International Finance Corporation
World Bank Group

Water Footprint Assessments

Dehydrated Onion Products
Micro-Irrigation Systems

Jain Irrigation Systems Ltd.

LimnoTech
Water | Environment | Scientists | Engineers

Jain Irrigation Systems Ltd.
Jalgaon - India
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JAIN IRRIGATION SYSTEMS LIMITED (also known as Jain Irrigation, JISL, or Jains) is an international organization headquartered at Jalgaon, Maharashtra, India. JISL employs over 5,000 associates and manufactures a number of products, including drip and sprinkler irrigation systems, PVC & PE piping systems, plastic sheets, greenhouses, bio-fertilizers and also solar products including water-heating systems, photovoltaic appliances and solar pumps. JISL processes fruits and vegetables into aseptic concentrates, frozen fruits and dehydrated vegetables respectively. The Company has a turnover exceeding 30 billion rupees. JISL also has 21 manufacturing plants spread over 5 continents. The products are supplied to 110 countries through 3000 dealers and distributors worldwide. **www.jains.com**

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PREFACE

September 2010

Water scarcity is one of the biggest challenges facing India today. Agriculture accounts for 85% of the nation's water consumption, and is a significant source of employment. Yet water tables are declining. Future strain from climate change, population growth with rising incomes, and increased water use are likely to put food security and local livelihoods at risk. Jain Irrigation Systems Limited (JISL) and the IFC have undertaken a water footprint assessment in order to gain insights into how we can work closer together to alleviate the pressing issue of water scarcity.

JISL has long been a pioneer in the production and use of micro-irrigation systems. IFC is an important investment and advisory partner for JISL. IFC is committed to helping its clients consume water in a sustainable manner and reduce their vulnerability to water risk. JISL and IFC are both partners of the Water Footprint Network, a network of knowledge institutions, non-governmental sector, private sector, and governments promoting the transition towards sustainable, fair and efficient use of fresh water resources worldwide. IFC is a founding partner, and JISL is the first partner from India, confirming its position as a global leader in its industries.

This work represents a pioneering effort to document the water consumption in JISL's production of dehydrated onions and of micro-irrigation systems, to assess the sustainability of this water consumption, and to formulate response strategies. It is one of fewer than 20 water footprint related assessments that have been completed to date. However, this report represents the first comprehensive effort to incorporate – in addition to an "accounting" of water consumption - a "sustainability" assessment and the formulation of response strategies. This completes all steps of a water footprint according to the current methodology standard developed by the Water Footprint Network.

This water footprint assessment has exceeded our expectations. JISL's water footprint response strategy provides a strong foundation for increasing farm resilience in the face of climate change, for sustainably meeting the growing global demand for food, for enhancing social well-being, and for reducing water-related risks to JISL's business.

At a local level, the strategy validates JISL's critical efforts that are making a profound difference in farmers' lives by providing extra income and sustaining rural livelihoods. At a regional level, the strategy will help increase water supply, and decrease demand for water. Drip irrigation was identified in the recent 2030 Water Resources Group's report, *Charting Our Water Future* as an important measure that will help address the future "water gap" in water-scarce countries including India. At a global level, the strategy provides an example of private sector engagement in sustainable water management, with concrete examples of corporate response strategies.

The JISL/IFC water footprint assessment attests to the leadership that both IFC and JISL are taking in the area of sustainable management and consumption of water resources. We hope that it will be of value to you.

Anil Jain
Managing Director
Jain Irrigation Systems Limited

Paolo Martelli
Director
IFC South Asia

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EXECUTIVE SUMMARY

Water footprint assessments were conducted for two products, dehydrated onions and micro-irrigation systems (MIS), produced by Jain Irrigation Systems Ltd. (JISL) in Maharashtra, India. A water footprint is an indicator of freshwater consumption that looks at both direct and indirect use, and considers where and when the water was used. It has three components, as defined by the Water Footprint Network[1]:

- The **green water footprint** refers to consumption of green water resources (rainwater stored in the soil as soil moisture);
- The **blue water footprint** refers to consumption of blue water resources (surface and ground water);
- The **grey water footprint** refers to pollution and is defined as the volume of freshwater that is required to assimilate the load of pollutants based on existing ambient water quality standards.

