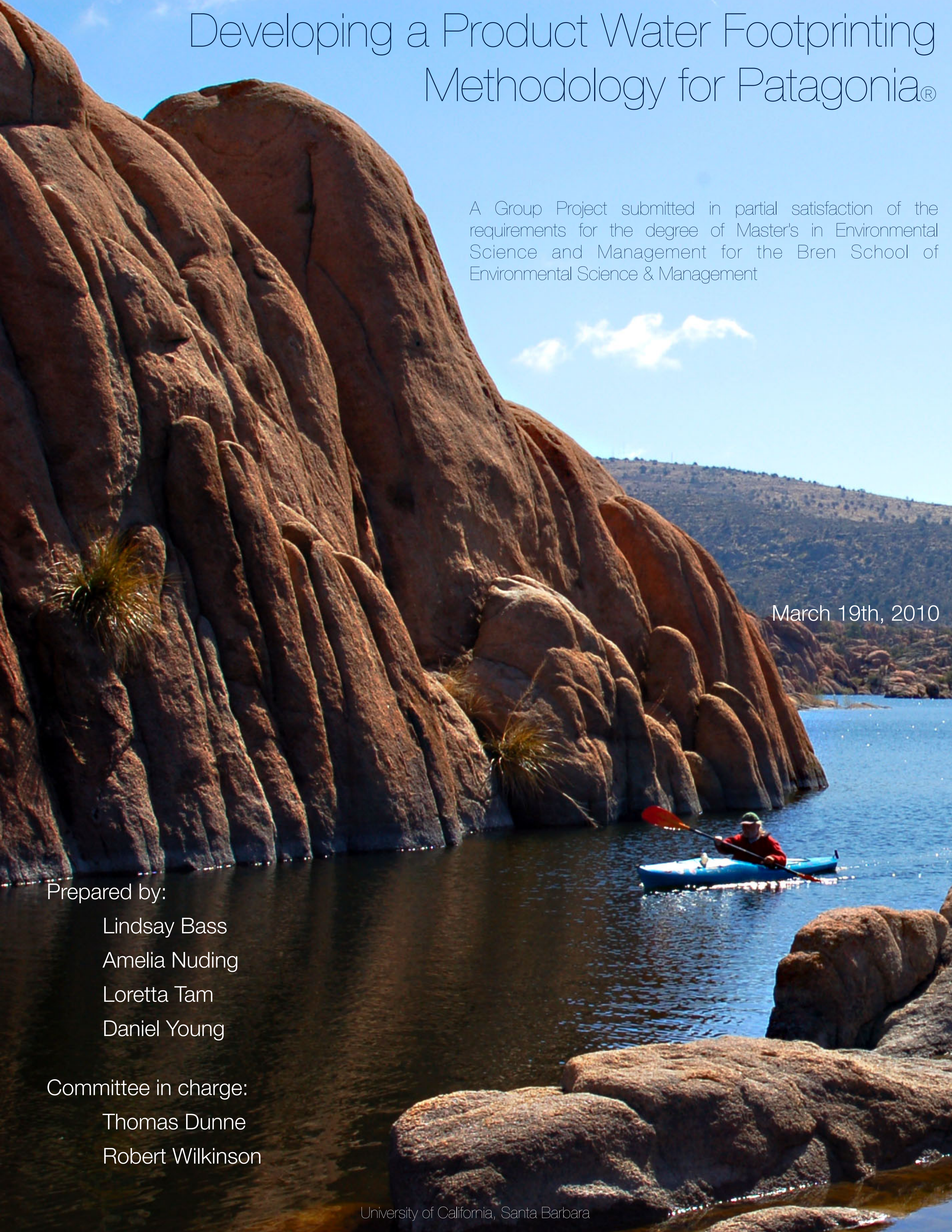

Developing a Product Water Footprinting Methodology for Patagonia®

A Group Project submitted in partial satisfaction of the requirements for the degree of Master's in Environmental Science and Management for the Bren School of Environmental Science & Management

March 19th, 2010

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As authors of this Group Project report, we are proud to archive this report on the Bren School's website such that the results of our research are available for all to read. Our signatures on the document signify our joint responsibility to fulfill the archiving standards set by the Bren School of Environmental Science & Management.

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The mission of the Bren School of Environmental Science & Management is to produce professionals with unrivaled training in environmental science and management who will devote their unique skills to the diagnosis, assessment, mitigation, prevention, and remedy of the environmental problems of today and the future. A guiding principal of the School is that the analysis of environmental problems requires quantitative training in more than one discipline and an awareness of the physical, biological, social, political, and economic consequences that arise from scientific or technological decisions.

The Group Project is required of all students in the Master's of Environmental Science and Management (MESM) Program. It is a three-quarter activity in which small groups of students conduct focused, interdisciplinary research on the scientific, management, and policy dimensions of a specific environmental issue. This Final Group Project Report is authored by MESM students and has been reviewed and approved by:

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March 19th, 2010

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Abstract

As anthropogenic climate change and population growth increase the stress on water resources in many parts of the world, businesses must begin to more closely monitor their reliance and impact on freshwater systems. Patagonia, an outdoor apparel company whose mission is to develop the garments while doing no unnecessary harm to the environment, has chosen to take a pro-active approach in assessing their water usage. We developed a methodology for Patagonia to account for the water quantity used and water quality affected through the life cycle its garments, beginning with the raw materials, through the production chain and finally to customer use. The methodology can be applied to all of Patagonia's product lines, and ultimately be extrapolated to the larger textile industry. This water footprint, combined with a map of water stress on a watershed basis, begins to define where the company is having the most impact on water resources through their supply chain. This analysis will help Patagonia to develop a more strategic method behind their external environmental initiatives, such as offsetting environmental impacts or mitigating risks in the locations where they have the most impact..

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Build the best product, cause no unnecessary harm, use business to inspire and implement solutions to the environmental crisis.

patagonia®

Executive Summary

Water scarcity has become a critical issue for many businesses, compelling them to measure, report and reduce their water use. Patagonia, a mid-sized outdoor apparel company, is concerned not only with the business risks that accompany water scarcity, but also with the environmental impacts associated with their water use. As a textile company, they use large amounts of water in just a few parts of their supply chain, such as the dyeing and raw materials stages. However, because their suppliers are distributed globally Patagonia does not have knowledge of the water stress in these regions or even the amount of water required to produce their goods. Water footprinting is an emerging practice to help connect these realities by quantifying water use, accounting for the source of water, as well as associated water pollution, in a regional context. Patagonia has chosen to conduct water footprinting at a product level to better understand the impacts of each garment they produce, and to communicate this information in a meaningful way to their customers.

Patagonia's main objective is to measure the water use requirement for any garment they produce, and to assess its environmental impact. Using a few contemporary resources on water footprinting, especially the Water Footprint Network, we developed a method of calculating a water footprint that is both environmentally meaningful and relatively easy to replicate. Patagonia can determine—to a first order approximation—their water use without extensive research or complex calculations. We also developed a method of scaling the water footprint by the degree of water stress in the regions where a garment is produced, thereby creating a water impact footprint. By using the water stress indicator, Patagonia can compare business risks and water impacts between suppliers and between garments. Since this methodology was developed to be applied to any garment, it may also be of use to other businesses, in the textile industry or otherwise.

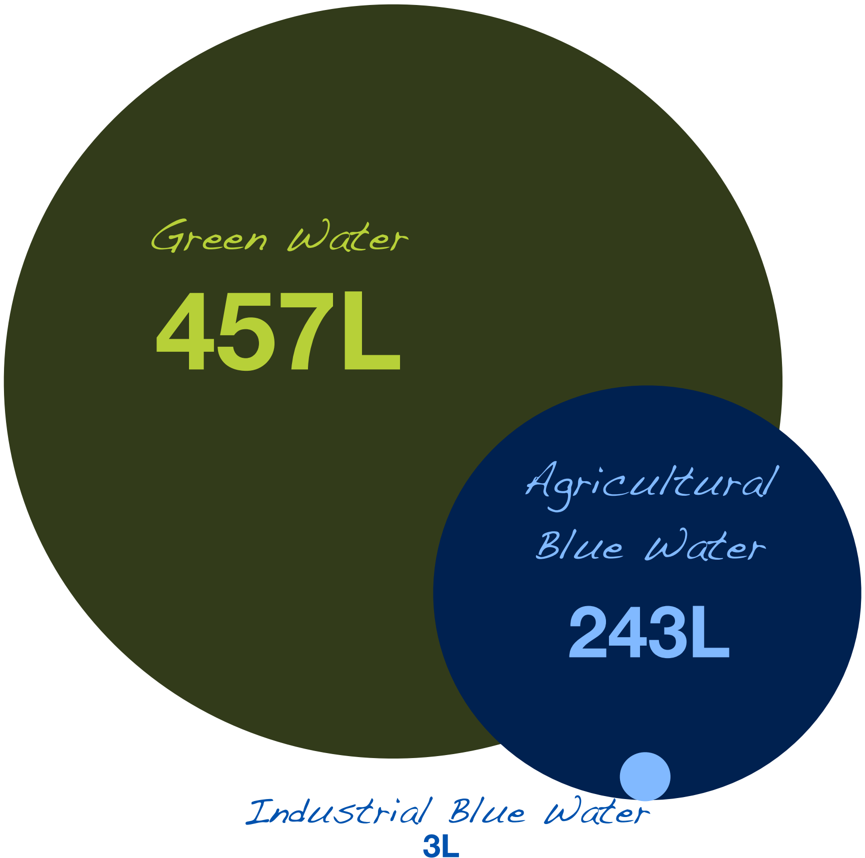
We present one case study here for Patagonia's Women's Organic T-shirt. This T-shirt is made from cotton grown in Turkey and dyed in Los Angeles. The product water footprint, which is the total volume of water directly used in the manufacture of this garment, is 703L—65% of which is from rainwater to grow the cotton and 35% of which is from surface or groundwater, used for irrigation and the dyeing processes. When the lifecycle water use of the garment is measured, the consumer use phase contributes an additional 144-312L of water to the product footprint, depending on the water efficiency of the washing machine. While consumer use is not directly controlled by Patagonia, it does constitute a significant volume of a garment's life-cycle water use. Patagonia may use this information as an opportunity to educate customers on their contribution to the water footprint.

This footprint is significantly smaller than cotton T-shirt footprints reported by Chapagain and Hoekstra (2007) and other websites, which range from 1,500-2,720L per cotton shirt. This discrepancy can be explained by a variety of factors. Differences in the water efficiency of Patagonia's supply chain actors and those of the other studies contribute significantly to the smaller footprint. Additionally, some studies include water requirements met through rainfall,

different estimations of consumer use, and all base their calculations on different baseline assumptions, such as T-shirt weight and size.

In order to determine the environmental impact of supply chain water use, we focused on the consumed water, which is water that is evaporated or transpired. Consumed water represents the greatest environmental impact, as this water is physically removed from the watershed and does not return. We utilized a global Water Stress Index (WSI) developed by Pfister et al. (2009) of the Institute for Environmental Engineering in Zurich Switzerland to determine water stress on a watershed basis. We then applied that stress level to the water footprint, causing the value to grow or shrink relative to the global average. Finally, we added a grey water component, as developed by The Water Footprint Network, which is a calculated volume of clean water that would be required to dilute polluted water to a clean standard. This is a representation of the impact on freshwater resources from the release of polluted water into the environment. This impact assessment framework can be used to compare supply chain actors, garments, or even processes from a water resource perspective.

Current water scarcity and future predictions are becoming a common topic of discussion in many arenas, and businesses are advised to begin understanding, measuring and improving their practices. The practice of water footprinting is still evolving, and we hope that this methodology will be a useful way for Patagonia, as well as other businesses, to consider their water use impacts without a significant investment of money or time. Numerous opportunities exist to become strategically engaged in water issues and this report provides a foundation for linking strategic investments in environmental initiatives to water-related business risks and environmental impacts.



Definitions

Gross Water – total amount of water required for processing and manufacturing. No distinction between consumed or non-consumed is made.

Direct water use - water used in the production of a good

Evapotranspiration – the process by which water is transpired by plant tissues, retained in plant tissues, and evaporated from plant tissues and surrounding soil surfaces.

Crop water requirement – the quantity of water that is required by a crop to mature.

Consumed water – water that is removed from a watershed during a production process via evaporation or transpiration.

Return flow – the quantity of water applied used in a production process that is not evaporated or transpired.

Green water – component of the water footprint comprised of precipitation.

Blue water – component of the water footprint comprised of surface and shallow groundwater.

Grey water – component of the water footprint calculated as the volume of non-polluted water required to dilute a polluted discharge to a chosen standard.

Net water – synonymous with consumed water, equal to the gross water minus the water returned to the environment.

Acronyms Guide

BOD – biological oxygen demand
BSR – Business for Social Responsibility
COD – chemical oxygen demand
EPA – Environmental Protection Agency
FAO – Food and Agriculture Organization
gal – gallon
GIS – Geographic Information Systems
GOTS – Global Organic Textile Standard
GWP – Global Warming Potential
ha – hectare
kg – kilogram
kmz – a compressed KML (Keyhole Markup Language) file
L – liter
LCA – Life-cycle Assessment
lin yard – linear yard
MFA – Materials Flow Analysis
mg – milligram
mm – millimeter
N – Nitrogen
NCAR – National Center for Atmospheric Research
P – Phosphorous
pH - potential of hydrogen
TSS – Total suspended solids
WFN – Water Footprint Network
WRI – World Resources Institute
WSI – Water Stress Index

Introduction

Access to freshwater has become a critical issue for many businesses, particularly the textile industry due to the significant use of water in certain production and crop cultivation processes (Morrison et al. 2009).

With the demand for water rising, competing interests are fighting harder to protect their water resources. Some companies have already experienced significant backlash with respect to their water use as a result of social demands or environmental damage (Vishnu et al. 2008, Morrison et al. 2009).

Acknowledging that the production of apparel products leaves a mark on the environment, Patagonia ascribes to a corporate philosophy to do less harm and use business to inspire solutions to the environmental crisis. With annual revenues of $316 million, Patagonia, a privately owned company, comprises 0.03% of the global apparel industry, which posted total revenues of $1,098.6 billion in 2005 (Datamonitor 2006). Their total corporate water use, which includes typical office water use at their headquarters in Ventura, California, distribution center in Reno, Nevada, and retail centers throughout the world, is dwarfed by the use of freshwater resources in their product supply chains. To date, studies addressing the impact of the textile industry on freshwater resources conclude that the majority of water impacts result from raw material production, wastewater from textile processing, and consumer care of the final product (Morrison et al. 2009). To understand the risks posed by their water use in the manufacture of their products, Patagonia decided to look at each stage of their product supply chains, on a per-garment basis. Given that Patagonia produces hundreds of products with supply chains distributed around the globe, they began this investigation with a handful of garments that would help address key questions about water use across their product portfolio. This report focuses on the Women's Simply Organic T-Shirt.

Patagonia's investigation into supply chain water use is preceded by their carbon footprinting and environmental evaluations of their products, reported on an interactive web site called the "Footprint Chronicles." To take on water footprinting, a practice that is still taking form, Patagonia enlisted a team of graduate students from the Bren School of Environmental Science and Management at the University of California Santa Barbara. The team worked closely with the company over the course of a year to develop a methodology to quantify supply chain water use per garment and to understand how this information could be used in strategic decisions regarding environmental initiatives.

A Closer Look at the Problem: Increasing Water Scarcity

Demand for water is increasing worldwide due to population growth, urbanization, and the globalization of the world economy. According to the United Nations, roughly two-thirds of the world's population will be living in water-stressed conditions by the year 2025 (Alter 2009, Rosegrant et al. 2002). Goldman Sachs, an investment banking and securities firm concerned with business risk, estimates that global water consumption is increasing at an unsustainable rate, doubling every 20 years (The Economist 2008). Current projections by the UN indicate that of the three major categories of water use—agricultural, industrial and domestic—industrial water use will show the greatest increase, by about 76%, between 1995 and 2025 (Cardone 2004).

Compounding the problem of increased demand for water is a growing uncertainty regarding the supply of freshwater. Climate change is projected to lead to major spatial and temporal changes in precipitation, affecting the availability of freshwater (IPCC 2007 as cited in Gerbens-Leenes & Hoekstra 2008). Climate change is also expected to diminish ecosystem capacity to filter water and create buffers from flooding, thereby resulting in degraded water quality as well (Morrison et al. 2009).

As humans place increased demand on water resources, the pattern of supply is expected to shift, which is expected to create additional and significant stress for certain areas of the world (Alter 2009, Rosegrant et al. 2002).

Patagonia's Objectives

To begin addressing the potential risks of water scarcity, Patagonia's first objective was to quantify the amount of water used on a per-garment basis through the supply chain of the garment. In this study, the supply chain boundaries included raw material production, manufacturing and processing of the fiber, fabric and garment. Although Patagonia could have conducted a business water footprint, which would have measured the direct water use of their Ventura headquarters, distribution center and retail outlets, a product level footprint was considered far more useful to Patagonia as it would focus on the most water-intensive aspects of their operations, which occur in the product supply chains. Additionally, a product level footprint is a more meaningful way to communicate with their customers about the environmental impacts of the goods they produce. To continue to earn the trust of customers, Patagonia needed a transparent methodology that would convey how calculations were made and what was being done in response to results. Thus, the methodology has been designed so that Patagonia can easily repeat calculations for other garments while also ensuring results are clear for customers to understand.

Patagonia's second objective was to make more strategic decisions about their environmental initiatives. Patagonia has taken many steps over the years to reduce a variety of their environmental impacts, and now they would like to make decisions in a more coordinated and comprehensive manner. Thus, the methodology incorporates a tool to provide the company with a sense of their water impacts anywhere in the world. The tool consists of a worldwide map of water scarcity numerically indexed on a watershed basis so that a water footprint can be scaled by the water stress of the regions that contribute to the footprint. This map tool allows Patagonia to understand the magnitude and location of their impact, which can help inform their decisions regarding sourcing. With this increased understanding, Patagonia may be able to link their philanthropic/environmental efforts to the locations in which they are having the most impact, thereby helping them to develop a more strategic plan for their environmental initiatives.

