References
Total	Increase Productivity & Soil Fertility: <ul style="list-style-type: none"> - Crop rotation; growing cotton after cotton should be avoided - Deep ploughing during summer - Conservation agriculture 	Long-term effect of nutrient management: cotton-sorghum rotation out-yielded cotton monocrop by 38% . Cotton-sorghum, cotton-sunflower and cotton-red gram rotations have also been found to be effective in keeping pests below the economic threshold limit (ETL). Deep ploughing prevents the occurrence of soil-borne pathogens, increasing productivity.	Ministry of Agriculture of India, 2004
	Crop Variety and Hybrids: <ul style="list-style-type: none"> - Zone-specific high-yielding varieties - Nutrient efficient / stress / pest resistant varieties 	High-yielding varieties have a lower consumptive water footprint per hectare. Hybrids also require less chemical input in terms of fertiliser and pesticide, thus lowering the grey water footprint as well.	CICR, 2015; Bennett, 2003; Halemani et al., 2009

4.1.3 Catchment management

One of the most telling pieces of information provided in this report is the blue water scarcity map of India, which shows that the majority of cotton production in India is occurring in areas with severe water scarcity. Water quality is also a significant concern in much of India. Improving cotton agriculture practices will contribute to improving this situation.

However, it should be stressed that, without engagement with other water users and stakeholders on the underlying causes of unsustainable water use in the catchments in which C&A is sourcing cotton, these improvements will fall short of achieving a supply of sustainably produced cotton.

The sustainability assessment is a helpful guide to determining the pertinent strategies to undertake when addressing the local catchment. The water footprint relative to benchmarks, environmental hotspots, e.g., blue water scarcity and water pollution levels, and the share of the catchment or basin water footprint, provides guidance on which actions would be most productive. C&A's cotton water footprint lands in blue water scarce and water pollution level hotspots, to greater and lesser degrees. Therefore, collective action (Figure 30) to reduce the water footprint of cotton, and to reduce the overall catchment water footprint such that water use is managed in a sustainable way, is required.