A full water footprint assessment goes beyond accounting of water consumption, in that it also addresses the sustainability of the water use, and allows a business to identify its water-related impacts and vulnerabilities and identify potential response actions. Of great pertinence to this assessment is the sustainability of the groundwater resource that supplies irrigation water for onions purchased by JISL. The company is but one of many users of groundwater, and water tables are declining rapidly due to expansion of the area of irrigated lands, particularly with water-intensive crops.

Separate water footprints were calculated for the two products. The accounting results are summarized below.

- The results indicate that water consumed at the farms accounts for 99% of the total water footprint of dehydrated onions. The water footprint of dehydrated onions accounts for water consumed in the supply chain to grow the onions, the production of MIS used on the onion farms, and in operations for dehydrated onion production.
- Onions grown under drip irrigation have a 42% smaller water footprint than onions grown under flood irrigation. The largest component of both water footprints is the blue water footprint, associated with irrigation.
- The grey water footprint for onions grown under drip irrigation is almost 90% smaller than the grey water footprint for flood-irrigated onions, reflecting the reduced application requirements and lower leaching rate when water and nutrients are applied at the root zone of the plants using drip irrigation.
- The results for MIS (drip irrigation) indicate that most of the water footprint lies in the supply chain, associated with production of raw materials (plastics) and accounting for 73% to 96% of the total water footprint.
- The water footprint of MIS (drip irrigation) used on a typical onion field is a negligible component of the total water footprint for growing onions.
- The water consumption associated with JISL's production of dehydrated onions and MIS accounts for approximately 1% of total groundwater draft in the Jalgaon District.

[1] Water Footprint Manual; State of the Art 2009

The sustainability assessment examined the sustainability of the groundwater resource that supplies irrigation water for onion growing, with a focus on potential social and economic impacts. Though onion farming constitutes a small percentage of the total area in cultivation, the results suggest that the sustainability of JISL's water use is vulnerable in several distinct ways, each of which suggests a different type of response strategy:

- The overdraft of groundwater due to cumulative uses in the onion growing regions suggests that response strategies should help farmers reduce their demand for water, thereby reducing their risk of shortages and helping to alleviate the regional declines in groundwater levels.
- Given current rates of groundwater overdraft, it may be very difficult or impossible to maintain or increase crop production. Therefore, the response strategies should also find ways to increase the supply of water.
- Finally, the complexity brought about by the presence of many different water users suggests that a community-based, multi-stakeholder approach to managing the groundwater resource could be of value.

The response strategies formulated for JISL include four different and complementary approaches to alleviating water scarcity and improving the sustainability of water use in the onion growing region:

- Through supporting increased use of drip irrigation by existing onion farmers, JISL can help these farmers reduce their water consumption and thereby alleviate local groundwater overdraft.
- Looking more broadly at agriculture in the Jalgaon growing region, JISL can also support the government's push for new, less water-intensive cropping strategies, which will reduce overall groundwater consumption.
- On the supply side, JISL can increase the amount of groundwater available by encouraging rainwater harvesting and aquifer recharge projects.
- JISL is considering supporting or establishing a Tapi River Basin Water User's Dialogue, through which representatives of local water stakeholders could work together toward sustainable water resource management.

These approaches address both water demand and water supply. They address very local applications (for local onion suppliers in Jalgaon) as well as applications that can make an impact on a regional and national level. Drip irrigation was highlighted in as a key vector to addressing the projected deficit between supply and water requirements in India in the recent report, *Charting Our Water Future* (2030 Water Resources Group, 2009). JISL's water footprint response strategies also provide a strong foundation for resilience in the face of climate change, and for sustainably meeting the growing global demand for food. As such, these approaches are of global importance as examples of a significant corporate response to agricultural water scarcity.

1 INTRODUCTION

Jain Irrigation Systems Limited (JISL) is the world's largest manufacturer of micro-irrigation systems (MIS) and plastic sheets and pipes. JISL also produces several other products including vegetable and fruit-based food products. The company is the world's largest producer of mango pulp, puree, and concentrate, and the second largest producer of dehydrated onions, which are used in dry soup mixes, pizza toppings, sauces and other products. JISL's headquarters are located in Jalgaon in the western state of Maharashtra in India.