This water footprint project is a first step in Patagonia's efforts to positively affect their supply chain water use in a manner consistent with their corporate philosophy. Although project deliverables were developed to meet the specific needs of Patagonia, this report is written in a manner to encourage use by other textile companies, as well as the business community in general. The recommendations provided to Patagonia present options for reducing environmental impact and furthering their efforts. In addition, recommendations to the larger water footprinting community are put forward with the intent to help develop business footprinting practices.

The Business Case for Water Footprinting

As business leaders plan for the future, they look for opportunities and risks that may have an impact on their company, industry, and even the world.

Water is now among these considerations. Companies routinely weigh long-term decisions in light of new, alternative sources of supply, new geographic markets and new products. Strategic supply chain planning should combine long-term business strategy with tactical supply chain decisions in light of water risks. Three types of risks to business have been identified: physical, reputational and regulatory (JP Morgan 2008). Analytical approaches to addressing these risks can help to reduce risk and create new opportunities.

Physical Risks

Physical risks, such as the non-availability of water, have the potential to disrupt operations and/or limit growth. In regions where water supply is a problem, it is in the company's best interest to engage early with the issue to bring about better water management practices, rather than face relocation or closure due to environmental concerns (Orr et al. 2009). Water scarcity can drive up the price of water and constrain growth, or result in regulatory changes, such as the suspension of permits for water withdrawal or discharge (JP Morgan et al. 2008). As a result, companies will increasingly be under pressure to disclose water use and impacts to investors by outlining costs and supply chain risks (JP Morgan et al. 2008).

Water quality risks may also have significant financial implications. Contaminated water supply may require additional investment and operational costs for pre-treatment. When alternative source water or treatment options are not feasible, facility operations may be disrupted or require relocation.

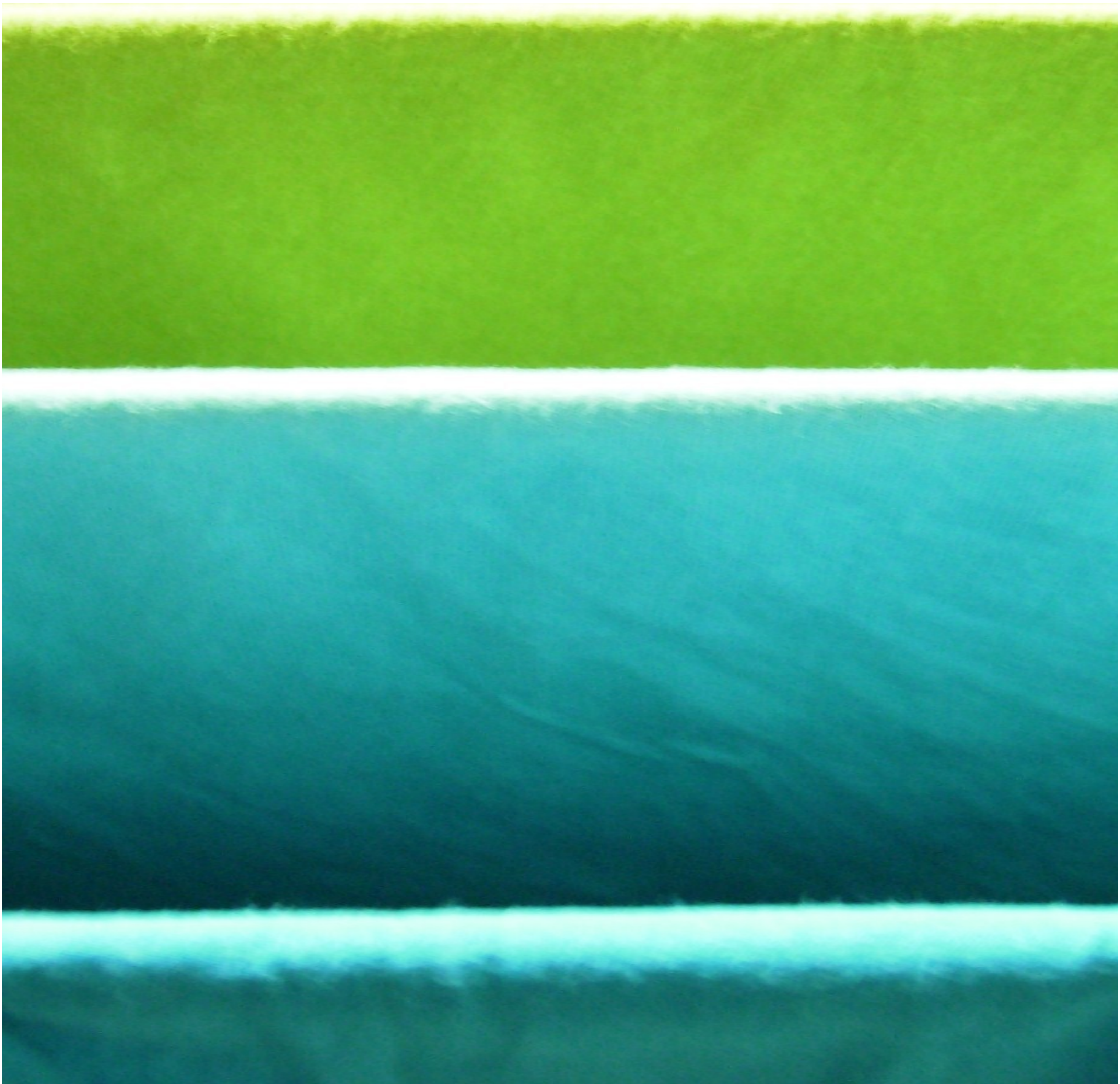
Reputational Risks

Reputational risks, such as damaged brand or reputation, can undermine a company's bottom line as well (L&L Manufacturing 2008). Business water accounting is increasingly regarded as an essential part of corporate performance accounting, valued by customers and shareholders (Gerbens-Leenes & Hoekstra 2008). Corporate disclosure of water use is beginning to raise public awareness of the issue. As a result, companies are being pressured to build "greener" reputations (Chapagain and Orr 2008). Additionally, a company's social license to operate in any market depends on constructive dialogue among key stakeholders—community members, farmers, companies, and others—about how water resources will be shared to meet competing demands. The manner in which a company conducts itself in these situations can either help or hurt the brand image (Flowers 2006).

Regulatory Risks

Regulatory risks, such as restrictions to a firm's license to operate and changing price structures, must also be considered in business strategy and decision-making

(Morrison et al. 2009). New or more stringent wastewater regulation could increase wastewater treatment costs in textile manufacturing (Morrison et al. 2009). Concern among local communities about water withdrawals can put pressure on governments to consider water reallocations and regulations, permit suspensions to draw water, and more stringent water quality standards. Some national governments already impose strict water quality standards for water supply and wastewater discharge. However, governments in emerging markets typically have yet to develop and/or enforce water quality standards. This is likely to change as economic development continues in these countries and per capita income rises.



Framing the Textile Water Footprint

The oldest known textiles date back to 5000 B.C.

Fabric selection is critical in determining the durability, breathability and warmth of a garment.

Textile Manufacturing

Different raw materials like cotton, wool and synthetic fibers are all processed in slightly different ways before they are made into a garment. However, they all share certain basic processes: preparation of the raw material for spinning into yarn, spinning into thread, weaving/knitting in a fabric, dyeing, cutting and sewing, printing and finishing. The following is a description of cotton processing, as it is the raw material used in the case study we present.

Cotton

Cotton is grown in fields and watered with either a combination of rain water and irrigation water. After cotton is picked from a field, the seeds in the cotton fibers are removed, and the fibers are carded and combed in order to remove impurities. Next, the fibers are spun, twisted and extended to form yarns, more commonly known as threads. Yarns are then sent to a knitting facility to be knit into a fabric. Fabrics are then treated to remove any remaining impurities, such as machine oils, and cotton waxes or grease. This treatment maybe a wet process, which uses water or solvents to remove the impurities, or dry process, which uses mechanical processes to remove the impurities (EPA 1997).

Washing and bleaching processes are typically carried out consecutively before dyeing, with the processes generally occurring in the same machines as the dyeing process. Dyeing may be performed at the fiber, yarn or fabric stage, though fabric dyeing is the most common, and is the stage at which our case study garment is dyed. There are three common methods of dyeing: vat, direct, and reactive dyeing. In vat dyeing, the dye is put on the fabric in a reduced state and then oxidized typically in a large vat. In direct dyeing, the dye is applied directly to the cloth, and in reactive dyeing, the dye reacts chemically with the fiber in a water solution to form a bond. Reactive dyeing is the process used by the case study cotton garment (UNIDO 1998).

After the dyeing process, the colored fabric is cut and sewn into a garment. Print images may then be applied to the garment at a printing facility. Cotton fabrics are usually wet-printed by roller, rotary screen or flatbed screen printing methods. The final stage of textile manufacturing is finishing. The purpose of the finishing process is to alter properties of the fabric that improve the care, comfort, durability, environmental resistance, aesthetic value, and human safety associated with the fabric. For example, finishes can be applied to make a garment wrinkle resistant, crease retentive, water repellant, flame resistant, mothproof, mildew resistant, and/or stain resistant. In wet-finishing, the sequence of steps typically includes chemical finish application together with mechanical techniques (EPA 1997).

Water Challenges in the Textile Industry

Most water use and water quality impacts in the textile industry occur during the raw material phase, preparation of the raw material and in the dyeing phase (Morrison et al. 2009). Increased water scarcity poses a challenge to the textile industry because of competing demands from other users, as well as changing environmental regulations, which can alter the volume of water allocated to businesses or the standards of wastewater they are required to meet (L&L Manufacturing 2008, Wu and Chang 2008). Therefore, quantifying water use and wastewater discharge in a standardized way for the water-intensive portions of the supply chain can provide a focus for water stewardship efforts.

Water Quantity

Synthetic fibers use very little water in the production process, whereas agricultural raw materials require water to grow, harvest and clean the natural fibers. Cotton is a water-intensive crop, and estimates of water requirements for growing cotton range from 8,000 to 40,000 liters per kilogram of cotton (Cherrett et al. 2005, Hwang 2008). This range is dependent upon the type of cotton grown and the type of climate. About 53% of the land that is used to grow cotton is located primarily in dry regions requiring irrigation (L&L Manufacturing 2008, Cherrett et al. 2005). Whether or not this cotton is primarily rainfed or irrigated carries with it different environmental, business and social implications. Later stages of processing, such as dyeing can take 38–143 liters per kilogram and the finishing of textiles can require up to 700 liters of freshwater per kilogram of textile (Bisschops and Spanjers 2003, BSR 2008).

A significant percentage of textile and garment manufacturing is located in water stressed regions, such as Southeast Asia, India and other areas where local communities do not have reliable access to drinking water. These regions also tend to be most susceptible to climate change impacts on water resources (Morrison et al. 2009). In some countries, such as China, efforts have been focused on the water quality impacts of dyeing processes, and less so on the water consumptive aspects from raw materials production, for example (Wu and Chang 2008).

Water Quality

Wastewater is by far the largest waste stream in the textile industry (EPA 1997). Textile effluents tend to contain high concentrations of salts, total suspended solids, color, nutrients, such as nitrogen and phosphorous, and toxic compounds, such as surfactants, heavy metals, and chlorinated organic compounds (Ergas et al. 2006). The majority of wastewater is generated during the raw materials preparation, dyeing, and finishing stages (EPA 1997). Pollutants vary greatly and depend on the chemicals and treatment processes used (Tufekci et al. 2007). Some processing which may be environmentally intensive result in improved appearance, durability, and serviceability of fabrics, which are of paramount importance to the industry (Kalliala and Talvenmaa 1999). Efforts have been made by some to reduce water use through zero discharge systems, but adoption has been slow due to the inability to consistently reproduce exact color, and the high cost of treatment to meet water quality standards for the dyeing processes (Ergas et al. 2006, Vishnu et al. 2008).

Calculated product water footprint for one Patagonia Simply Organic Women's T-Shirt...

703 liters

Textile Water Footprinting Efforts

Many businesses, including Patagonia, have completed carbon footprints of their products. A growing awareness of water scarcity has now given rise to the concept of a water footprint.

The water footprint concept has gained prominence recently because of the growing awareness of water scarcity and because of the high value of water to many businesses. A single methodology has yet to be adopted, and accordingly different sectors have approached it in different ways. In the textile sector only a few water footprints have been conducted, and they are described below.

Worldwide Cotton Water Footprint

Chapagain et al. (2005) developed a global water footprint for cotton consumption—from crop growth through garment production, including import and export patterns and waste disposal. The report characterizes both the location and the impact of cotton consumption. The impacts considered in this report include: evaporation of infiltrated rainwater for cotton growth (green water use), withdrawal of ground- or surface water for irrigation or processing (blue water use) and water pollution during growth or processing (grey water). Grey water is quantified in terms of the volume of water required to assimilate the pollution.

This study shows that 256 giga-cubic meters of water is required annually for the worldwide consumption of cotton products. 42% is blue water, 39% is green water and 19% is grey water. Impacts from cotton consumption were typically cross-border, with approximately 84% of the cotton consumption water footprint in the EU25 region located outside of Europe. Major impacts from cotton consumption are located in India and Uzbekistan (Chapagain et al. 2005).

Levi's 501 Jeans

Levi's Strauss & Co. (LS & Co.) completed a "cradle-to-grave" lifecycle assessment (LCA) of their 501® medium stonewash jeans to provide insight on the environmental impact of their products—from the cotton fields, through production and consumer use, and finally disposal. The LCA included impacts related to air emissions, water usage, waste production and other areas. LS & Co. complied data from suppliers and used Gabi4 software to analyze the data. They found that the 501® Jeans use 49% of the water consumption during the cotton production stage, and 45% of the water use occurred in the consumer use phase assuming regular washing of the jeans, yielding a total water footprint of about 3,478 liters of water. The method by which the total water footprint was calculated as well as definitions of terms used were not expressed in their publicly available study. However, as a result of this study, LS & Co. has chosen to employ water reduction activities in their distribution centers and owned manufacturing facilities, including dyehouses. LS & Co. is now in the process of finalizing a methodology for conducting water footprints for their supply chain partners.

Patagonia

As a business that places a high value on the integrity of its products, Patagonia works closely with their suppliers on product quality control, corporate social responsibility, and environmental accounting. Because of their careful selection process, Patagonia tends to find suppliers with lower environmental impacts. Patagonia has established a relationship with Bluesign Technologies AG, who works to encourage vendors to remove substances that are potentially hazardous to human health and/or the environment. Thus, some of their suppliers have lower water usage than standard suppliers due to efficient equipment or less harmful chemicals and dyes used. However, water use and water quality information is a new area of focus for Patagonia, and not all suppliers have been engaged on water issues. This study will help determine the degree to which suppliers measure and record water use and water quality information at different stages of textile manufacturing. While this water footprinting project does not assess supplier efficiency, it does lay a foundation for supplier comparisons on a per-garment and regional basis.

A Simple, Replicable Methodology

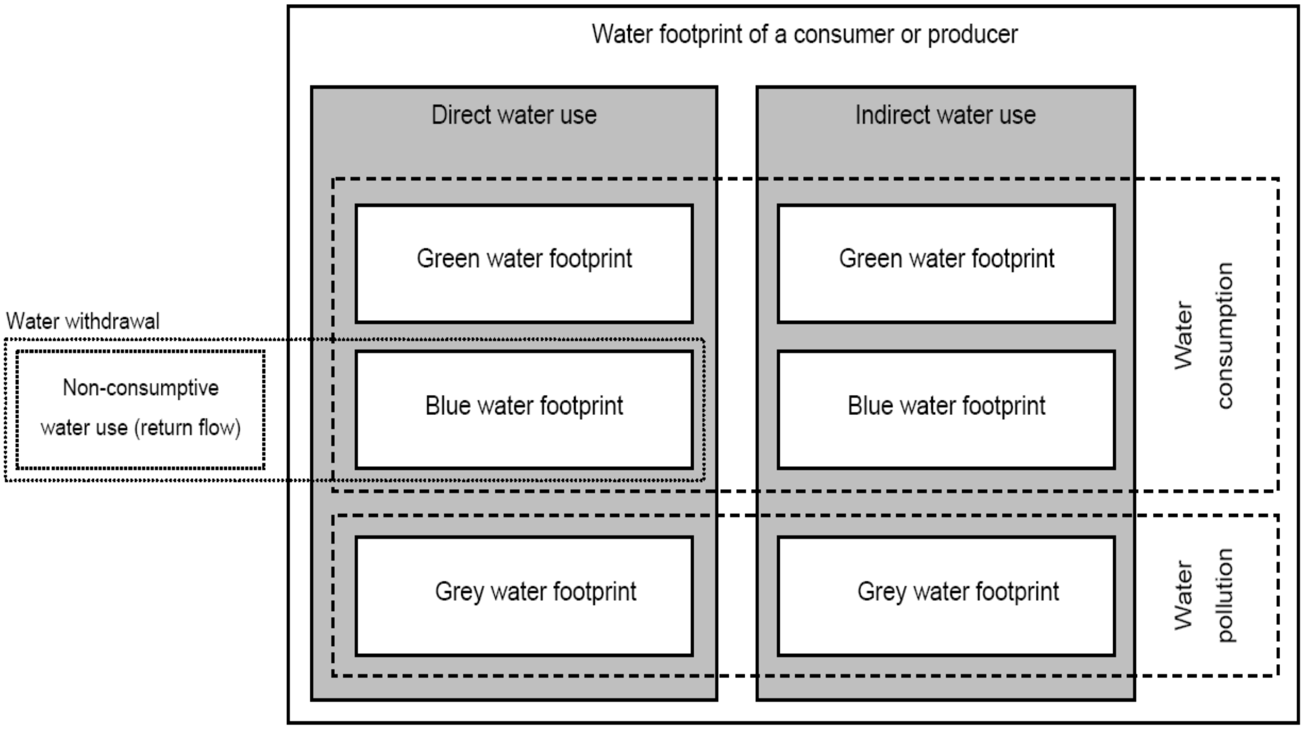
Many businesses, including Patagonia, have completed carbon footprints of their products. A growing awareness of water scarcity has now given rise to the concept of a water footprint.

Patagonia needed a simple yet meaningful methodology for quantifying the water used in garment production so that it could be easily applied to any product line without a huge investment of time or resources. Patagonia also wanted to incorporate water resource issues into their strategic business planning and environmental initiatives. By borrowing from existing water footprinting concepts and tactics, and by conducting supply chain research, we created an original framework for determining a product's water footprint and interpreting its regional impact on water resources.