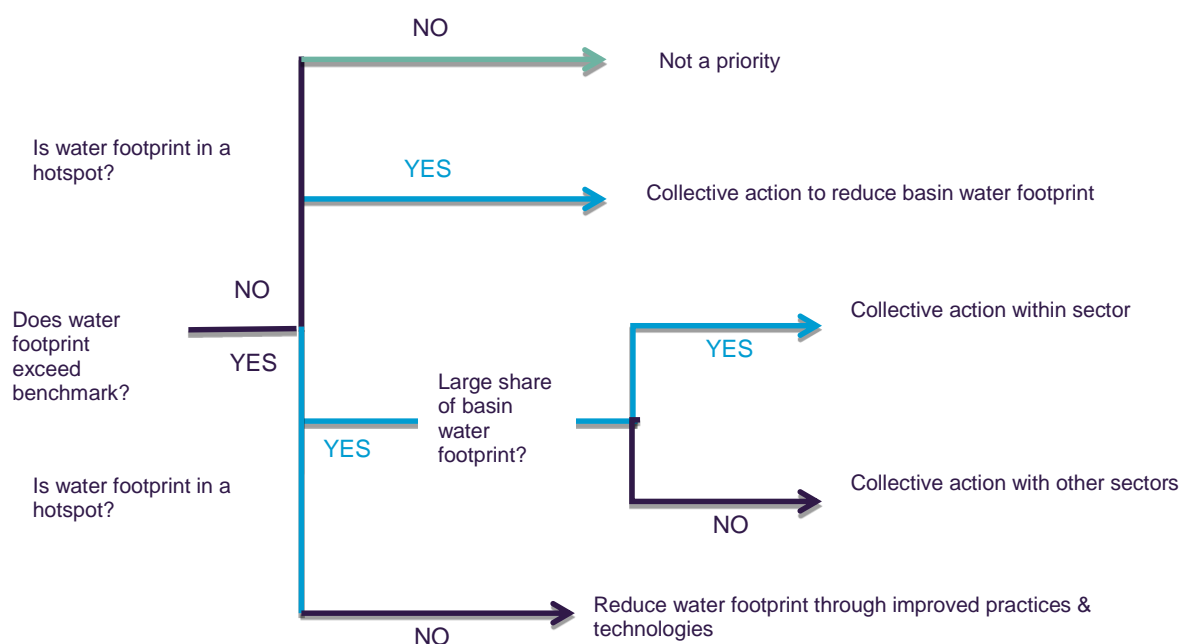


Figure 30 – Flow chart of strategic actions

Pinpointing where C&A sources its cotton from, beyond the farms included in this study, will allow a deeper understanding of the local catchment context. For example, in the Indus River basin as a whole, cotton accounts for 11% of the green water footprint, 16% of the blue water footprint and 11% of the grey water footprint related to Nitrogen (Mekonnen and Hoekstra, 2011), with other prominent crops being rice, wheat and sugarcane.

This report forms the basis for investments in improving cotton agriculture practices and will need to be supplemented with further understanding of the local context and other interventions needed.

Engagement in a river basin as large as the Indus is a daunting task; it will be more fruitful, at first, to identify smaller sub-basins or catchments where cotton plays a prominent role. Through its partners, C&A can gain strong knowledge on the local characteristics of water use, governance and the problems that need to be addressed to move toward local sustainability in these areas.

4.1.4 Collective action

Unsustainable water use and management is, in most cases, a result of a multitude of actions, poor or inadequate information, policies with divergent aims and weak governance. Addressing these underlying factors can rarely be done by one party but instead must be done collectively. With the dual aims of achieving the most efficient production of cotton possible and for cotton to be produced in sustainably managed basins, there are a range of options for C&A to engage in collective action.

- **Sector standards:** Many companies rely on multi-stakeholder initiatives to develop the criteria for a sustainably produced commodity, provide the training for auditors, and manage the certification system. A company buys the commodity from producers who have been certified as a proxy for providing its own oversight of the commodity's production. By joining forces with other companies and the standard system, the production of the commodity is improved. The Better Cotton Initiative (BCI) is one such standards organisation that C&A has already begun engagement with. It is important through this engagement that C&A ensures that the standard's criteria include all aspects of concern for C&A and that they are being met by the certified producers. In addition, given the poor condition of water resources in many cotton growing areas, the catchment and river basin context needs to be addressed.

C&A, and other clothing retailers, can use the results of this study to advocate for the agricultural practices used by farmers to be those with the lowest green, blue and grey water footprint, both in terms of the overall pressure on freshwater resources, i.e., the water consumed or polluted throughout the growing season and the efficiency, i.e., the water consumed to produce a tonne of cotton.

- **Public – private partnerships:** There is a growing number of positive examples of the public and private sectors collaborating, in some cases also with non-governmental organisations, to achieve shared goals of greater social, economic and environmental sustainability in development. These public – private partnerships (PPP) benefit from the interests of the private sector in economic development and the interests of the public sector and civil society in social and environmental values and may focus on a specific project or outcome. Mapping of potential partners from the public sector, other

businesses and civil society, in relation to C&A's core aim for sustainable cotton and the issues of improving efficiency and reducing environmental impact, would be useful in identifying potential partners.

Water Footprint Assessment could be valuable as a means for monitoring the impact of public-private partnerships in terms of reduced water footprint and improved environmental sustainability and for tracking its contribution to mid- and long-term targets.

- **Existing multi-stakeholder processes:** An option for collective action is to join already existing regional processes, e.g., river basin organisations that have been formed to address concerns such as water use, pollution and how to manage competing uses. These may be formal engagements under a basin treaty or other agreement or a more localised or issue specific convening of stakeholders. These multi-stakeholder processes can serve the function of building a shared understanding about the current situation with regard to water use and management, opening a dialogue about desired futures and identifying solutions and those best placed to achieve them, whether individually or through partnerships. The existence of a functioning multi-stakeholder platform could be one element for choosing a specific geography to work collectively in, as this can be the means for establishing the partnerships necessary for this work. Furthermore, C&A can bring its experience with Water Footprint Assessment to the other stakeholders, helping to develop a common language across the parties and the issues – from cotton to other crops, at the farm scale up to the river basin.