This report describes water footprint assessments for JISL's MIS (drip irrigation) and dehydrated onion products. A water footprint is the total volume of freshwater consumed in the production of a product, summed over the various steps of the production chain. Both direct (operational) water use and indirect (supply chain) water use are addressed, and the volumes are spatially and temporally explicit. A water footprint assessment goes beyond accounting of water consumption, in that it also addresses the sustainability of the water use, and allows a business to identify its water-related vulnerabilities and identify potential response actions (Hoekstra, et al., 2009).

This study was a collaborative effort between the International Finance Corporation (IFC) and JISL, with support from The Nature Conservancy and LimnoTech. IFC is interested in helping advance the development of water footprinting, because it is seen as a tool that can help its clients reduce their water consumption and associated social and environmental impacts, and reduce the company's exposure to water-related risks. JISL is interested in using water footprinting to evaluate its own water consumption, and to quantify savings associated with its micro-irrigation products as compared to traditional flood irrigation.

1.1 PURPOSE AND GOALS

The purpose of this water footprint assessment is to provide JISL with a framework to measure and report on the water footprints of its products, assess the potential influence of those footprints on local hydrologic systems, assess potential social and ecological impacts, and identify possible response strategies. Most importantly, this assessment addresses the sustainability of water use throughout JISL's supply chain for dehydrated onion products in the context of physical water scarcity concerns in the local (Tapi River) watershed.

The goals of the water footprint assessment are to:

1. Measure the volumes of water consumed in JISL's operations and supply chains for MIS and dehydrated onions in the Tapi River watershed;
2. Assess the sustainability of this water use, particularly at the farm level;
3. Identify appropriate response actions to address the outcomes of the sustainability assessment; and
4. Document and share publicly through the Water Footprint Network the water footprint assessment results and lessons.

1.2 CONTEXT

A map of the region with key features is presented in Figure 1-1. MIS is manufactured at JISL's Plastic Park, Jain Fields, Jalgaon. MIS includes drip and sprinkler irrigation equipment and this study addresses drip irrigation only. Dehydrated onions are processed at JISL's Agri Food Park in Jain Valley, Jalgaon.