Water Footprint Definitions

Currently, the most robust water footprinting methodology has been developed by the Water Footprint Network, a non-profit foundation dedicated to raising awareness about water issues and standardizing the concept of water footprinting. The Water Footprint Network has defined the components of a water footprint by use, its fate, and its source, as illustrated in the figure below. While this diagram was developed for the footprint of a consumer or producer, it can also be applied to a product, as described below.

A water footprint can be divided into direct and indirect water use, as shown by the two, grey vertical columns. Direct water use is the water that is used in production of a garment, for example the irrigation water applied to a cotton field to grow the raw materials for a T-shirt. Indirect water use is the water that is



used in the production of a peripheral good necessary for the manufacturing of the garment, for example the production of fertilizer for the cotton field used to grow the raw materials.

The water footprint is further categorized according to its fate, namely water consumption and water pollution. Water consumption is water that is used and not returned to the watershed from where it was withdrawn, resulting in its loss to further beneficial use due to evaporation and transpiration, or discharge to another watershed or the ocean. Water that is not consumed in the production process, for example runoff (return flow) from agriculture, is not included in the water footprint as defined by the Water Footprint Network. Lastly, water is defined by its source: precipitation, or "green water," and surface/groundwater, or "blue water." The summation of these values yields the total volume of water used in the manufacturing of a product.

Impact on water quality is communicated through the "grey water" component of the footprint, which is a measure of the pollution load discharged into the environment. Grey water is defined to be the volume of fresh water required to dilute a polluted volume of water discharged to the environment to a given standard of quality for beneficial use. It is important to distinguish the difference between this calculated volume of grey water and the measured volumes of green and blue water. Grey water should not be interpreted as an actual of volume used by a particular process, but only as a measure of the level of water pollution to be associated with the process.

Patagonia's Water Footprint

We have chosen to create two separate footprints that deliver different messages to our different audiences. Our first footprint is directed towards Patagonia's consumers. This footprint reports a product's life-cycle water use throughout its supply chain and consumer use stages – it does not distinguish consumed from non-consumed. Additionally, we created a footprint designed to communicate a product's impact on regional water resources. This footprint is primarily for use by Patagonia to compare environmental impacts between garments and suppliers, and also as a first step toward incorporating water risk management in their strategic planning decisions.

Boundaries and Scope

Our water footprint methodology was designed with simplicity and replicability as our primary drivers, so that it could be applied to Patagonia's full line of apparel. We have defined our footprint boundaries to best meet Patagonia's needs, considering only direct water uses. As such, water used in production of peripheral goods indirectly used in the supply chain, such as capital equipment,

BLUE	*Surface and shallow groundwater*
GREEN	*Rainwater*
GREY	*Dilution volume for untreated polluted water*

fertilizer, packaging, etc. are not included. We also do not include facility water use (water consumed by facility workers, landscaping, etc.) in our footprint.

Additionally, while we acknowledge that an energy/water use nexus exists in some regions and at some scales of water-supply integration, the water component of energy use is not included here. The water component of energy use can be derived from the calculation of a product's carbon footprint, which focuses more strongly on the product's life cycle energy use. Therefore, the transportation component of the supply chain is also omitted, as there is very little freshwater input in this stage, aside from the water use related to the energy used in transportation. Attempting to include these indirect water uses on a per T-shirt basis is time consuming and difficult, creating additional allocation issues while contributing very little to the overall footprint in terms of water volume and information.

Lastly, industrial discharge that is treated at a wastewater treatment facility is not included in our footprint. While polluted water, even when treated, clearly represents an environmental impact, we believe that this impact is beyond the scope of a footprint centered on water use and consumption. Treatment of wastewater costs money and requires energy, but essentially does not use or consume fresh water, and therefore has no water footprint. This categorization of industrial, treated wastewater is consistent with that of the Water Footprint Network.

Methodology Boundaries and Scope

Only include direct water uses in the manufacturing processes, such as irrigation and dyeing.

- Exclude indirect water uses, such as facility water use and transportation.
- Exclude water used in the production of peripheral goods, such as capital equipment and packaging.
- Exclude industrial discharge that is treated at a wastewater treatment facility.

Data Collection and Calculation

In order to calculate the components of a product's water footprint, we designed Excel-based surveys specific to each segment of the production supply chain: raw material production, fiber spinning, fabric weaving, dyeing/finishing, cutting/sewing, and printing.

First, we used survey questions sent to all of the stages in the supply chain to determine the production waste at each step. This provided us with a ratio of each stage's product (ie: cotton lint from the cotton farm, linear yards of fabric from the dye house, etc.) to the final T-shirt. This initial step must be completed for each raw material, and each type of garment, as production chains and waste ratios may differ. Next, survey questions focusing on determining the amount of water used per quantity of product were then used to calculate the T-shirt's footprint components.

The Excel-based surveys allow Patagonia to identify processes that require direct water use in production. The footprint calculator tool draws information from those specific surveys to determine the garment's product water footprint (Appendix A). It is important to note that this tool differs according to garment and raw material.

Blue Water

Green Water

Consumer Use

Product Water Footprint

Our life-cycle water footprint, directed at consumers, communicates the total water used throughout the product's useful life. This includes gross blue and consumptive green water as well as the consumer use phase. We consider only consumed green water because, in most cases, green water is used for agriculture, and if rain fall exceeds the crop water requirement it would not count toward the product water footprint.

We estimated the volume of water used in washing a garment based on the EPA's cost savings analysis for Energy Star washing machines. While this water is not something that Patagonia has direct control over, there are opportunities for them to communicate with customers about responsible care and reducing their environmental impact. Grey water is not included in this representation as it is not a volume of water that is actually used in production. See Appendix A for more details.

Regionalizing Impacts for Strategic Planning

Our second footprint focuses on consumed water, because that reduces the supply of water in a watershed, and so has a significant impact on regional water resources. In this footprint we define consumed water to be water that is transpired or evaporated, thereby leaving the watershed. The other methods by which water can leave a watershed, such as a transfer into another watershed or into the ocean, would be difficult for Patagonia to track repeatedly. In agriculture, a large portion of the gross water use is consumed, while in industrial processes it is much smaller.

Our regional impact assessment also only considers the blue water that is consumed, and omits the green water component of the original footprint. Green water, while if affects the amount of blue water used in agriculture, is not controllable by humans, and its use does not have the same impact as blue water. By focusing on blue water, we are directing Patagonia's focus toward the aspects of the footprint they can influence. Furthermore, blue water has a cost associated with it, whereas rainwater is essentially free [1], which is an important distinction to businesses.

In addition to focusing on consumed water, we also took into account polluted water that is directly discharged to the environment. As specified previously in the boundaries and scope, polluted water that is treated is not included in the impact footprint. The impact of treated water may be best expressed exploring the energy or cost associated with treatment rather than in a water footprint that focuses on freshwater consumption. See Appendix D for information regarding pollution loads.

While a product's water footprint provides a useful number for analyzing the total water requirement and pollution potential associated

Regionalized Blue Water Volume (per T-shirt)

Blue Water Volume x (WSI / $\text{WSI}_{\text{Global Average}}$)

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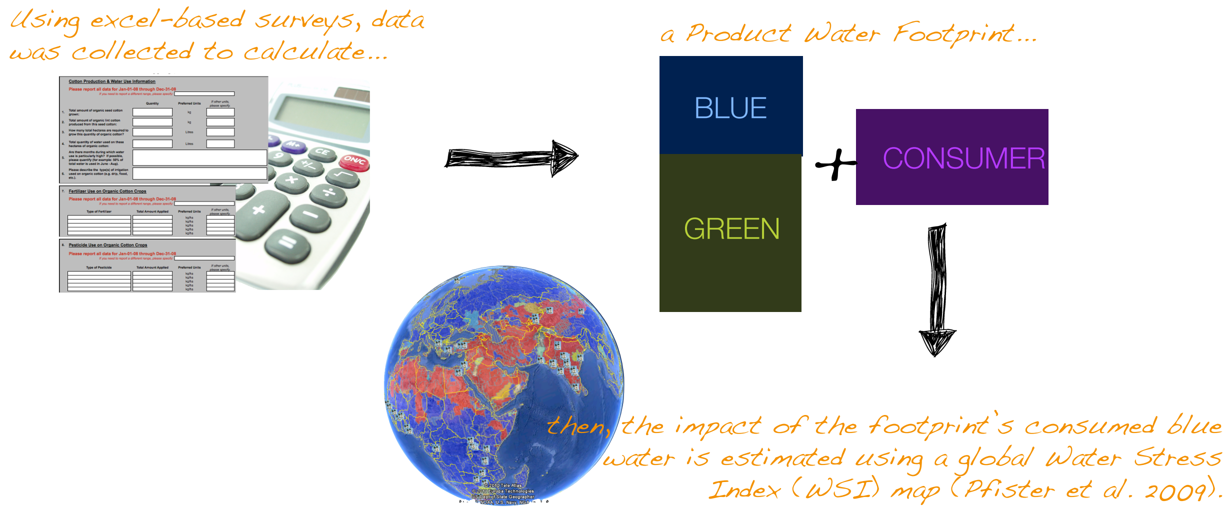
[1] While rainwater itself may be free, the value of this resource is expressed in the value of the land over which it falls. Neither Patagonia nor its suppliers are in a position to influence this value in the same way that they may control their blue water usage.

with a product, it does not provide any indication of the regional impact on water resources that a supply chain may have. Determining the precise impact of a water footprint presents a unique challenge, as water resources, policies, and politics vary significantly, geographically and temporally.

In order to link the impact of a required volume of blue water to a region of the world, we relied on the Water Stress Index (WSI) developed by Pfister et al. (2009) to scale the impact of the blue water component of our footprint. We chose not to regionalize the impact of grey water, because grey water is a representation of a process's pollution potential, not an actual volume of water used or polluted. The WSI is a ratio between water use and water availability, and is estimated using the the WaterGAP2 model, which combines global water use and global hydrology (Appendix C). The WSI of a watershed ranges from 0.01 to 1, with 1 representing the most water stressed areas and 0.1 representing the least. We took the average of the WSI values across all watersheds to obtain a global average (0.1336). We then multiplied the consumed blue water by the WSI of its location, and then divided by the global average. By dividing by the global average, we produce a regional impact of the water use relative to the global average. When consumptive use occurs in a more water stressed region, the value of the "impact" water footprint increases. Likewise, if consumptive use occurs in a non-water stressed region, the value of the "impact" water footprint decreases. Regionalizing the blue water component of the footprint changes the units from liters to "liters of potential impact." This regionalized blue water can then be added to the grey water component[2] to determine the full supply chain's overall potential impact on local water resources. This "footprint impact" can be used to evaluate the relative effect of water withdrawal on a region, as well as the pollution potential of the production process.

The Google map application allows for quick visual approximation of the level of water stress for certain watersheds. However, it is important to be mindful of the fact that while we used the WSI to characterize impact in this study, it is only a first approximation of the conditions in a region. The WSI does not necessarily convey the full water resource situation in the watershed. It is crucial to also consider water availability, as well as the socioeconomic and political climate of the region to fully capture the business risks related to water. We have developed a series of questions that will help Patagonia to formulate a more detailed understanding of a supplier's water situation.



Using excel-based surveys, data was collected to calculate...

a Product Water Footprint...

then, the impact of the footprint's consumed blue water is estimated using a global Water Stress Index (WSI) map (Pfister et al. 2009).

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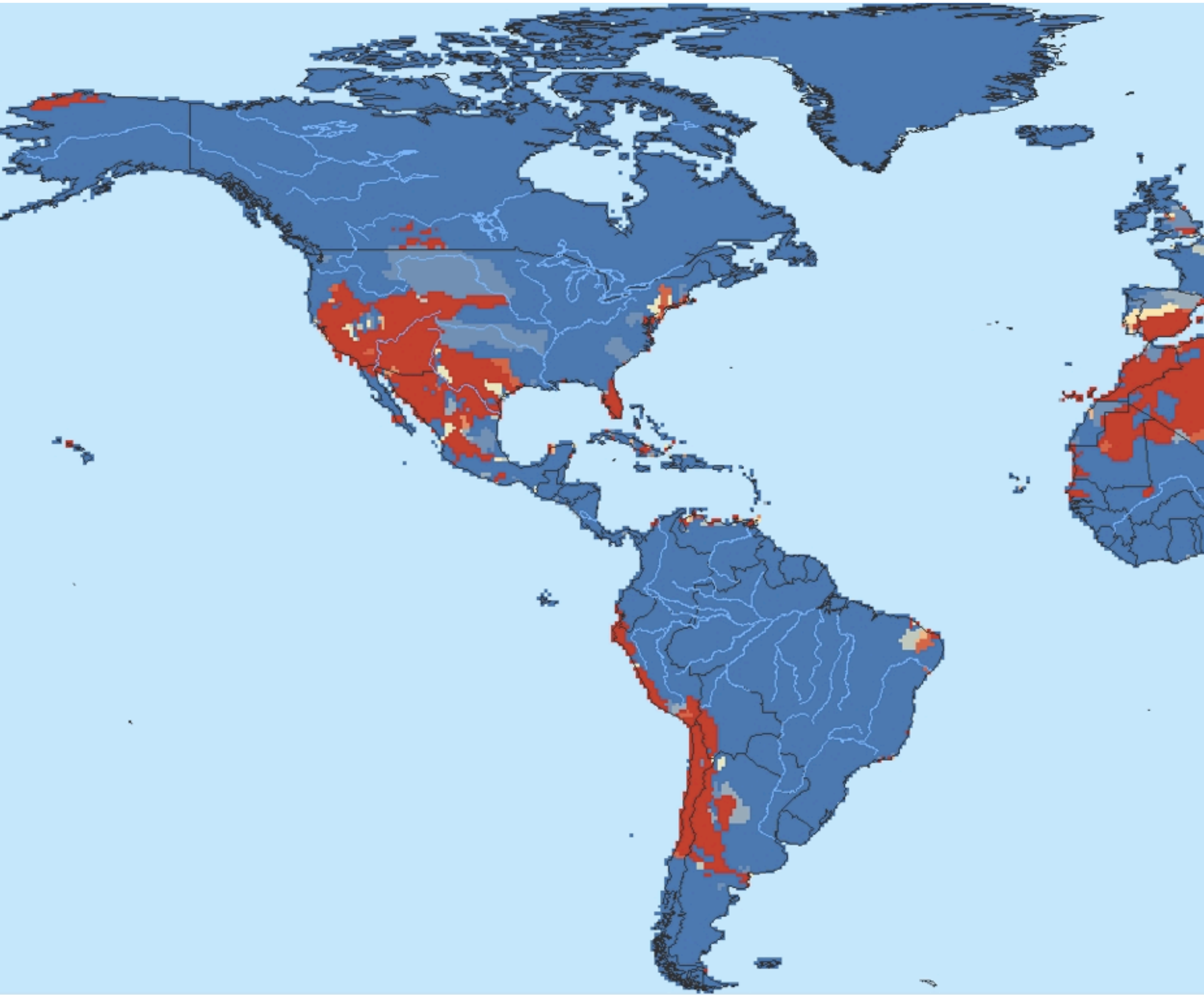
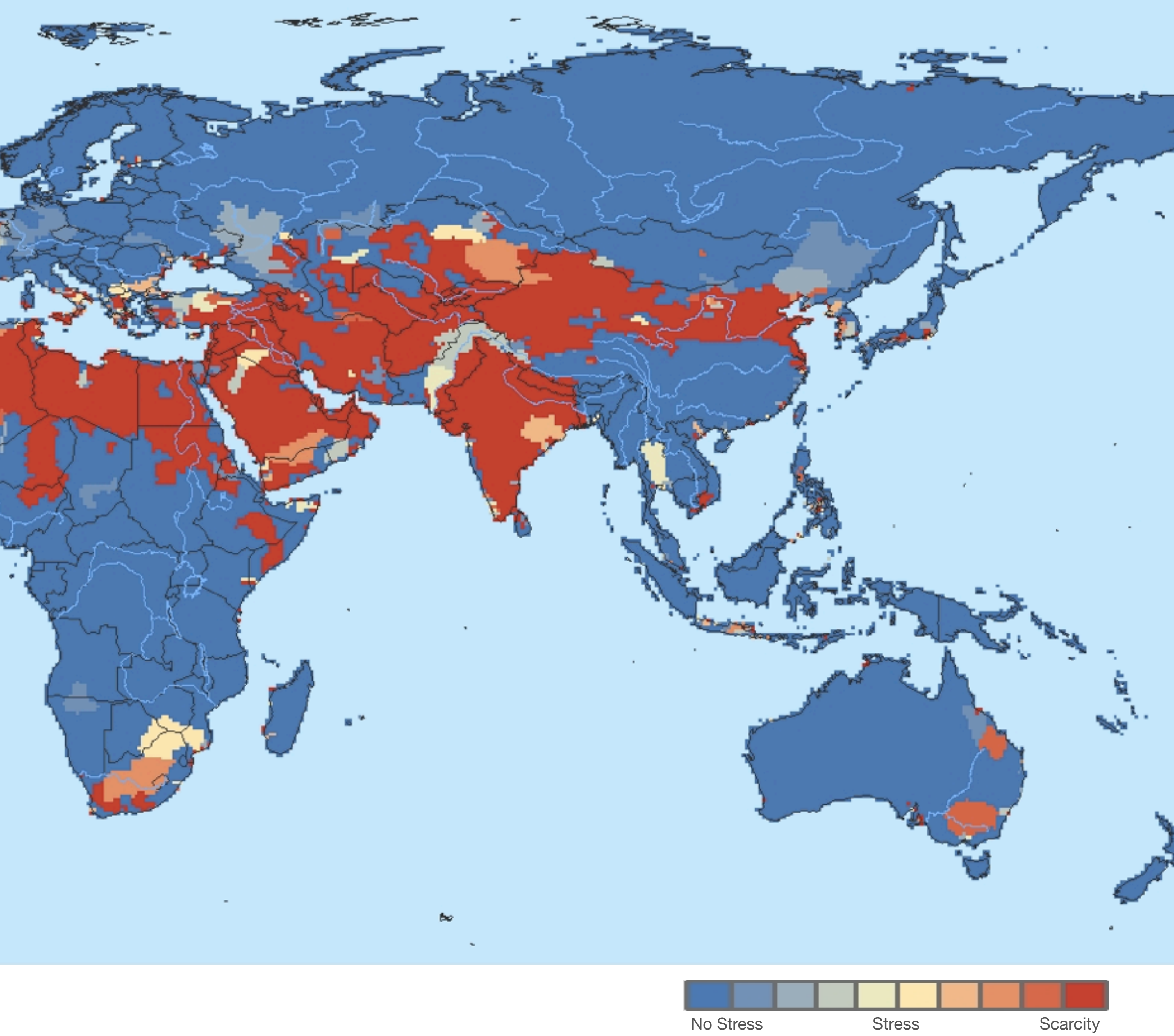
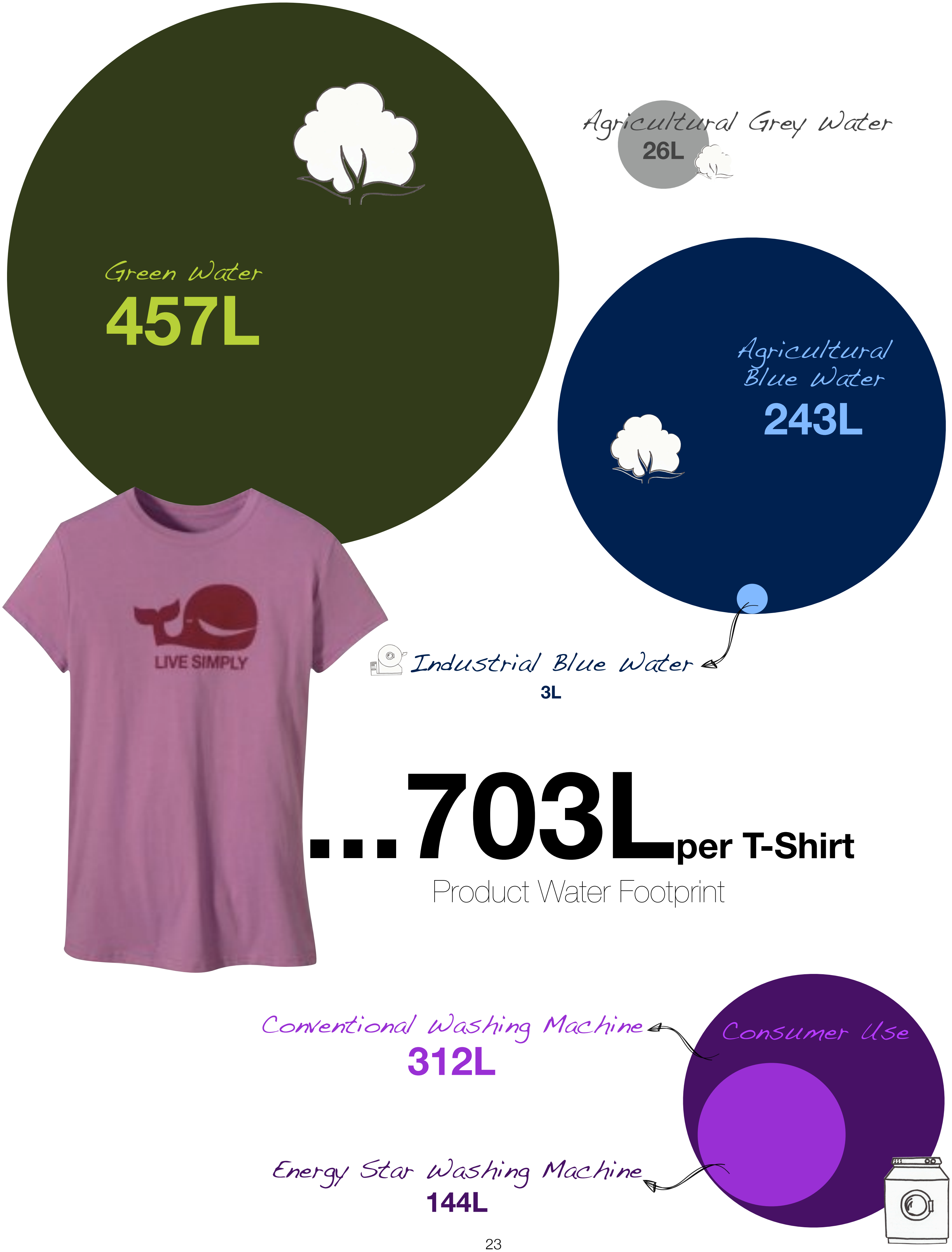
[2] Grey water is already a measure of potential impact. We consider the units for grey water to also be "liters of potential impact."