This report is a starting point for C&A's engagement in collective action as it provides an analysis of different agricultural practices and proposes solutions that will be valuable contributions to collective action within the cotton sector, in PPPs or as part of a multi-stakeholder dialogue.

4.1.5 Public policy

The laws, regulations and policies governing water use and its various components are often handled by different governmental departments, leading to a lack of coherence, weak

enforcement or a need to strengthen them. Recognising the risks associated with poor water governance, companies are looking to address regulatory and other policy related risks before they cause real problems. Stronger regulations and their enforcement can reinforce financial security, even with their potentially higher costs. C&A can test with its producers and other partners what can be achieved through reasonable means. Once demonstrated, the 'proof of concept' can be transferred to regulators to ensure the reductions in the impacts to water from cotton production are adopted sector-wide.

The water footprint results for farms in Gujarat and the yields achieved on REEL farms indicate the improvements to be had both in farmer's incomes through increased yields and for the environment when training and improved agricultural practices are combined. The comparison between conventional, REEL and organic farms shows the water footprint savings potential if better practices were to be introduced throughout the cotton sector.

The findings in this report can be used to advocate for farmers to receive the information, training and financial resources that will support agricultural practices leading to sustainably produced cotton. They demonstrate the value and efficacy of using the grey water footprint to understand the pressures on water quality and can open the dialogue on recommended pesticide use and/or banned substances.

4.1.6 Community engagement

Taking direct action on reducing the geographic water footprint of cotton will contribute to improved conditions in the local water resources and thereby reduce the impact that over abstraction of surface and groundwater and degraded water quality have on local communities. Engaging with local communities to build awareness of the actions that farmers are taking, as well as those that they can take individually and collectively to reduce their own water footprint, would be a step toward embedding the values of water stewardship throughout society. These values will broaden the support for taking the steps necessary for improving local water conditions.

4.1.7 Transparency

Achieving a source of sustainably produced cotton is not a solo journey and must be done in combination with a wide range of other organisations. Openly sharing data, results, lessons learned and priority actions with others on this journey will help speed the process. C&A already has a history of sharing its information, e.g., the two previous reports conducted with Water Footprint Network. This report represents the most in-depth study to date, comparing the water footprint of different agricultural practices, which can be used as a basis for developing a targeted strategy for reducing cotton's water footprint and will be useful to others working actively in this sector or other brands. Investors are showing more concern about how companies are addressing water-related business risks. As a private company, the pressure of shareholders is not relevant for C&A. However, by sharing this and other reports and by presenting information about its water footprint, C&A is joining other leading companies in water disclosure.

Although it is not an end in itself, transparency about a company's water footprint and other water issues helps build an informed community, one that can drive the agenda of sustainable, efficient and equitable water use forward and support leaders on this journey.

In summary, the strategic actions are:

- Advocate the impressive results achieved in reducing water pollution levels from organic farming to employees and customers as a way to build support for the transition to sustainable cotton for C&A and other retailers;
- Improve agricultural practices at the farm level such that the green, blue and grey water footprint are reduced and strengthen supportive mechanisms for building farmer capacity, for providing accurate and timely information and for expanding expert knowledge in Water Footprint Assessment and its applications;
- Understand the local context in select priority catchments and contribute to actions that will improve local water conditions;

- Engage with standards organisations, PPPs, river basin organisations and other collective actions to accelerate improvements in the sustainability of cotton production and the local water conditions;
- Encourage coherent and effective regulations, laws and policies that will support progress toward sustainable, efficient and equitable water use and management; and
- Support the development of informed communities committed to sustainable cotton through water stewardship, and
- Be open and transparent about the water stewardship journey – where you are now, what you are doing, what you have learned and where you are headed.

5 Conclusions

This report is part of the project 'Building Capacity in the Apparel Sector on reducing and managing the Water Footprint: C&A Water Footprint Strategy 2013 – 2015'. Water Footprint Network investigated the link between the water footprint and the various practices concerned in cotton cultivation in three states of India during the 2012 and 2013 growing seasons. The practices were conventional, REEL Cotton and organic farming from a sample of 1,144 farms selected across Madhya Pradesh, Maharashtra and Gujarat, India. The findings support previous assessments which analysed the comparison between conventional and organic farming and their respective grey water footprints (Franke and Mathews, 2013b). However, this assessment took the work to a new level by providing far more detailed analysis, based on farm field data supplied by CottonConnect. This local data made it possible to identify more detailed, strategic insights which can be used to move towards sustainable cotton production.