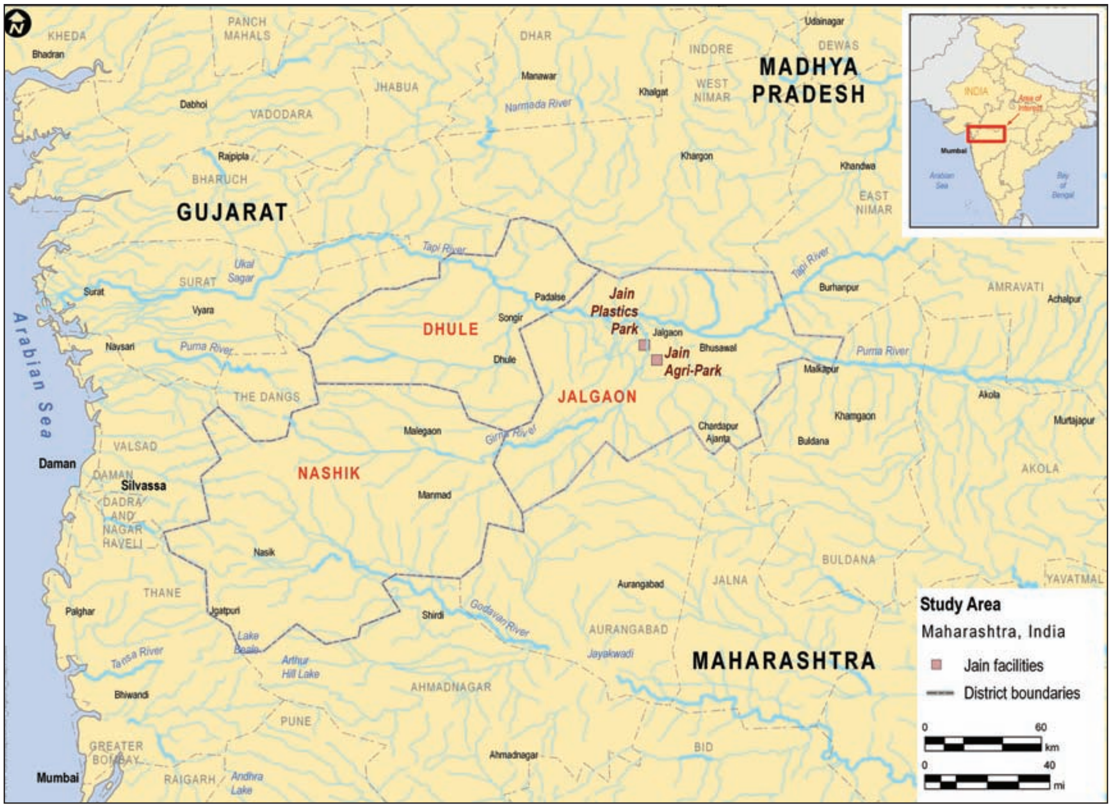


Figure 1-1. Map of Study Area with Key Features

Approximately two-thirds of the onion farms that supply JISL are located in the Jalgaon District and adjacent Dhule and Nashik Districts, an area referred to in this report as the "Jalgaon growing region." Most of the remaining onions are grown in the state of Gujarat. The Jalgaon growing region was the focus of this study; other growing regions were not assessed due to time and resource constraints.

Climate

The climate in the Jalgaon region is generally dry except during the monsoon, which occurs from June to September. October and November form the post-monsoon season. This is followed a prolonged dry season with minimal rainfall. The average annual rainfall is 822 mm, with about 87% of the rain falling between June and September. Average daily temperatures in Jalgaon range from 20° to 34° C (68° to 93° F). May is the hottest month, with mean daily maximum temperatures of 42.5° C (108.5° F). Evaporation rates in the region, with a mean daily maximum of 13 mm/day, are among the highest in the world.

Surface waters

The Jalgaon onion growing region is located almost entirely within the Tapi River basin. The Tapi River flows from east to west through Madhya Pradesh, Maharashtra, and Gujarat states for a total of 724 km and discharges into the Arabian Sea near Surat. A portion of the growing region is in the sub-watershed of the Girna River, the second largest of the Tapi's 14 tributaries in terms of watershed area. The waters of the Girna River are used for irrigation in the Nashik and Jalgaon Districts. Surface runoff is significant during monsoon rains in river systems that are generally dry during the rest of the year.

Hydrogeology

Figure 1-2 depicts key hydrogeological features for the region. The major part of the district is covered by Deccan Trap Basalt flows of the upper Cretaceous to Palaeogene age (68 to 62 million years ago). Deccan Trap Basalt formation is characterized by simple and compound lava flows, which are shown as variation in green shades in Figure 1-2. Ground water in the Deccan Trap Basalt occurs mostly in the upper weathered and fractured parts down to about 20-25 meters depth. There is a thick alluvium deposit at the Tapi River and along its bank, shown in light yellow on Figure 1-2. The upper 70-80 meters of younger alluvium (sand and gravel) form the potential aquifer (Ministry of Water Resources, 2009). The depth to ground water typically varies from 1 to 15 meters below ground level (bgl) in the Basalt region and 10 to 50 meters bgl in the Tapi Alluvial plain.