Global Water Stress Index (Pfister et al 2009)

The Water Stress Index (WSI) is a ratio between water use and water availability, and is estimated using the combination of a global water use and global hydrology model, known collectively as the WaterGAP2 model.


No Stress
Stress
Scarcity



Green Water

457L

Agricultural Grey Water

26L

Agricultural Blue Water

243L

Industrial Blue Water

3L

...703L per T-Shirt

Product Water Footprint

Consumer Use

Conventional Washing Machine

312L

Energy Star Washing Machine

144L

A Case Study: Women's Simply Organic T-Shirt

Patagonia undertook its first product water footprint exercise for the Women's Simply Organic cotton T-shirt.

Product Water Footprint

The figure below represents the quantity of water required by the T-shirt from a life-cycle perspective. Since this is directed at consumers, we believe that total volume of water input is of greatest importance.

In accordance with our boundary definitions, the water footprint of Patagonia's cotton T-shirt is 703L plus a variable quantity for consumer use, for a total range of 847L -1015L. It is comprised of the following components: (for more details see Appendix A)

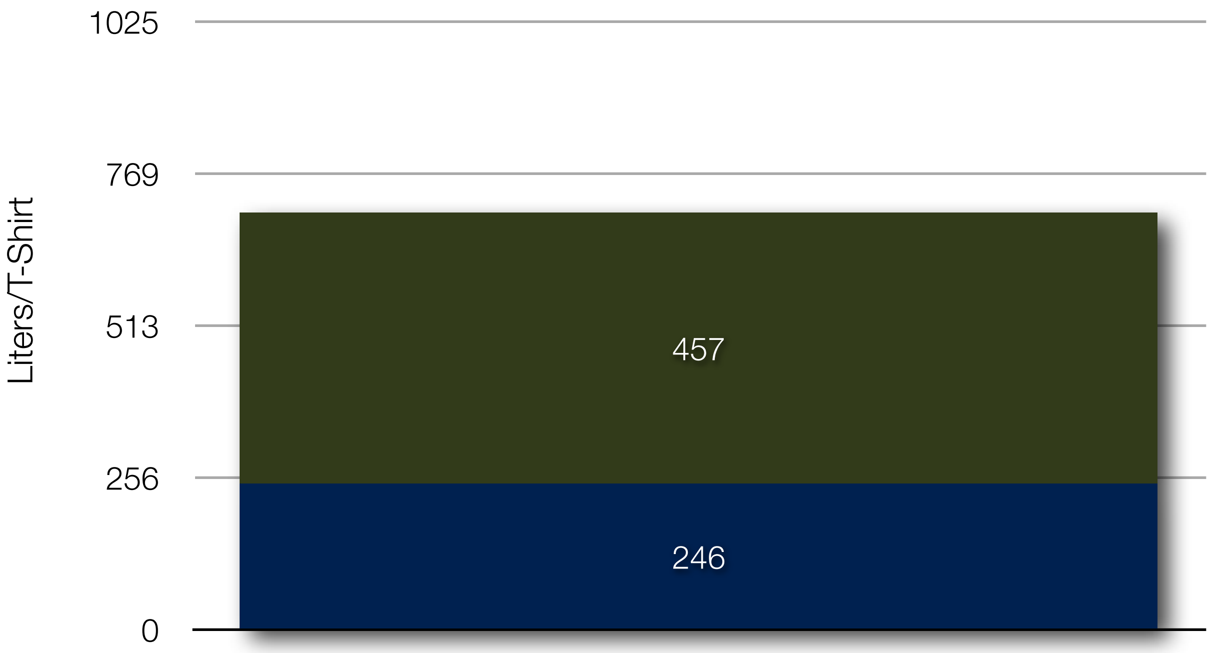
Green water – 457L Calculated volume of rainfall that contributes to meeting the crop water requirement of the cotton

Blue water (agricultural) – 243L Reported total volume of irrigated water for the cotton;

Blue water (industrial) – 3L Reported total volume of water used to dye/finish the cotton

Consumer use – 144-312L Calculated volume of water that would be required to wash one T-shirt during its use by a customer.

Product Water Footprint



The figure on page 27 illustrates the complete supply chain for the Women's Cotton T-shirt. First the cotton is organically grown in Turkey and spun into fiber. Next it is shipped to the US, where it is knit into fabric, dyed, and cut & sewn into the final product. The agriculture and dyeing stages are highlighted in blue, as these two supply chain processes represent the areas of direct water use that we focused on in our footprint calculations.

The green water component of the footprint was calculated based on the crop water requirement of cotton grown in Turkey. The crop water requirement is the volume of water required by a crop to mature, which this was calculated using the Food and Agriculture Organization's ClimWat and CropWat databases. Using information gathered from the cotton grower in Turkey, we then determined how much of this requirement was met through irrigation and subtracted to calculate the volume met by rainwater.

The blue water from industrial processing consists of the total amount of water input into the dye machine, while consumed blue is the gross blue minus the percentage that is evaporated as the fabric dries.

The consumer use value was based on figures from the EPA's cost savings analysis for Energy Star washing machines. We assumed the useful life of the T-shirt to be five years, and that the average customer washes a T-shirt twice monthly. The range represents differences in washing machine water use efficiency.

Regionalized Impacts

The figure below represents the regionalized potential impact of the supply chain water use and water pollution for the T-shirt. This relies on the WSI to determine the potential impact of blue water consumption relative to the global average watershed. We consider this

Impact Analysis

footprint to be most useful to Patagonia as a way to quantify the environmental impact of consumptive water use and water pollution throughout the supply chain of the T-shirt. This may be applied as a strategic planning tool for selecting vendors based on their impact on local water resources.

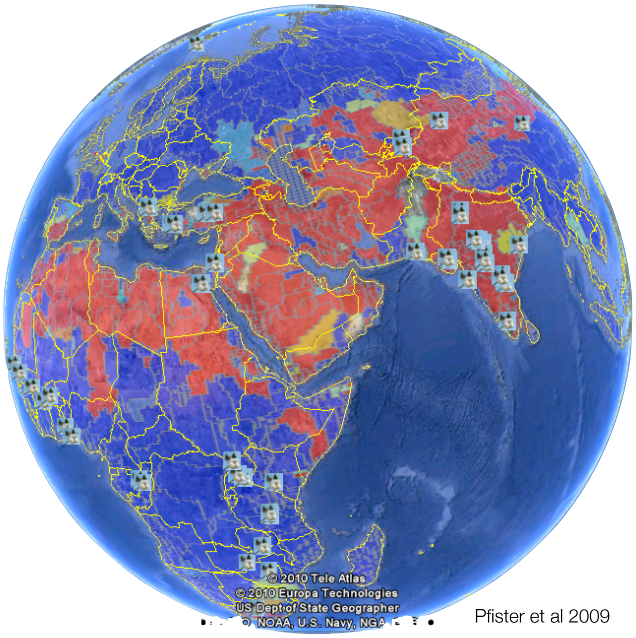
The consumed blue water in cotton growing is the amount of irrigation water that was evapotranspired by the crop. This was calculated by subtracting an estimated runoff percentage from the gross blue value.

To calculate the grey water associated with agriculture, we chose to focus on the nitrogen content of the runoff as the primary pollutant in the irrigation return flow (i.e. runoff). In a calculation we "diluted" the effluent with nitrogen-free water, until the EPA drinking water standard for total nitrogen (N) was met.

We acknowledge that this calculated measure of grey water tells an incomplete story. In this case, while the runoff is discharged directly into the environment, it is not immediately diluted by downstream water resources and along the way the nitrogen may be assimilated into the environment. These processes are not captured in the grey water calculation.

The table below illustrates the calculation of the water footprint impact.The cotton is grown in Turkey, which has a WSI value of 0.126. As this is considered an unstressed region, in terms of water consumption and availability, the potential impact of the volume of water used in agriculture shrinks only slightly. Meanwhile, the fabric is dyed in Los Angeles, which has a high WSI value of 1.0, indicating it is in a highly water stressed region. This component therefore increases rather dramatically.

	Net Blue Water (L)	**Regional WSI**	Global Average WSI	**Impact Potential (L)**
Agriculture	194	0.126 (Turkey)	0.1336	183
Dyeing	2	1 (US)		15
			TOTAL	**198**



Pfister et al 2009

Supply Chain Segments

Turkey → United States →

Growing and harvesting cotton

Spinning raw cotton into fibers/yarn

Knitting the fibers/yarn into fabric

Dyeing the fabric into various colors

Cutting and sewing the fabric into a T-shirt. Printing graphic.

		Growing and harvesting cotton	Spinning raw cotton into fibers/yarn	Knitting the fibers/yarn into fabric	Dyeing the fabric into various colors	Cutting and sewing the fabric into a T-shirt. Printing graphic.
Water Use	Intensity	**HIGH**	*No significant direct water use*	*No significant direct water use*	**Low**	*No significant direct water use*
	Description	Water required to mature a cotton crop			Water used for bleaching and dyeing fabric	
Volume	Blue	243L	-	-	3L	-
	Green	457L	-	-	-	-

← That's 4 average bath tubs...

703L

Strategic Planning

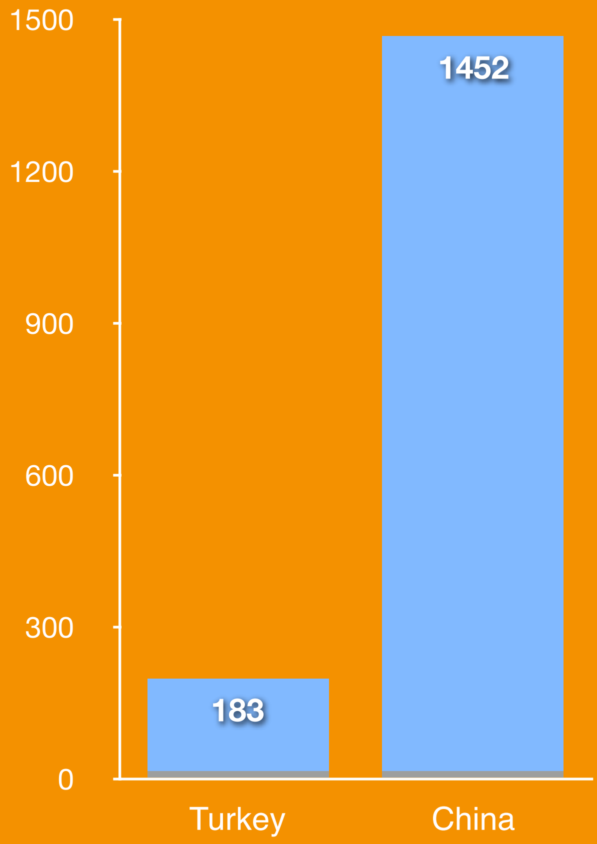
Virtually all business organizations, whether small or large, utilize water in the production of their goods and services. Product water footprinting allows business managers to get a sense for where water is a key input, allowing for a comparison of different suppliers within the value chain.

Comparing Supply Chain Actors

The impact assessment can be used to compare supply chain actors. For instance, Patagonia sources organic cotton from Turkey and China. As previously demonstrated, growing cotton is a water-intensive process. Suppose we assume that the same volume of blue water is consumed to produce the same amount of organic cotton in both regions. The region in Turkey has a WSI of 0.126 and the region in China has a WSI of 1.0.

Assuming both growers require the same volume of consumptive blue water, the footprint in China grows because they're in a water stressed region. However, the actual volume of water consumed in China could vary significantly from the volume of water consumed in Turkey. While the Turkish supplier uses flood irrigation, the Chinese supplier uses drip irrigation. Therefore, the Chinese supplier's superior efficiency may potentially reduce its footprint impact. This application of the WSI can be used to evaluate and compare any suppliers using actual or estimated consumed blue water values. (See Appendix C for more details on the Waters Stress Index)

The Google map application allows for quick visual approximation of the level of water stress for certain watersheds. However, it is important to be mindful of the fact that while we used the WSI to characterize impact in this study, it is only a first approximation of the conditions in a region. The WSI does not necessarily convey the full water resource situation in the watershed. It is crucial to also consider water availability, as well as the socioeconomic and political climate of the region to fully capture the business risks related to water. We have developed a series of questions that will help Patagonia to formulate a more detailed understanding of a supplier's water situation.



...Taking a closer look at cotton production

Regionalizing the impacts of consumed blue water in cotton growing using the Water Stress Index (WSI) begins to communicate the environmental impacts of cotton production on water resources.

Comparing Suppliers...

Organic cotton can be sourced from both Turkey and China. Suppose we assume that the same volume of blue water is consumed to produce the same amount of raw material in both regions. Also, suppose that both regions have a grey water dilution volume of 15L per T-shirt. The region in Turkey has a WSI of 0.126 and the region in China has a WSI of 1.0. Assuming both growers require the same volume of consumptive blue water, the footprint in China grows because they're in a water stressed region.

Growing cotton is a water intensive process and the impact assessment can be used to compare supply chain actors.