Sustainable farming is intelligent farming and, in order to source sustainable cotton all of the recommended response actions must be implemented in adequate measure. For example, sustainable farming involves using resources efficiently, timing planting and irrigation optimally as well as using the best methods, such as rainwater harvesting instead of groundwater extraction. In order to achieve the maximum crop per drop and increase yields, C&A needs to develop a strategy that will help improve farm level water management by strengthening engagement with farmers and partners located in the river basins in which cotton is produced. It is also evident that there are significant variations in performance between farms, even those located in the same areas, so part of this engagement should focus on building capacity by facilitating information and knowledge sharing, as well as training farmers and strengthening local networks.

Producing cotton in line with nature, which ultimately enhances the soil quality and enhances biodiversity will reduce water pollution generated from cotton production due to more reliance on naturally occurring pest control agents instead of agro-chemicals. Careful management of soil and nutrients will reduce soil loss and eutrophication. Building up soil quality should, in turn, lead to improved productivity over time. Considering that every drop of water in these regions is precious, the move to organic farming with a focus on water efficiency and improving yields, and thereby increasing organic farmers' income, is the top practice to consider for a long-term strategy.

In order to ensure a sustainable cotton supply, C&A needs to take a broader approach to sustainability which involves working to improve conditions in the river basins in which the cotton farmers operate. This means not only tackling water pollution levels by investing in organic farming and REEL (or other sustainable cotton sourcing programmes, e.g., BCI) practices, but addressing the fact that the majority of cotton production is located in river basins that are under stress and including actions to improve basin conditions where cotton is produced.

C&A can use the results of this Water Footprint Assessment as an indicative baseline for the water footprint and sustainability of its cotton supply chain. The farms included in the study are a small sample compared to the total tonnes of cotton sourced by C&A; however, the results demonstrate some key factors that can be used to develop its strategy around engagement with farmers, local partners and other river basin stakeholders. Measures that optimise green water use and reduce reliance on irrigation should be implemented. However, the greatest opportunity to reduce cotton's impact on freshwater resources is through reducing or eliminating chemical pesticide use and the appropriate management of nutrients. Expanding this study to include cotton supply sourcing regions where local conditions, such as soil and climate, are known and in which agricultural practices and their associated water footprints will be different, will strengthen this baseline and can be used to further elaborate priority strategic actions for C&A to take.

The results from this study can be used for awareness raising and for building broad support for the transition to sustainable cotton. They can be a basis for establishing benchmarks and for setting targets for the sustainability of C&A's supply chain, which is useful in programme planning and resource allocation, and can inform a sourcing strategy. They can be used as a starting point for understanding catchment conditions and for building meaningful collective actions with others. The response strategies identified for reducing the green, blue and grey water footprint of cotton at the farm level can inform institutes, trainers, technical service providers and others supporting cotton farmers and can be used to advocate for better regulation, in particular relative to pesticide use. The benefits of taking these steps along the corporate water stewardship journey is that greater environmental, social and economic sustainability will be enjoyed by the farmers, the sector and importantly, the local communities. Sharing this journey – the results of this study and the steps taken or planned – will further develop a base of support for improving the sustainability of cotton production.

This Water Footprint Assessment of cotton farms in India was made possible through funds from C&A Foundation. Given the significant impact the sector has on the world's water resources, C&A's efforts to improve its environmental, social and economic sustainability are to be applauded. The Water Footprint Network encourages C&A, and other clothing retailers, to use the outcomes of this work to formulate solid recommendations for others in the sector. As steps are taken to improve the sustainability of cotton production, lessons will be learned, and an iterative approach to deepening understanding such that resources are directed in the most beneficial way should be used. As these changes in cotton farming are implemented in production sites around the world, the cotton supply chain will become more sustainable. The insights this report provides and the strategic actions and investments it recommends will contribute to transforming the sustainability of the textile sector.

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