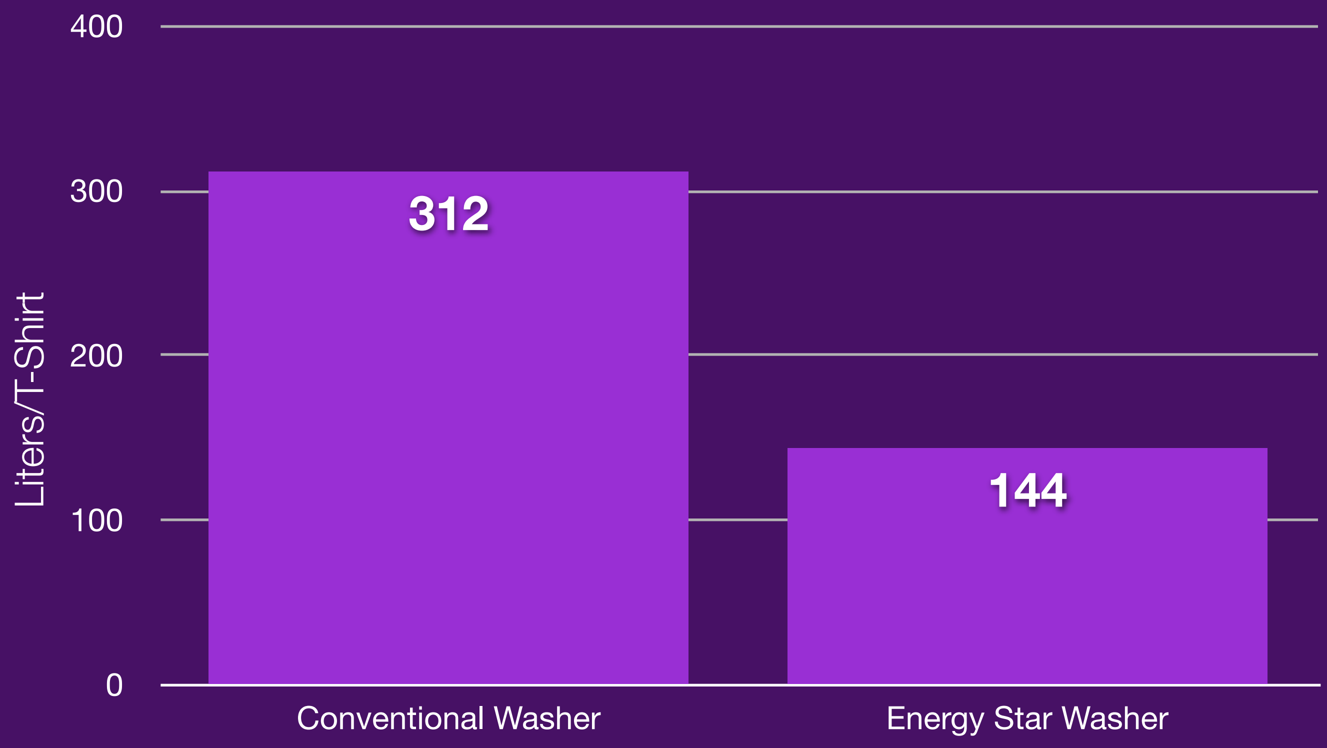
Consumer Use

Laundering uses a large volume of water...from **312L** per T-shirt in a conventional machine down to **144L** per T-shirt in an Energy Star washing machine (EnergyStar 2010). There is great opportunity for consumers to alleviate environmental impacts associated with water consumption.

Wash full loads of laundry. By washing full loads once every two weeks instead of once a week, you can decrease your overall impact on water resources.

Wash in cold water. You can reduce the impact of your clothes on the environment by taking a simple step: wash them in cold water instead of hot.

Use water efficient machines. By using a front loader washing machine you can reduce your water use by up to 45% .




EXTRA RINSE
FINAL SPIN SPEED
AUTOMATIC DISPENSER
WARM WARM
COLD COLD
COLD COLD
WARM COLD
WARM COLD
HOT COLD
WARM WARM
PrecisionTemp
CONTROL
YES
NO
WASH
RINSE
FINAL SPIN
DOOR LOCK
SLOW
NORMAL
FAST
END OF CYCLE CHIME
ON

Recommendations for Patagonia's Water Strategy

Water footprint methods are rapidly changing, and country, product & business studies are advancing methods towards a generally accepted water footprinting methodology.

Product Water Footprint

The following are recommendations for conducting a product water footprint, with an emphasis on capturing the most significant and business-relevant components of water use.

Focus water footprinting efforts on the most water-intensive aspects of direct water usage in a garment supply chain.

Processes that are water intensive are most relevant to business decisions from a financial and environmental perspective. In the textile industry, a first approximation was achievable by capturing only the water intensive processes through surveys and personal correspondence. We excluded the production of peripheral goods (i.e. tags or zippers) that are indirectly used in the supply chain, facility water use, or the water used in transportation. These components use very small quantities of water in comparison and are time intensive for the supply chain and for Patagonia to incorporate. Attempting to incorporate these smaller water uses on a per garment basis would yield a more comprehensive water footprint, but contributes little to the overall understanding of a garment's water footprint.

Report the total water used to make a garment, which includes green and blue water, as well as the water used by consumers in laundering.

By focusing the product water footprint on the total water required to produce the product can be communicated to consumers. The inclusion of green water (rainfall) and blue water (surface water) in the product water footprint allows for an organization to account for the full volume of water required to yield a mature crop of a given raw material and complete the manufacturing processes. This product water footprint also incorporates the water use of the consumers it is intended to educate, providing an opportunity for Patagonia to encourage consumers to change their behaviors.

Remain invested in industry efforts and studies to further define and develop textile water footprinting, especially in the areas of recycling/reuse and water pollution.

Current efforts in the LCA community to address the characterization of textile water use and especially water quality impacts should be monitored. Furthermore, increased water recycling and reuse efforts have the potential to complicate water footprint accounting. Although initial efforts in this study did not encounter these issues, we recommend that Patagonia continue to investigate and track how future water footprint efforts account for recycling and reuse.

Strategic Planning Recommendations

Environmental Impacts

Focus on the consumed, blue water use in a supplier's location as the first step in quantifying the environmental impact of water consumption.

Consumed water has a meaningful impact on a watershed environment because it is water that has been removed from the watershed, thereby reducing the supply. The reason for focusing on blue water is its significance to business operations, as most businesses have to purchase "blue" water. In agriculture, both blue and green water are important in terms of quantity used, but looking only at blue water is a sufficient measure of impact. Whereas rain water falls to the ground regardless of land use choice, blue irrigation water could be used for purposes other than agriculture in the watershed, therefore it has a more significant affect on water resource decisions and trade-offs in the watershed.

Use the Water Stress Index map to determine the stress in a supplier's location as the second step in quantifying the environmental impact.

The water stress map developed by Pfister et al. (2009) provides a useful, first approximation of competition for water resources in a watershed, given by the ratio of demand to supply. By providing estimates of human pressure on the natural availability of water in a given watershed, the WSI map creates a picture of where water-related business risk might be greatest. Like all global water resource assessment models, the WSI map cannot account for all circumstances. In some areas, such as the interior of the Australia—a region known for its dry, harsh climate, the map shows no stress because limited water is matched by low numbers of people. In these cases, a useful complementary map would be water availability per capita. We have created such a map using hydrology data from the University of New Hampshire Global Runoff Data Center paired with population data from Columbia University's Center for International Earth Science Information Network, or CIESIN (Fekete et al. 2000, CIESIN and CIAT 2005).[3] It should be noted that no map we know of fully accounts for all human-made water infrastructure (i.e. aqueducts), which has a significant impact on water resource reliability. However, these maps can still be used in a meaningful way to compare the impacts of suppliers and of garment production in different locations.

Address treated wastewater separately. Untreated wastewater should be addressed through a grey water calculation.

Water pollution is a challenge for businesses to characterize. In the case of agricultural runoff or untreated manufacturing process return flows, the use of a dilution factor to calculate grey water, as recommended by the Water Footprint Network, is reasonable method because it is actually diluted in nature.

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[3] see Appendix G for maps

With respect to treated wastewater, the impact is not in water used, but rather, the energy and monetary resources needed to treat water to accepted water quality standards. As a result, we recommend additional research focused on characterizing a pollution footprint for each textile process as a way for textile and apparel companies to determine a better approximation of the business impacts of water quality.

Reducing pollution potential of wastewater streams is a 'no regrets' strategy that will maximize resource efficiency and minimize environmental harm. This strategy aligns with Patagonia's existing partnership with Bluesign Technologies, which conducts extensive audits for textile manufacturers to help them accomplish these goals.

<u>Keep an eye out for future water scarcity scenarios</u>.

Future water scarcity projections should be considered when businesses choose to contract with suppliers. There are a number of water scarcity projections available, and the one most useable in this water footprinting framework is currently being developed by Stephan Pfister and others at the Institute for Environmental Engineering in Switzerland. Other projections should be looked at for comparison as well. A corporation faced with an investment decision to utilize these global resources for anything but a first crude filtering of options followed by a higher resolution local assessment of water availability and its implications. There is no substitute for on the ground evaluations.

Business Risks

...need to be addressed at the facility level

As water becomes increasingly scarce, many companies will be exposed to escalating pressures because their supply chains span the globe, exposing them to local and national water challenges. Climate change will likely exacerbate three types of risks: physical, reputational and regulatory. Analytical approaches, such as water footprinting, begin to address these risks and assist companies in making strategic decisions regarding water.

<u>Be aware of which suppliers are located in the most water stressed regions, and factor water scarcity into the decision making when contracting with new suppliers.</u>

Patagonia's most water-intensive operations occur in the supply chain. Therefore their risks are somewhat diminished because only a small part of their product line could be affected by water problems. It is in Patagonia's best interest to be aware of which of their suppliers are located in the most stressed regions, as there is a greater likelihood of disruption. When evaluating supplier risk in water stressed regions, the relevant information to consider is the value of Patagonia's products produced in the region, and how much water the supplier uses compared with other, similar suppliers. In this case, the business (facility) water footprint is relevant in addition to the product water footprint, as indicators of efficiency. This study does not provide facility-type benchmarks, and recommends this as further research.

<u>Reduce the likelihood of reputational risks by maintaining transparency on websites and other materials with regard to how water footprints are calculated. Communicate next steps in addressing water-related environmental problems.</u>

Patagonia has distinguished itself as one of the most environmentally conscientious companies today, and this has helped to build their reputation and brand name. By being transparent in reporting actual water use, metrics and methods, and future strategies to mitigate risks, they can continue to earn the trust of their customer base. Furthermore, a transparent approach will reduce reputational risks and help to create benchmarks for subsequent product water footprinting efforts. Publicly reporting key metrics on water use and impacts will help stakeholders understand how they are addressing water risks. In addition to communicating a water footprint and the methods by which it was calculated, future strategies for environmental mitigation should also be communicated.

Choose to do business with suppliers who are already engaging with local stakeholders.

Physical water resource constraints expose companies to reputational risks. Declines in water availability and quality can increase competition for clean water. Tensions can arise between businesses and local communities, particularly in developing countries where local populations often lack access to safe and reliable drinking water. Community opposition to industrial water withdrawals and perceived or real inequities in use can affect businesses profoundly. Local conflicts can damage brand image.

Consider supply chain responses to regulatory and governance questions to provide an approximation of regulatory risks in a region.

Physical pressures affecting water availability and wastewater discharge can result in more stringent water policies. Concern among local communities about water withdrawals, will put pressure on governments to consider water reallocations and regulations, permit suspensions to draw water, and stricter water quality standards.

Some national governments already impose strict water quality standards for water supply and wastewater discharge. However, governments in emerging markets typically have yet to develop and/or enforce water quality standards. However, this is likely to change as economic development continues in these countries and per capita income rises. (See Appendix H for suggested questions)

Physical, regulatory, and reputational risks often appear in combination. Water scarcity (physical) may lead to the revocation of water licenses (regulatory), or to damage to a firm's image and brand (reputation). These risks may impact different points along the value chain and may affect suppliers, production facilities, or users of the product.

Mitigating Impacts

There are a number of ways in which a business can take action to offset its water use. One emerging concept is that of water neutrality.

Moving towards "water neutrality."

Strictly speaking, no individual or entity that uses water can ever be entirely water neutral; water use cannot be reduced to zero. However, if the term is used in a consistent and transparent manner, it has potential similar to that of carbon neutrality.

There are two requirements to be "water neutral" (Gerber-Leenes et al 2007):

1. All that is 'reasonably possible' should be done to reduce the existing water footprint;
2. The residual water footprint is offset by making a 'reasonable investment' in establishing or supporting projects that aim at the sustainable and equitable use of water.

Patagonia can have an influence on its suppliers, which could lead them toward reducing their water footprint. Alternatively, Patagonia can switch to more water-efficient suppliers. Patagonia also has direct control in the design of its products, and can choose to produce garments that are less water intensive. Should Patagonia choose to engage in water projects to offset their use, they should consider where they are having the most impact and how they can help to make improvements.

The Future of Water Footprinting

The future of water footprinting depends on an ability to measure, understand, and engage.

As water footprinting gains traction and acceptance in the business world, we expect the methodologies to become more refined. While calculating a volume of water associated with the production of a garment is relatively straightforward, a major challenge lies in characterizing the environmental impact of the water consumed. Our water footprinting framework takes a first step towards linking a product water footprint with a regional water stress indicator, in an attempt to quantify the impact of water consumption in a given watershed.

Robust discussions surrounding water use and disclosure are occurring in businesses and academic institutions worldwide. Advocacy for water footprints will continue, and more people will be made aware of the complex and significant role of water in our lives and economies. Climate change will exacerbate many of the challenges associated with our reliance on freshwater, and companies must be prepared to venture beyond their comfort zone to sustain the viability of this critical resource. Continued discussion about these methods creates an opportunity to share meaningful strategies to address water footprinting, impacts assessments, and associated business risks, thereby improving ‘measure to manage’ efforts. (SABMiller 2009).

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APPENDICES

Appendix A: Cotton T-Shirt Case Study Calculations

First, we used survey questions sent to all of the stages in the supply chain to determine the production waste at each step. This provided us with a ratio of each stage's product (ie: cotton lint from the cotton farm, linear yards of fabric from the dye house, etc.) to the final T-shirt. This initial step must be completed for each raw material, and each type of garment, as production chains and waste ratios may differ. Next, survey questions focusing on determining the amount of water used per quantity of product were then used to calculate the T-shirt's footprint components.

Industrial Blue Water

The gross volume of industrial blue water to be attributed to a cotton T-shirt is determined by looking at the total quantity of water used to dye a batch of fabric, which varies according to fabric color. The water must then be divided to determine the proper allocation for a single T-shirt. Our dye house reported its water use in terms of volume of water per linear yard. Combining this information with survey data from the cut/sew facility allows us to calculate the dye water to be allocated to one T-shirt:

$$\begin{aligned} &Gross\ dye\ house\ blue\ water\ per\ shirt\ (L/shirt) \\ &\qquad = Dyewater\ per\ linear\ yard\ (L/linear\ yard) \\ &\qquad * \frac{Pct.area\ of\ a\ linear\ yard\ required\ to\ produce\ 1\ shirt\ (linear\ yard)}{1\ shirt\ (shirt)} \end{aligned}$$

To calculate the net blue water, we used to ratio of the dye house's water discharge to water intake, as follows:

$$\begin{aligned} &Net\ dye\ house\ blue\ water\ per\ shirt\ (L/shirt) \\ &\qquad = \ Gross\ dye\ house\ blue\ water\ per\ shirt\ (L/shirt) * (1 - \frac{Water\ discharged\ (L)}{Water\ purchased\ (L)}) \end{aligned}$$

Agricultural Blue Water

The gross volume of agricultural blue water to be attributed to a single cotton T-shirt is determined by looking at the total quantity of water used to mature the cotton crop. By analyzing supply chain surveys, we were able to determine the approximate share of the cotton crop's overall water use to be allocated to one T-shirt.

First, based on survey responses, we calculated the amount of irrigated water required to produce 1 kg of lint cotton:

$$Water\ to\ produce\ 1\ kg\ fiber\ (L/kg\ of\ fiber) = \ Water\ to\ produce\ 1\ kg\ lint\ cotton\ (L/kg) * \frac{Total\ mass\ of\ lint\ cotton\ required\ to\ produce\ 1\ kg\ fiber\ (kg\ of\ lint\ cotton)}{1\ kg\ fiber\ (kg\ of\ fiber)}$$

Next, we related this to the amount of irrigation water required to produce 1 kg fiber:

$$Water\ to\ produce\ 1\ kg\ lint\ cotton\ (L/kg\ of\ lint\ cotton) = \frac{Total\ volume\ of\ irrigated\ water\ applied\ to\ the\ field\ (L)}{Total\ mass\ of\ lint\ cotton\ produced\ at\ the\ field\ (kg\ of\ lint\ cotton)}$$

Next, we related this to the amount of water required to produce 1 linear yard of fabric:

$$\begin{aligned} &Water\ to\ produce\ 1\ linear\ yard\ of\ fabric\ (L/linear\ yard) \\ &\quad = Water\ to\ produce\ 1\ kg\ fiber\ (L/kg\ of\ fiber) \\ &\quad * \frac{Total\ mass\ of\ fiber\ required\ to\ produce\ 1\ linear\ yard\ of\ fabric\ (kg\ of\ fiber)}{1\ linear\ yard\ of\ fabric\ (linear\ yard)} \end{aligned}$$

Finally, we related this to the amount of water required to produce 1 shirt:

$$\begin{aligned} &Gross\ agricultural\ blue\ water\ per\ shirt\ (L/shirt) \\ &\quad = Water\ to\ produce\ 1\ linear\ yard\ of\ fabric\ (L/linear\ yard) \\ &\quad * \frac{Pct.\ area\ of\ a\ linear\ yard\ required\ to\ produce\ 1\ shirt\ (linear\ yard)}{1\ shirt\ (shirt)} \end{aligned}$$

The net blue water is calculated using an estimate of the amount of runoff typically expected from flood irrigating cotton crops. Kanber et al. estimate this value to be from around 20% to over 30% of the applied irrigation water (gross blue water). We chose to assume runoff (agricultural return flow) to be roughly 25%. Runoff and consumed blue water are therefore expressed as follows:

$$Runoff\ per\ shirt\ (L/shirt) = Gross\ blue\ water\ per\ shirt\ (L/shirt) * 25\%$$

$$\begin{aligned} &Consumed\ blue\ water\ per\ shirt (L/shirt) \\ &\quad = Gross\ blue\ water\ per\ shirt\ (\ L/shirt) - Runoff\ per\ shirt\ (L/shirt) \end{aligned}$$

Agricultural Green Water

Green water is estimated using the crop water requirement for cotton grown in Turkey. The crop water requirement is the volume of water required by a crop to mature; this was estimated using the Food and Agriculture Organization’s ClimWat and CropWat databases. The crop water requirement for cotton was then converted to a per T-shirt basis, applying the same methodology used to calculate blue water on a per T-shirt basis. We calculated the green water by subtracting the portion of the crop water requirement met by irrigated water (consumed blue water) from the total crop water requirement per T-shirt, as follows:

$$\begin{aligned} &Green\ water\ per\ shirt\ (L/shirt) \\ &\quad = Crop\ water\ requirement\ per\ shirt (L/shirt) \\ &\quad - Consumed\ blue\ water\ per\ shirt\ (\ L/shirt) \end{aligned}$$

Agricultural Grey Water

To calculate the grey water associated with agriculture, we chose to focus on nitrogen (N) content of the runoff. We assumed that the volume of runoff was 25% the volume of irrigated water and the N concentration was 14.23 mg/L (McHugh et al. 2008). We then chose to dilute the effluent with nitrogen-free water, to meet the EPA drinking water standard for nitrate, 10 mg/L, measured as total N (EPA 2010). This standard represents the boundary beyond which nitrogen begins to negatively impact human health. Setting up the following equation, we can solve for the total volume of water that brings the polluted discharge down to the acceptable standard:

$$\begin{aligned} &Dilution\ volume\ (L/shirt) * EPA\ standard\ concentration\ (mg/L) \\ &\qquad = Discharge\ volume\ (L/shirt) * Discharge\ concentration\ (mg/L) \end{aligned}$$

$$\begin{aligned} &Dilution\ volume\ (L/shirt) \\ &\qquad = \frac{Discharge\ volume\ (L/shirt) * Discharge\ concentration\ (mg/L)}{EPA\ standard\ concentration\ (mg/L)} \end{aligned}$$

Grey water is defined as the ***additional*** volume of water, so we must then subtract the discharge volume from the dilution volume, as follows:

$$\begin{aligned} &Grey\ water\ per\ shirt\ (L/shirt) \\ &\qquad = Dilution\ volume\ (L/shirt) - Discharge\ volume\ (\ L/shirt) \end{aligned}$$

Consumer use

The consumer use phase contributes a large volume of water, in the form of laundry use, to the life-cycle footprint of the garment. We calculated this quantity based on figures from the EPA's cost savings analysis for Energy Star washing machines, which are based on the Department of Energy J and J1 test procedures (EnergyStar 2010). The upper bound of our consumer water use number is based on the EPA-defined conventional unit's average water consumption per cycle, which is 31.07 gallons per load. A conventional unit is defined as all non-qualified Energy Star machines as of July 2009. The lower bound uses the average water use per cycle of all EPA-certified Energy Star washing machines, estimated to be 14.38 gallons per load (EnergyStar 2010). Using capacity statistics from Consumer Products, wash water was allocated based on the garment's share of water by weight with a full capacity load assumed to weigh five kilograms (ConsumerGuide 2008).

After adjusting all units to metric kilograms and liters, the following relationship calculates the total volume of wash water attributable to a single T-shirt for a single wash, based on our given assumptions:

$$\begin{aligned} &Water\ required\ per\ shirt\ per\ wash\ (L/shirt) \\ &\qquad = Water\ required\ per\ load\ (L/load) \\ &\qquad * \frac{Pct.of\ load\ allocated\ to\ 1\ shirt\ (load)}{1\ shirt\ (shirt)} \end{aligned}$$

Finally, we assumed garments were washed twice monthly for a period of five years. We multiplied the water required for a single wash accordingly, to reflect the full useful life of a T-shirt:

$$Life - cycle\ consumer\ use\ per\ shirt\ (L/shirt) = \\ Water\ required\ per\ shirt\ per\ wash\ (L/shirt) * 2\ times\ per\ month * 12\ months * 5\ years$$

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Appendix B: FAO Database

The crop water requirement for cotton was assessed using the FAO CLIMWAT database and CROPWAT program. CROPWAT is a decision support system developed by the Land and Water Development Division of FAO (FAO 2003a). Its main functions are to calculate reference evapotranspiration, crop water requirements and crop irrigation requirements. To derive values for the cotton crop water requirement for organic cotton suppliers, we use climate and precipitation information from the FAO CLIMWAT database, which houses observed agroclimatic data from over 5,000 stations worldwide (FAO 2003b). This data is provided in two files—one that includes long term average monthly precipitation data and effective rainfall values (1960-2000), and one that provides climatic information (mean daily maximum and minimum temperature, mean relative humidity, mean wind speed, mean sunshine hours, and mean solar radiation) for the FAO Penman-Monteith reference evapotranspiration calculation. The FAO Penman-Monteith method is recommended as the sole standard method, most likely to correctly predict reference evapotranspiration in a wide range of locations and climates (Allen et al. 1998).

Locations of organic cotton suppliers were obtained through the Organic Exchange website (OE 2009). Climate stations were selected based on their proximity to organic cotton supplier coordinates. 84% of selected stations were within 60 miles of the supplier and 56% were within 30 miles. However, 11 suppliers were located in regions with very few CLIMWAT stations. In these cases, distance between the supplier and the climate station was greater. However, in every instance precipitation maps and topography were considered to ensure that the selected station was as representative as possible.

Using this information in the FAO's corresponding CROPWAT database, we employed a generic FAO cotton growth profile (AGLW 2002). The crop coefficient curve, Kc, of this profile follows that of literature on cotton Kc estimates (AGLW 2002; Allen et al. 1998). Our analysis uses FAO values and range mid-points when necessary, as Kc values can change as a function of cotton crop variety and climatic conditions, which can influence the crop development profile. Plant dates were selected based on date ranges provided by FAO for major cotton producers in both hemispheres. For our analysis, Northern Hemisphere supplier coordinates were assigned a plant date of April 1 and harvest date of September 19, while Southern Hemisphere supplier coordinates were assigned October 1 and March 21 respectively. Using precipitation, climate and crop information, CROPWAT generates the crop water requirement, ETc. For Turkey, this gives a value of 768.5mm. This is within 8% of a study which calculated the ETc for cotton crops within the same Turkish watershed (Beyazgül et al. 2000). The difference between the numbers is likely due to the short time frame of climate data used by Beyazgül et al., along with their incorporation of soil moisture in their calculation. This calculation method was also compared with ETc estimates from a study on cotton in Uvalde, Texas. The value produced through our method, 828.8mm, fell within the study's reported range of 689mm-830mm for cotton in Uvalde (Ko et al. 2009). Additional research for applying this methodology to a global crop water assessment should include a sensitivity analysis of CROPWAT parameters across different regions, a more refined approach to the plant and harvest dates for different countries, and a regional soil profile. Furthermore, given the challenge of finding specific crop profile information in the literature, this study suggests the addition of regional cotton crop profiles to the CROPWAT database, which would strengthen estimates of this nature.

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Appendix C: Water Stress Index

Global assessments of water resources indicate that around 2 billion people live in watersheds with high water stress and that this number likely to increase with climate change and population growth (Alcamo et al. 1997; Alcamo et al. 2000; Cosgrove and Rijsberman 2000; Vörösmarty et al. 2000). While the top-down approach of global assessments is useful in identifying critical areas of water stress, we acknowledge that these tools are most powerful when paired with more detailed bottom-up studies of specific watersheds (Alcamo 2000).

The Water Stress Index (WSI) used by Pfister et al. (2009) is a ratio between water use and water availability, and is estimated using the combination of a global water use and a global hydrology model, known collectively as the WaterGAP2 model. Calculations include the land surface of the globe (except Antarctica) at a spatial resolution of 0.5° by 0.5°. The Global Water Use Model simulates both consumptive and withdrawal water use for three sectors—domestic, industrial, and agriculture (Döll et al 2001). Withdrawal water use is defined as the quantity of water taken from its natural location, while consumptive water use is considered the part of the withdrawn water that is lost by evaporation (Döll et al 2001).

For the domestic and industrial sectors, the model distributes World Resources Institute (WRI) country-level data on water withdrawal to grid cells in accordance with the spatial distribution of the population, as well as statistics on urbanization and access to safe drinking water. Then, the model estimates consumptive water use by multiplying water withdrawal with an efficiency factor (Alcamo et al. 1997). The domestic sector includes household use, small businesses and other municipal uses while the industrial sector includes power plants manufacturing facilities

With respect to agriculture, both irrigation and livestock water use are measured. A sub-model using independent data on soil, climate and irrigated area from the Global Hydrology Model is employed to compute the consumptive use for irrigation. This allows optimal crop water requirements to be calculated for irrigated crops in each cell. Net irrigation, or consumptive use, is determined first by modeling the cropping patterns of rice and non-rice crops, along with the optimal growing seasons for each cell with irrigated land. Afterward, net irrigation water intensities are determined by taking the difference between the crop-specific potential evapotranspiration and the effective rainfall. Finally, region-specific irrigation efficiencies are considered, and a gross irrigation water requirement per unit of irrigated area is derived (Alcamo 2003). Livestock water use is computed by multiplying livestock numbers with the typical water use of one animal. The model uses livestock density provided by NCAR on the GlobalARC GIS Database (Alcamo et al. 1997).

The main driving forces of water use—population in the domestic sector, national electricity production in the industry sector, area of irrigated land and climate in the irrigation sector and the number of livestock in the livestock sector—are multiplied by the water use intensity figures calculated for each sector to ascertain future water use. The base year for the computation is 1995.

Water availability is derived from the Global Hydrology Model, and includes runoff, and natural and engineered surface and shallow ground water recharge. Water availability is calculated for the climate normal period of 1961-1990 for over 10,000 individual watersheds using daily water balances of the vegetation canopy and soil. In addition, a water balance for open waters is conducted, and river flow is routed through the DDM30 global flow routing scheme (Alcamo 2000).

WaterGAP2 calculations of withdrawals and availability have been either calibrated or independently tested against existing data sets. Even so, the WSI of Pfister et al. (2009) applies a variation factor (VF) to watersheds with strongly regulated flows. This accounts for the effects of dams/reservoirs in mitigating water stress during variations in precipitation in addition to evaporative losses from storage structures. The VF can be characterized as a multiplicative standard deviation of the monthly and annual precipitation variation. They are calculated for each grid cell, and aggregated to the watershed level, weighted by the mean annual precipitation (Pfister et al. 2009).

Using the Pfister et al. (2009) 0.5° by 0.5° grid, ArcGIS was used to create a world map of Water Stress to evaluate the impact of water use through Patagonia supply chains. A WGS 1984 spatial projection was used. Additionally, a Pfister et al. (2009) kmz file was used to project global Water Stress Index values in Google Earth. To make the Google Earth tool more applicable to Patagonia's interest in organic cotton, coordinates for global organic cotton suppliers available from Organic Exchange were layered as points on top of the WSI projection. Included in the file of organic cotton supplier locations are estimated crop water requirements, effective rainfall and irrigation requirements for each location. These estimates were calculated using FAO ClimWat and CropWat software.

Future Opportunities to Improve the WSI

At present, global water assessments cannot accurately model WSI in areas where human-engineered watersheds exist (Vörösmarty 2002). For example, the WSI value for Los Angeles and the surrounding area indicates a water stressed region. However, the degree of stress is mitigated by imports from the Colorado River, Owens Valley, and California State and federal water projects (Hudley 2001). Globally, human migration to urban areas is expected to increase dramatically in the coming years in many regions of the world. Where water resource development is low and urbanization rates are high, human-engineered water resources are likely to increase in order to satisfy urban water demands. Clear evidence of this trend can be found in China's efforts to divert water to the arid northern section of the country from the Yangtze River via dams and canals. As human control of the hydrosphere increases to meet the demands of growing cities, models to assess regions of water stress and scarcity will need to reflect this reality in order to understand the state of global water resources.

While better spatial resolution of assessments has increased understanding of global water resources, further refinement of the underlying data sets, such as more comprehensive sub-country level data on water use in the domestic and industrial sector, would improve accuracy. Additionally, increased understanding of irrigation distribution and associated water use is needed. Currently, 'irrigated area' is defined differently depending on the region. Standardizing this definition along with the use of a wider catalog of crops in agricultural water use estimates would improve results. Furthermore, new satellite-based techniques for estimating irrigated areas and water balances should continue to be refined for use in global water assessments.

Finally, use of the WSI ratio for strategic planning is limited. For the purposes of this study, the indicator identifies water scarce regions. Yet, fails to generate a clear picture of where water abundant regions exist. For example, both Sudan and Australia have WSI values that indicate no water stress, and this is known to not be the case. These situations can be explained because they are areas with little population relative to water availability. As a result, the regions appear to have no water stress, but they could not support increased water demands. From a business standpoint, adding this distinction to a global water assessment would be incredibly useful, especially if a business is interested in determining alternative options for siting water-intensive manufacturing processes. Water availability per capita could be used in tandem with the WSI to provide businesses a more complete picture of the water resources of a region.

Finding the best method to express the WSI continues to be a challenge. One option that could be more meaningful would be to subtract the water use for industrial, agriculture, and potentially, environmental sectors from water availability, and state the remaining resources on a per capita basis.

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Appendix D: Water Pollution

Pollutant types and loads vary greatly and depending on the chemicals and treatment processes used in preparation, dyeing and finishing of a garment (Ergas et al. 2006). Salts, total suspended solids, color, chemical oxygen demand (COD), nutrients (nitrogen and phosphorous) and toxic compounds, such as surfactants, heavy metals, and chlorinated organic compounds are the most common pollutants (Ergas et al. 2006). Bisschops and Spanjers (2003) conducted a literature review of the pollutant loads in textile effluent for different materials during key manufacturing stages. In their search they found that chemical oxygen demand (COD), color, biochemical oxygen demand (BOD), total suspended solids (TSS) and pH were the most widely reported pollutants that characterize textile wastewater streams. A brief description of each water quality parameter follows (Pepper et al. 2006), and the table on the following page details the typical pollution loads associated with different materials and processes are reported.

> **COD** – Chemical oxygen demand is the amount of oxygen required by all organic compounds in a sample of water. If the levels are high, it is an indication that a large amount of organic material is present in the water, the effect of which in a natural water environment is the reduction of available oxygen needed by other life forms such as fish to survive. Higher levels of COD mean that more water treatment will be required to clean the waste water.
>
> **BOD** –Biochemical oxygen demand is the amount of oxygen required for microorganism. BOD is a subset of COD, and is a measure of organic pollution in water. It has a similar effect in nature as COD.
>
> **Color** – Color from the dyestuff reduces the transparency of water, which tends to block light from passing through water. Light is necessary for aquatic plant life, which helps to create a healthy habitat for a variety of aquatic organisms.
>
> **TSS** – Total suspended solids also reduces the transparency of water. The solids may be any of a variety of substances, and in the textile industry often is composed of fibers.
>
> **pH** – A measure of how acidic or alkaline a solution is. A specific range is required by aquatic species, and values outside that range can result in severe harm or death.

A major finding of Table X is that the most polluting material to process is wool, followed by cotton and lastly synthetics. Of all the processes, scouring and dyeing are the most water polluting. Scouring uses water or solvents on the fabric to release waxes and oil (either natural or added for knitting) from the fibers, and is a necessary step before the dyeing can take place (Bisschops and Spanjers 2003). Dyeing pollution is caused not only by the dyestuff, but also results from additive agents, such as salts (Bisschops and Spanjers 2003).

Characterization values for different textile wastewaters. All values are in mg/l unless otherwise stated (Bisschops and Spanjers 2003).

Parameter	Fabric Type	Desizing	Scouring	Bleaching	Dyeing	Printing
COD	Wool	-	5,000-90,000	-	7,290	-
	Cotton	950-20,000	8,000	288-13,500	1,115-4,4585	-
	Synthetic	-	-	-	620	1515
BOD	Wool	-	2,270-60,000	400	400-2,000	-
	Cotton	-	100-29,000	90-17,000	970-1,460	-
	Synthetic	-	500-2,800	-	530	2,225
Color	Wool	-	2,000	-	2,225	-
	Cotton	64-1,900	694	153	1,450-4,750	-
	Synthetic	-	-	-	1,750	-
Total Suspended Solids	Wool	-	1,000-26,200	900	-	-
	Cotton	18-800	184-17,400	130-25,000	120-190	-
	Synthetic	-	600-3,300	-	140	-
Total N	Cotton	70	-	40	-	-
	Synthetic	-	-	-	-	164
Total P	Cotton	6-10	-	6-60	-	-
	Synthetic	-	-	-	-	21
Oil & Grease	Wool	-	580-55,000	-	-	-
pH (unitless)	Wool	-	7.6-10.4	6-60	4.6-8	-
	Cotton	8.8-9.2	7.2-13	6.5-13.5	9.2-10.1	-
	Synthetic	-	8-10-	-	11.7	-
Water Usage (L/kg of fabric)	Wool	-	4-77.5	-	40-150	280-520
	Cotton	-	2.5-43	30-50	38-143	-
	Synthetic	-	17-67	-	38-143	-

Water Pollution Footprinting

Two ways of accounting for water pollution are considered the most useful to this project. The first is the grey water calculation presented in this report, as developed by the Water Footprint Network. Its merits include its simplicity and ability to be added volumetrically to the other components of the footprint. In addition, it carries some real-world meaning if the polluted water is released into the environment because the polluted water actually gets diluted. Lastly, the Water Footprint Network has helped to create the practice of and dialogue around water footprinting; therefore, attempting this method has value to the many businesses that have yet to try it and who are eager to learn from any attempts.

However, this grey water calculation does not provide information about the harmful effects of individual pollutants in the environment. Although the formal calculation does require that the released, polluted water be compared with ambient water quality standards, this is not an easily replicable task for Patagonia because of the complexity of water quality data and the geographical extent of their supply chain operations. If polluted water is treated to ambient standards, then the grey water component is zero, but making sure that this is in fact the case is a significant undertaking. Additionally, the meaning of the grey water footprint and why it is calculated as directed by the WFN is not easily communicated or understood by the general public. Given that Patagonia customers are a target audience of the project, the grey water calculation is not included in the footprint reported to consumers.

LCA characterization factors

LCA uses a set of characterization factors that calculate the effect of a pollutants release on an environmental impact category like global warming potential, aquatic toxicity or eutrophication (SAIC 2006). The result produces scientifically-based comparisons between processes or products. This system provides a relatively simple expression for the degree of environmental impact a substance has on an environmental issue, and can help in making a decision between products or processes.

Characterization of Global Warming Impacts

The following calculations demonstrate how characterization factors can be used to estimate the global warming potential (GWP) of defined quantities of greenhouse gases:

Chloroform GWP Factor Value* = 9 Quantity = 20 pounds
Methane GWP Factor Value* = 21 Quantity = 10 pounds

Chloroform GWP Impact = 20 pounds x 9 = 180
Methane GWP Impact = 10 pounds x 21 = 210

*Intergovernmental Panel on Climate Change (IPCC) Model
Source: SAIC 2006

This type of characterization could be applied to polluted effluent released into the environment. Like the grey water calculation, it would apply only to water released back into the environment. A much more complex system than grey water, LCA provides some indication of the effect of an effluent on the environment. This type of characterization could be useful going forward. However, the reason LCA characterization was not included in this project was in part due to the lack of access to the GaBi4 textile database, which is only available at significant cost. The database includes information for virgin polyester and conventional cotton. Even so, the database would also need to include information on recycled polyester and organic cotton. Still, the results from LCA could have been useful, but could not have been repeated by Patagonia due to software access issues.

Recommendations

Characterizing the impacts of water pollution for a single garment in a simple and comprehensive manner for Patagonia is challenging primarily because of the way in which water quality data is collected, and also because of the variety of pollutants present. Ideally, the characterization of the pollution load associated with a garment would allow for comparisons between garments to be made. For this study, the pollution footprint is considered a separate entity from the water footprint; while being able to combine water pollution and water use is advantageous in some ways, we feel they are best characterized separately. The methods of handling water quantity in a meaningful, regionalized manner cannot be replicated by Patagonia in a similar way for water quality. At present, no single metric of measurement or regionalized database for water quality worldwide exist.

Strategic Planning Recommendations to Patagonia

Patagonia should continue to strive to use the least harmful chemicals, and in the smallest quantities. Processes that generate less pollution require less energy, resources and capital to treat. Furthermore, minimizing pollution along with Patagonia's impact on the environment is in keeping with their corporate philosophy. One way to do this is to adopt an official policy regarding dye use. Implementation of a consistent and transparent policy should ensure all dyes meet a certain standard, like GOTS.

We recommend Patagonia prioritize obtaining better information on the location of their dye houses suppliers. Currently, the best proxies for Patagonia's dyehouses are their fabric suppliers. While these suppliers presumably contract with dyers in the vicinity, and potentially the same watershed, this assumption should be verified. Patagonia will be able to make more informed decisions about their sourcing if they consider water availability and water quality conditions in the region of their dyer among their decision making factors. Patagonia can use the chart of country characterizations by Hessel et al (2007) to help determine where treatment standards are stringent.

We recommend that Patagonia have more transparency regarding their supplier decision making. To facilitate this decision making process, we have prepared a set of questions for suppliers to help Patagonia understand the nature of their water treatment, discharge location etc. They may compare the results with the Business for Social Responsibility (BSR) guidelines, which is a reasonable first step. The BSR, a non-profit organization, convened a working group to establish these water quality standards for the textile industry.

Recommendation for Further Research

We recommend that the scientific community conduct more studies to facilitate the creation of a worldwide water quality database so that local impact of using and polluting water in a specific region can be assessed. Tying characterization factors to local regions seems a valuable addition to the water and water pollution footprinting process. A database of ambient conditions would be ideal. In addition, treatment and freshwater supply costs would be informative pieces of information to help identify business risk and potential regulation.

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Appendix E: Other Water Footprinting Tools

The water footprint is part of a family of footprint concepts, the oldest being the ecological footprint introduced by William Rees and Mathis Wackernagel in the 1990s (Rees, 1992; 1996; Rees and Wackernagel, 1994; Wackernagel and Rees, 1996). The ecological footprint measures the use of available bioproductive space in hectares. The carbon footprint concept originates from the ecological footprint and refers to the sum of greenhouse gas emissions caused by an organization, event or product, and is expressed in terms of CO2 equivalents (Safire, 2008). Although the carbon footprint concept is relatively new, originating in 2005, the idea of greenhouse gas emissions accounting dates back to at least 1990 with the first assessment of the Intergovernmental Panel on Climate Change (Hoekstra, 2003). Water footprinting, a relatively new concept, was not introduced until 2002 (Hoekstra, 2003).

There is currently no standardized process of determining a water footprint, but methodologies that have been developed to date provide useful metrics and tools that will be the foundation for this project's methodology. Among the first organizations to develop water accounting methods are the Water Footprint Network (WFN), the World Business Council for Sustainable Development (WBCSD), the Organization for Economic Co-operation and Development (OECD), and the University of Groningen (Gerbens-Leenes, Hoekstra, 2008). The following is a description of the currently most widely accepted water footprinting tools, which have been instrumental in the development of Patagonia's product level water footprinting effort.

The Water Footprint Network

Water footprinting methodology introduced in 2002 by researchers at the University of Twente measures the total annual volume of freshwater used to produce the goods and services consumed by any well-defined group of consumers, including a family, village, city, province, state, nation, and more recently, a business or its products. Water footprinting was originally developed as an indicator of fresh water use for water resources management (WRM). The spatially- and temporally-explicit water footprint allows managers to identify and map various water uses in a system (e.g. agricultural, municipal, industrial), as well as quantify the amount of water used by the community, country, region, etc. to produce the goods and services they consume. The total volume of water used is critical information for managers to understand how water use affects overall supply volumes, how water is allocated among users within their system (and if it is allocated equitably), which needs (e.g. environmental, basic human) are being met, and which water uses are providing the most economic value per unit volume.

Water footprinting, as promoted by the WFN, focuses on providing a method for companies to measure their water use and discharge. This water footprint itself does not consider the status of local watersheds or assess regional water-related impacts; instead, the water footprint captures the volume and location of water uses and discharges.

The WFN's water footprint is divided into three separate components –blue, green, and grey – expressed in terms of water volume. The green and blue components of a water footprint focus on consumptive water. They do not include uses of water that are eventually returned to the same system from which they are withdrawn (i.e. non-consumptive uses, or return flow). Non-consumptive water use is partially addressed within the grey water component. The components can be considered both separately and conjunctively as a total water footprint (i.e. the sum of the blue, green, and grey water components).

Material Flows Analysis and LCA

It is important to differentiate a water footprint from a life cycle assessment (LCA) because they share many similarities. An LCA is carried out for one particular product or region and looks at the use of the various types of environmental resources consumed and impacted, including water (Hoekstra, 2008). LCA ISO 14044 is the official standard for life cycle assessment, and does acknowledge freshwater impacts; however, there is no defined set of standards for incorporating water resource impacts (Llorenc 2009). Additionally, LCA studies do not take into account the source of the water inputs or the condition of the water as it leaves the system (Llorenc 2009). Material flow analysis (MFA) is a method of analyzing the flows of materials in a system. In a product system, MFA refers to the study of inputs (resources) and outputs (emissions) along the different steps in the production system of a product. The material flow analysis is similar to the 'inventory phase' of an LCA.

LCA includes the investigation and evaluation of the environmental impacts of a given product or service and consists of four phases: goal and scope, life cycle inventory, life cycle impact assessment and interpretation (Rebitzer et al., 2004). Frameworks like MFA and LCA modeling consider the use of a range of resources and analyze the associated environmental impacts. In contrast, a water footprint takes the perspective of one particular resource, water, or impact.

MFA and LCA do not currently evaluate freshwater use or water resource impact in a meaningful and sufficient way. However, there is an increasing interest to include water in these tools, as water footprinting has been recognized as a potentially useful concept. LCA has been criticized for the absence of appropriate characterization factors to weigh volumes of consumed water to accurately reflect their impact. LCA practitioners have suggested redefining the water footprint from a volumetric measure to an index that results from multiplying volumes by impact factors (Pfister et al., 2009; Ridoutt et al., 2009).

However, redefining the water footprint would eliminate spatially and temporally explicit information on water footprints in real volumes and impacts in real terms. From an LCA viewpoint, the proposal to use the term water footprint for the final aggregated index is confusing. The water footprint can best be used solely in its original and well-established meaning, excluding impact. The non-volumetric index is not a water footprint, but rather an aggregated, weighted water footprint impact index (Hoekstra et al 2009a).

Recent efforts in the LCA community have focused on improving the methodology's ability to characterize the impact of freshwater consumption (Pfister et al 2009, Morrison et al 2009). This work is building on the water footprint concept by multiplying water volumes by impact characterization factors to yield a weighted index (Pfister et al., 2009, Morrison et al 2009). However, determining what constitutes a negative impact is subjective. According to Morrison et al (2009), characterizing freshwater impacts would require determining what constitutes "sufficient in-stream flows, basic human water needs, or the point at which water is polluted to the extent that it is not available for use." In the end, this methodology ascribes values to environmental and social activities that may not reflect the local norms. Additionally, the aggregation of multiple factors into a single index abstracts the volumetric water footprint values to the point that they are no longer scientifically valid (Morrison et al 2009, Hoekstra et al 2009a).

Pfister et al (2009) has demonstrated how spatial modeling tools could enhance and facilitate the adoption of the water footprint concept by decreasing the data gathering requirements for an impact assessment. Robust, regionalized indicators paired with spatial modeling tools, such as GIS and Google Earth, will provide significant assistance to businesses that are working to lower their water related risks in increasingly resource-constrained environments.

Identifying the most appropriate way to conduct a water footprint impact assessment is currently a topic of debate within the Water Footprinting community, as well as LCA circles (Morrison et al. 2009). From a water footprinting perspective, valuable information about actual water use is lost when volumetric measures are multiplied by subjective impact factors (Hoekstra et al 2009). Although the WFN is developing a decision support tool to assist in the evaluation of local conditions, the current methodology does not include an impact assessment component (Morrison et al 2009). Some experts assert that a water footprint impact assessment should compare the volume of water used by a product to the available water in local areas at certain times, taking into account environmental water requirements (Hoekstra et al 2009a).

Other Tools

While several tools, including LCA and MFA as previously discussed, are available to document water use, many are either too simplistic to demonstrate environmental impact, too complex or expensive for a business to easily replicate or too vague to be meaningful within the scope of the analysis.

Global Water Tool

The World Business Council for Sustainable Development's (WBCSD) Global Water Tool provides simple measures to assess business risk in terms of regional water use. However, this method is designed for large corporations rather than specific product supply chains. The tool compares a company's water uses with water availability and sanitation information on a country basis.

Corporate Water Gauge

The Corporate Water Gauge, which compares facility water use to a specific watershed supply, is another option for businesses wishing to assess their water resource impacts. However, the Corporate Water Gauge requires acquiring professional consultants to compile and analyze the information.

Water Sustainability Tool

Global Environmental Management Initiative (GEMI) has developed a website—the Water Sustainability Tool—to assist companies to better understand how emerging water issues might impact their business, given their operations, needs, and circumstances. The tool is designed to help build a business water strategy. The tool provides guidelines and suggestions for a business to conduct a systematic assessment of water use, identify specific opportunities and risks with that water use, and assess the appropriate strategic approach that addresses specific needs and circumstances of the company.

- Conduct a systematic assessment of water use.
- Identify specific opportunities and risks with that water use.
- Assess the appropriate strategic approach that addresses specific needs and circumstances of the company.

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Appendix F: Additional Case Studies

In constructing a water footprint methodology for distributed apparel supply chains, the project focused on supply chain steps that consume the greatest volume of direct water use. Boundaries were set so that Patagonia employees and suppliers would not be overburdened with data gathering for aspects of the water footprint that did not meaningfully contribute to the garment's water use and impacts. As the methodology is applied to different garments, the water footprint drivers will be identified and baseline numbers will be established to compare differences between raw materials and the textile processes used to construct each garment. In addition to the cotton tee-shirt case study, Patagonia has identified five other garments for water footprinting that span different regions, materials and textile processes.

Cotton

An additional cotton case study will be completed for the Women's Simply Organic Cotton Polo (#54381) allowing Patagonia to assess the water use of cotton supply chains in two regions while also highlighting differences in water use between a vertically integrated supplier and a more conventional distributed supply chain.

The Women's Simply Organic Cotton Polo is made from 100% organic cotton jersey. The polo has natural stretch and classic styling, and is recyclable through Patagonia's Common Threads Recycling Program. Using 4.5-oz of organic cotton jersey, the garment has a finished weight of 153 g (5.4 oz) (Patagonia 2010). Made in China, the polo supply chain is vertically integrated with production beginning in the Xinjiang province of northwestern China where the organic cotton is grown. Through the use of drip irrigation, the supplier has reduced water usage by 20% and improved crop yield by increasing cultivable farmland. Cotton is knit into fabric and piece dyed before being sew into a garment. Water used in manufacturing processes is reused before being passed to the wastewater treatment plant. In addition, local partnerships with area universities are leveraged to further develop technologies to reuse treated wastewater (Esquel 2009).

Based on knowledge of the location of the cotton fields for the Cotton Polo supply chain, we estimate the effective rainfall for the region and irrigation requirements using the CLIMWAT and CROPWAT databases. With a crop water requirement of 783.5mm, the cotton crop receives an effective rainfall of 137.9mm, and therefore, requires irrigation in the amount of 644.8mm.

Given the distance of the climate station used from the actual farm location, we recommend that information be verified with the supplier, and inputs be adjusted accordingly to better reflect conditions on the ground. Also, the USDA Foreign Agriculture Service yield estimates do not indicate whether values are for seed or lint cotton. Therefore, yield information from the supplier with respect to lint cotton will also help improve the accuracy of these estimates. The use of drip irrigation by the supplier effectively eliminates any agricultural return flows, as well as additional irrigation requirements for flushing salts from the soil.

Green Water: Growing Cotton

$$\frac{1{,}379m^3}{ha}x\frac{1000L}{m^3}x\frac{ha}{1299kg}=1{,}062L/kg$$

$$\frac{0.128kg_{L\,\mathrm{int}\,Cotton}}{CottonPolo}x\frac{1{,}062L}{kg}=136L/Crew$$

Blue Water: Irrigating Cotton

$$\frac{6{,}448m^3}{ha}x\frac{1000L}{m^3}x\frac{ha}{1299kg}=4{,}964L/kg$$

$$\frac{0.128kg}{CottonPolo}x\frac{4{,}964L}{kg}=635L/Crew$$

Based on the existing information regarding the efficiency of the manufacturing process for the Cotton Polo, we anticipate low water use in garment dyeing. However, information from the supplier will help verify this assumption. Values for consumer use will be identical to those used for the Cotton T-shirt case study.

Wool

Two garments— the Men's Wool 2 Crew (36501) and Men's Long-sleeved Cashmere Crew (50920)—are in the process of being assessed to benchmark the volume of water required in two different types of wool (cashmere versus merino) from two different regions (Inner Mongolia versus New Zealand).

The Men's Wool 2 Crew is a blend of 100% chlorine-free merino wool and recycled polyester. Using an extra-fine-gauge yarn and a jersey-knit construction, this garment provides superior insulation for the active lifestyle while the inner polyester core wicks moisture away. Recyclable through the Common Threads Recycling Program, each Crew uses 4.85oz (165g) of 73% chlorine-free merino wool/27% recycled polyester (Patagonia 2010). The wool comes from sheep ranches at the base of New Zealand's Southern Alps where environmental standards are stringent and the ratio of cattle to land area is low (Patagonia 2010). A large component of the water needed to produce wool comes from the feed consumed by sheep (CSIRO 2010). In the Wool Crew supply chain, the pasture that sheep eat is rainfed. Assuming 80% moisture content, this study uses an average specific water demand for pasture of 445m3/ton (Chapagain and Hoekstra 2003). The sheep stocking unit for New Zealand's Otago region is 2.9 sheep/ha based on estimates from the Ministry of Agriculture and Forestry. Given that an adult sheep eats between 1 to 4 kg of pasture per day, depending on the moisture content of the food (DEEDI 2005), this study uses the midpoint in this range, 2.5kg of pasture/day for calculations. Also, the amount of pasture or rangeland required to feed a sheep depends upon the quality of the soil, the amount and distribution of rainfall, and the management of the pasture. An acre of pasture in the wet season can feed more sheep than an acre in the dry season (Schoenian 2009). The mean production for non-irrigated pasture in New Zealand is 2800 kg pasture/ha/year. Additionally, clean, fresh water during periods of extreme heat is extremely important in maintaining sheep health; the presence or absence of a clean water supply impacts the production potential of sheep (Schoenian 2009). An adult sheep requires an average of two to six liters of water a day, and up to 80 per cent more on days over 35ºC (DPI 2009). Survey responses from the supplier will provide a comparative value to those identified in the literature. In the Otago region, a single Merino fleece can produce around 4.37kg of high quality wool (Smallfield and Douglas 2005). Cleaning of wool fleece, or scouring, requires high amounts of water and energy to emulsify the grease in the fleece. According to research literature, the volume of water consumed during the scouring process ranges between 19-43L/kg (OECD 2004). In addition to consumptive use, process water return flows give rise to wool grease sludge that has a high pollution index and high levels of total suspended solids (Fletcher 2009).

The wool supply chain's knitting and dye factories located in Japan employ the best available practices and use no heavy metals in the garment dyeing, which reduces the pollution footprint of the resulting wastewater (Patagonia 2010). In the Wool 2 Crew supply chain, fabric is batch dyed—a process that consumes approximately 17L/kg (Patagonia 2010; OECD 2004). Little to no water is used in the final garment construction, which occurs in Los Angeles before the Crew is shipped to Reno, Nevada for distribution (Patagonia 2010).

To determine the product water footprint for the Wool 2 Crew, values obtained through literature make it possible to estimate the gross use water in producing the raw material, wooly fleece. However, pasture and water requirements for the sheep, as well as sheep stocking unit, should be verified with the supplier to confirm accuracy. In addition, the calculations above do not incorporate wool fiber waste, which will increase the amount of raw wool needed to produce a final garment. Consumer use estimates calculated for the Cotton T-shirt Case Study could be employed for use in the Wool 2 Crew product footprint. However, consumer care instruction for the wool garment may shift underlying assumptions regarding how often the garment is washed. Generally, one would assume that a consumer would wash a wool garment less frequently than a cotton garment given wool garments do not soil as easily (Patagonia 2010).

Values are known for the consumptive use of blue water in wool manufacturing. However, information on scouring should be verified with the Malaysian supplier. Peer-reviewed values for the consumptive use of a sheep's drinking water remains to be obtained, and is needed to carry out the impact analysis for the wool garment. Consumptive use for the amount of water contained in the sheep's forage material is unnecessary as green water is not included in the impact analysis.

The Men's Long Sleeved Cashmere Crew uses the finest gauge, ultrasoft cashmere wool from the high arid plateaus of Inner Mongolia, China. The Cashmere Crew is recyclable through the Common Threads Recycling Program, and creates a soft hip-length, long-sleeved cashmere polo weighing 213g (7.5oz) (Patagonia 2010). Fleece from Inner Mongolia is known globally for producing the finest cashmere in the world (15 microns in diameter). The length and fineness of

this high quality cashmere means the fibers pill less and maintain their shape better than cheaper lower quality cashmere. As a result, the garment texture gets better with each wash (CCMI 2009).

In terms of water use, the average daily consumption of goats is estimated at 4 L/head (MacGregor 2004). Total water consumption by cashmere goats has risen tremendously to meet demand. When market supply was at a peak in 2004, the number of cashmere goats in Inner Mongolia climbed to 25.8 million, a ten-fold increase from their numbers in 1949 (Osnos 2006). This rise in goat numbers represents an increased water demand equivalent to 13,667 olympic-sized swimming pools, or approximately 34.16 million m3/year. In addition to straining regional water resources, the recent growth of cashmere goat herding has increased grazing pressure on the area’s fragile, microbiotic soils, which are critical to preventing soil erosion and subsequent desertification (Osnos 2006). In 2005, the Chinese government supported the relocation of hundreds of thousands of nomads off the delicate lands to help protect the environment and reduce dust storms that were threatening air quality of several large cities. In Inner Mongolia, they have banned grazing on 163,000 square miles—more than a third of the province—since 2000 (Osnos 2006).

The average cashmere yield from one goat amounts to about 0.113kg annually, but there is a wide range of variation (ECA 2009). According to an Inner Mongolia study on the nutritional requirements of goats, we assume a stocking rate of 6 mature goats per hectare with each goat consuming about 438kg DM/year (based on a daily consumption rate of 1.2kg dry mass (DM)) (Sun et al. 2008).

To begin determining the product water footprint for the Cashmere Crew, the following calculations help estimate the gross use of water in producing the raw material, cashmere fleece. However, values for stocking rate, feed and water consumption should be verified with the supplier. Additional verification of the specific water demand for pasture should also be verified. This could be done using FAO CLIMWAT information from the closest climate station and determining the crop water requirement for pasture in the area. This would entail creating a crop profile for Inner Mongolia pasture. The rainwater for pasture (445 cubic meters per ton of pasture) was derived from Hoesktra et al 2009.

Green Water: Annual Forage Material Consumed

$$\frac{445m^3}{ton_{pasture}} x \frac{1000L}{m^3} x \frac{2.9ton_{pasture}}{6goats} x \frac{goat}{0.113kg_{wool}} = 1,903,392L/kg_{wool}$$

$$\frac{0.213kg_{wool}}{garment_{CashmereCrew}} x \frac{1.903,392L}{kg_{wool}} = 405,423L/garment_{CashmereCrew}$$

Blue Water: Annual Drinking Water Consumed

$$\frac{1,460L}{year} x \frac{goats}{0.113kg_{wool}} = 12,920L/kg_{wool}$$

$$\frac{0.213kg_{wool}}{garment_{CashmereCrew}} x \frac{12,920L}{kg_{wool}} = 2,752L/garment_{CashmereCrew}$$

Given the Cashmere Crew uses a single supplier for this product, information on the knitting and dye factories is needed to determine the blue water used in production of the garment (Patagonia 2010). Again, little water is used in the final garment construction before the Crew is shipped to Reno, Nevada for distribution (Patagonia 2010). Peer-reviewed values for the consumptive use of a goat's drinking water need to be obtained before the impact analysis for the cashmere garment can be completed. Similar to the raw material from sheep, the consumptive use for the amount of water contained in the goat's forage material is unnecessary as green water is not included in the impact analysis.

With overgrazing and environmental impacts a concern, Patagonia should continue to encourage good stewardship of the land in goat ranching for its products (Patagonia 2010). Looking forward, herders are observing more frequent droughts and patchy rains. In the period from 1999 to 2007, the region experienced the longest series of droughts and the driest summers of the last 47 years (Marin 2010). This finding is consistent with IPCC predictions of greater areas of drought and higher likelihood of extreme events for Asia (Marin 2010). Given the unique and delicate nature of the Inner Mongolia grasslands, restraining the impact of cashmere goat herding with ecosystem functioning will be key to maintaining a supply of raw material that has a low environmental impact.

Polyester

The Men's Synchilla Snap Zip Jacket (#25395) and Men's Better Sweater Jacket (#25525)—have been identified for water footprinting to highlight differences resulting from two polyester blends. The study would also provide important baseline information on the differences in water use between garments produced from agricultural raw materials and those made from synthetic and recycled synthetic materials.

The Men's Synchilla Snap-Zip Jacket is made primarily from recycled polyester fleece, using 86% recycled soda bottles, unusable second quality fabrics and worn out garments. The recycled polyester fibers are combined with conventional polyester fiber to produce the Synchilla jacket. This 10.6 oz, thick, double-faced polyester fleece provides maximum warmth on brisk days, and is made in the southeastern region of the United States (Patagonia 2010). While the initial fiber color of the recycled material may be slightly different from that of virgin, conventional polyester fiber, the dyed and finished fabrics are identical. Garment construction is completed in Colombia with the final product weighing 524 g (18.5 oz) and the jacket is recyclable through the Common Threads Recycling Program (Patagonia 2010). Used garments are shipped to Patagonia's partner in Japan and recycled using their ECOCIRCLE process to create new polyester (Patagonia 2010).

The Men's Better Sweater Jacket combines the aesthetic of wool with the easy care of polyester fleece. This technically proficient garment is made from 9.5 ounces of high-performance, sweater-knit polyester fleece with a final weight of 553 grams (19.5 oz), and is recyclable through the Common Threads Recycling Program (Patagonia 2010). An early partner to efforts at lowering the environmental footprint of polyester fleece, Patagonia has helped encourage the creation of recycled polyester materials. The recycled polyester Synchilla Vest production is estimated to yield energy savings of three quarters of a gallon of gasoline. These savings also conserve the water that would have been used to produce the energy (FC 2009).

Manmade fibers are produced primarily for use as raw materials for the textile industry. Synthetic fibers consist of fibers that are formed by the polymerization and subsequent fiber formation of synthetic organic chemicals and refined petroleum products. Petroleum refining and synthetic organic chemical manufacturing facilities produce the raw material feedstocks used to make plastic resin and manmade fibers. In some cases, these facilities also make plastic resins and manmade fibers. Crude oil production and refining can require up to 2,500 gallons of water per million Btu of heat energy produced, depending on production methods (USDOE 2006). However, the allocation of this water use to the crude oil refining waste stream that produces polyester manufacturing feedstock presents an allocation challenge.

Fibers are the fundamental unit of textiles and fabrics. Polyethylene terephthalate (PET) or polyester fibers can be produced from polymers that have been continuously or batch polymerized, or by dissolving cellulosic materials. The polymer or cellulosic solution is then forced through tiny holes of spinnerets (which function much like bathroom shower heads) and extruded into fibers. Subsequent processing steps typically include drawing, crimping, texturizing, and twisting. These processes, however, do not require direct water use (EPA 1997).

The PET recycling industry started as a result of environmental pressure to improve waste management. PET is a non-degradable plastic in normal conditions as there is no known organism that can consume its relatively large molecules. Biologic PET degradation requires complicated and expensive procedures. Recycling is the best way to economically reduce PET waste. Polymer recycling takes end products and produces semi-finished stock material ready for reuse. The PET recycling industry concentrates primarily on recycling bottles, which are used for all kinds of liquid packaging. Bottles are easily distinguishable because of shape and consistency and are easily separated from waste plastic streams either by automatic or hand sorting processes. Purification and decontamination are the most important processing steps during PET recycling. These processes have direct uses of water, including pre-washing and caustic washing/rinsing to remove contaminants. As an example, an Austrian produced PET bottle recycling machine uses 1 m^3 of water per 1000 lb of clean flake (Schut, 2009). In typical operating conditions, no more than 0.005% water by weight is allowed to be present in final recycled PET stock material (i.e. flakes or pellets). Therefore, at least 50 ppm of water is consumed in the processing of recycled PET for use in textiles.

Both virgin PET and recycling PET manufacturing are industrial processes that typically treat their water prior to discharge. In fact, some recycled PET processing equipment includes wastewater treatment capabilities. For example, a Chinese machinery manufacturer, designed a PET recycling line that includes capabilities not only to treat wash water, but also to recycle and reuse the treated water. Likewise, refineries also release treated wastewater into surface water sources (NAS 2003). As defined by our boundaries, treated wastewater is not included in the water footprint.

The use of PET fibers also presents water allocation difficulties. PET is a by-product of crude oil refining and therefore should not be allocated the full volume of water required to refine crude oil. Recycling of wash water presents another allocation difficulty. Additionally, only 86% of the fiber for the garments are made from recycled PET. In the case of the Men’s Synchilla snap-zip, a percentage of the fiber is from reprocessed waste fiber from the facility that may also contain yet another ratio of virgin to recycled PET.

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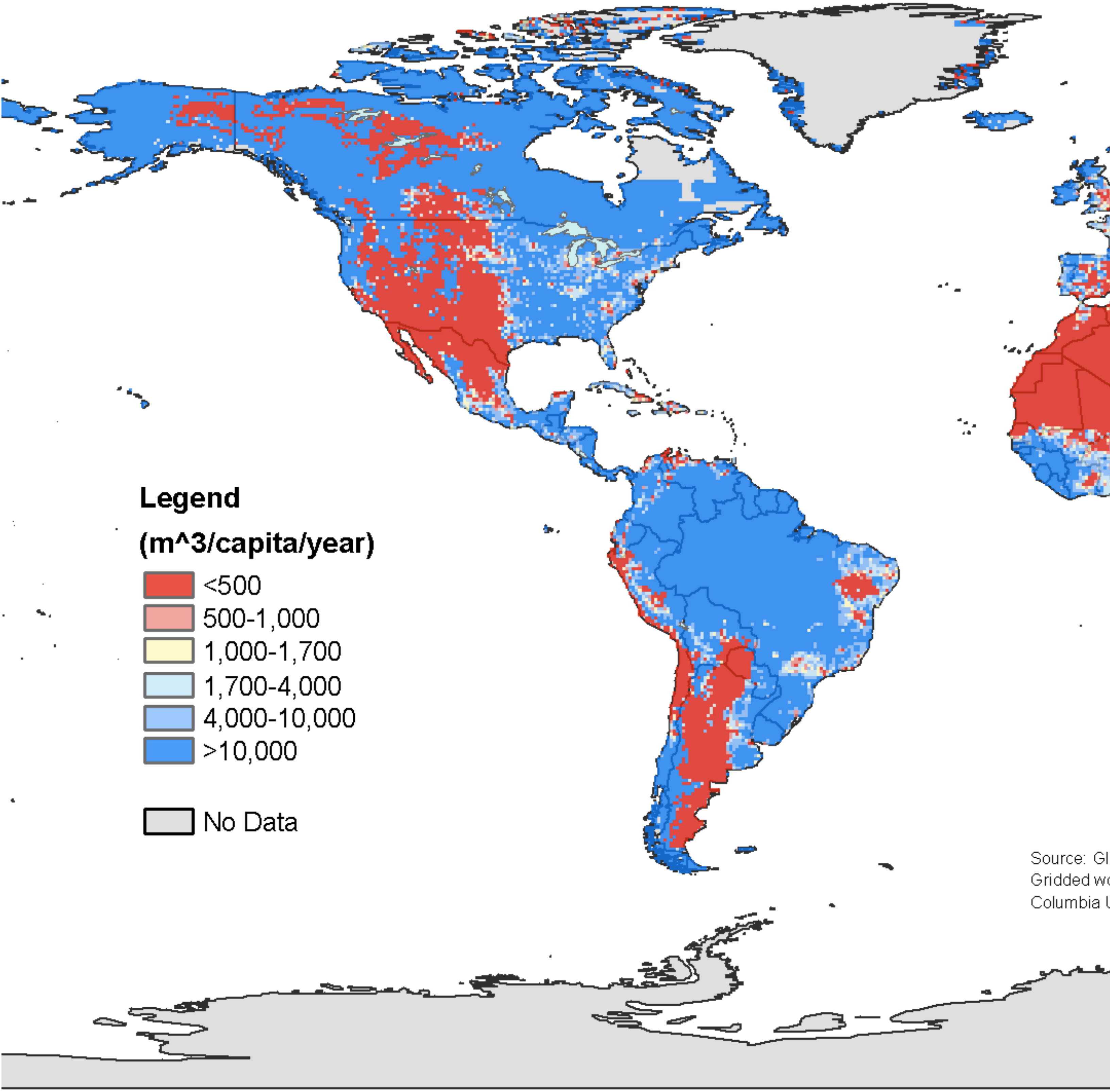
Appendix G: Maps



Source: Gl
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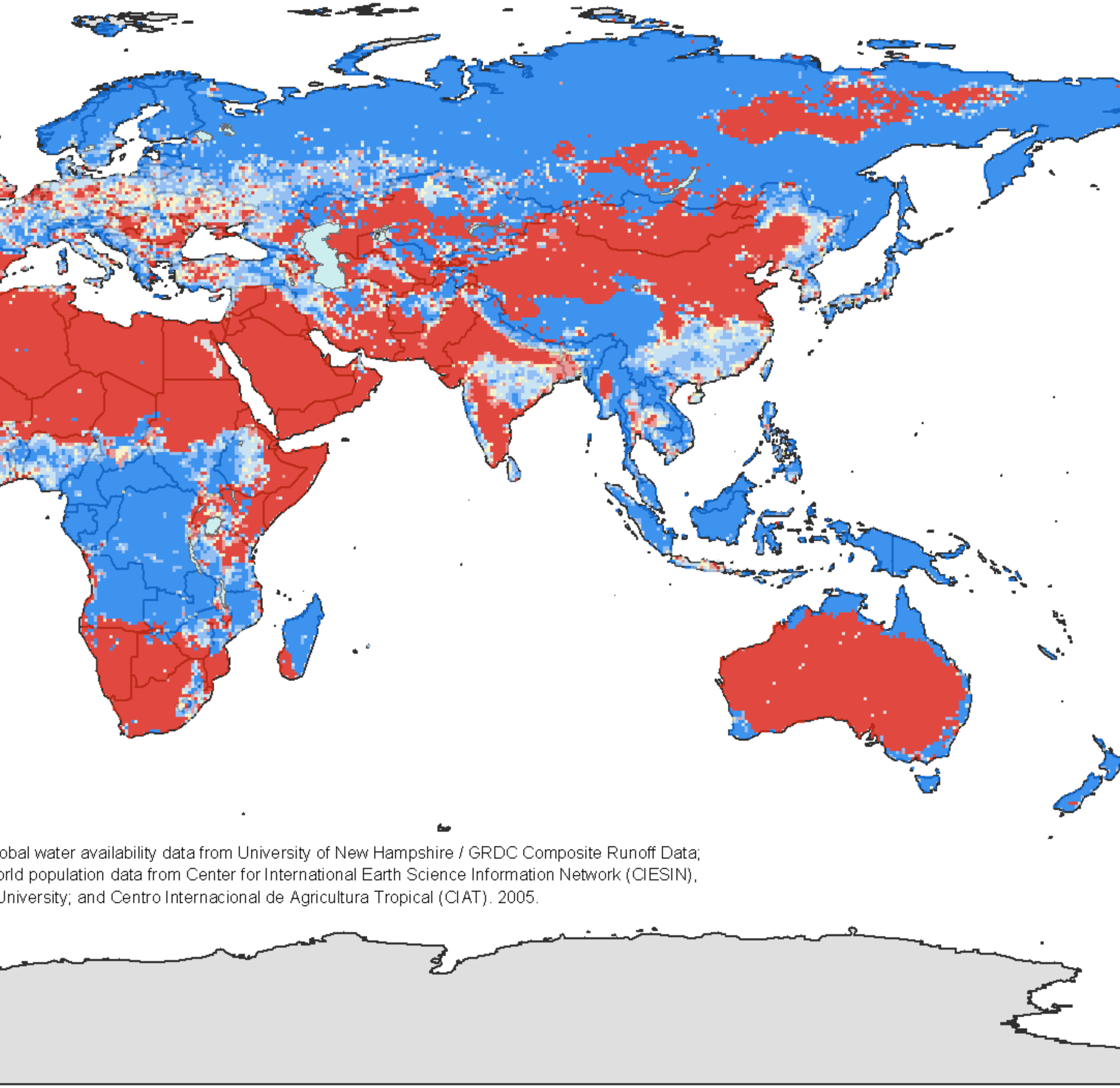
This map of Global Water Availability (in cubic meters per capita) is based on mean annual composite runoff and 2015 population estimates. Water scarcity is considered less than 1,000 m³/person/year while water stress is considered between 1,000-1,700 m³/person/year.



obal water availability data from University of New Hampshire / GRDC Composite Runoff Data;
orld population data from Center for International Earth Science Information Network (CIESIN),
University; and Centro Internacional de Agricultura Tropical (CIAT). 2005.

Appendix H: Beyond the First Approximation

Suggested Questions to Suppliers for on-the-ground assessment of local water resource conditions.

1. Is water quantity and/or quality identified as a local or regional political issue?
2. Do you expect significant water policy changes in the next 5 years that could impact your facility's water use?
3. What are your water rights and legal obligations with regard to water supply and water quality?
4. Could unstable political systems affect your production facility's water supply and usage? If the answer is yes to either, please explain.
5. Has your production facility been asked to limit or conserve water by an external planning or regulatory entity for the following sources: external water provider, groundwater (at your facility), water (at your facility)? If the answer is yes to any source, please explain below.
6. What percentage of your local population has access to clean and affordable drinking water?
7. Do you engage with stakeholders in your region on water issues (e.g. external water provider, government bodies, non-governmental organizations, local communities, employees)?
8. Do you have a water supply management plan? If the answer is yes, how does the plan promote continuous improvement in water management and performance?
9. Describe usage of best available technologies that improve water efficiency or wastewater quality.