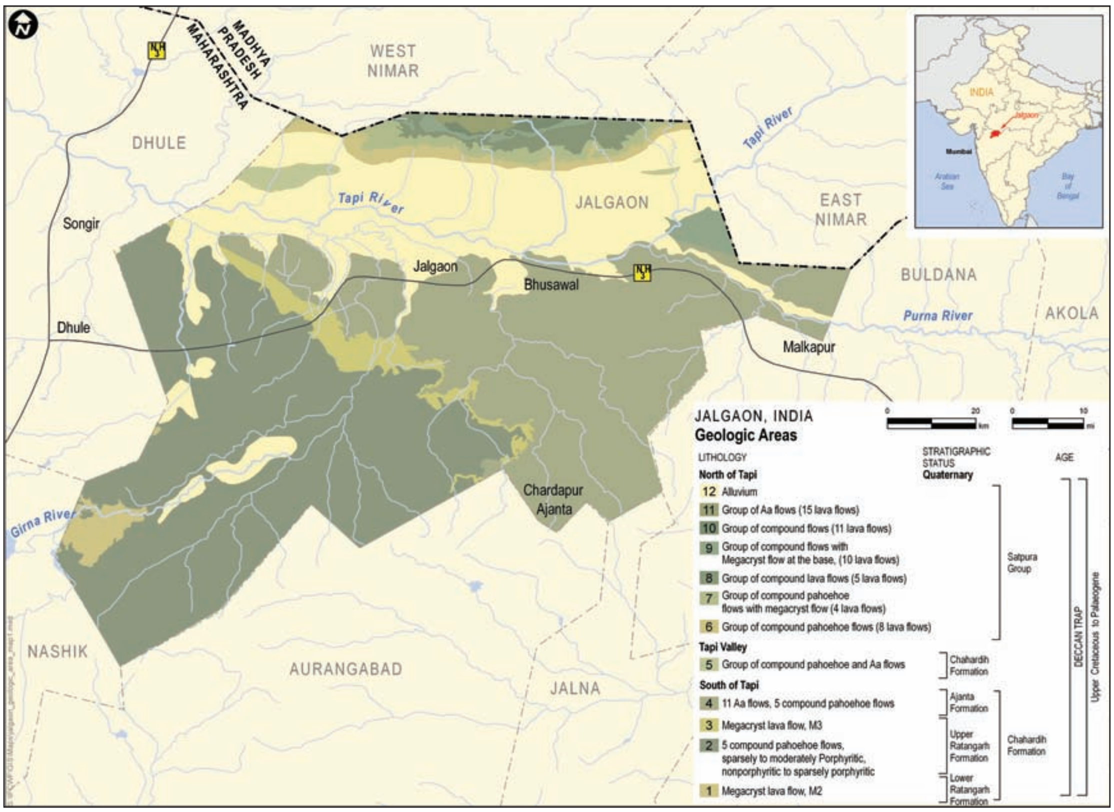


Figure 1-2. Hydrogeological Features: Jalgaon District

Regional land use

In 2005-2006, more than 80% of the land area in the Jalgaon District was under cultivation, and approximately 22% of cultivated lands were irrigated (Ministry of Water Resources, 2009). The principal crops are cotton, cereals, and pulses (beans) (Ministry of Water Resources, 2009). Bananas are also a significant crop in terms of land area and water use. Irrigated banana plantations have increased significantly in the Jalgaon District over the past two decades, increasing from 18,700 hectares (ha) in 1990 to 46,000 ha in 2004 (ATMA, 2007). The cropping area of major commodities increased from 867,000 ha in 1980 to 1,254,600 ha in 2004 in the Jalgaon District (ATMA, 2007).

Irrigation practices

Groundwater is the primary source of irrigation water in the Jalgaon growing region, and flood irrigation is the predominant irrigation practice. The area under irrigation has increased significantly in the Jalgaon District, increasing from a total of 43,000 ha in 1960 to 295,000 ha in 2005 (Ministry of Water Resources, 2009). Between the 1962-63 and 2002-03 seasons, the groundwater irrigated area in the State of Maharashtra increased from 613,000 ha to 1,922,000 ha (Narayanamoorthy, 2010a), an increase of more than 200%.

The positive benefits of this groundwater use including increased crop productivity and farm incomes are well documented (Narayanamoorthy, 2010a). However, adverse impacts from over-exploitation of groundwater are also recognized. Measurements by the Central Groundwater Board (CGWB) of the Ministry of Water Resources indicate that the Jalgaon District has experienced a decline in groundwater levels of more than four meters during the pre and post-monsoon period between 1981 and 2000 (Narayanamoorthy, 2010a). According to a recent report by the Ministry of Water Resources (2008), four talukas (counties) in the Jalgaon District are considered "semi-critical" and two (Raver and Yawal), are considered "over-exploited." These categories are defined by the ratio of the volume of water withdrawal to water availability. Wider use of drip and microspray irrigation during the dry season is recognized as one measure to reduce non-beneficial evaporation in the Deccan Traps Basalt region of Maharashtra during the dry season (Foster, et al., 2007).

1.3 SCOPE AND METHODS

This water footprint assessment addresses the water footprint of dehydrated onions produced at the Food Park from onions grown in the Jalgaon growing region and MIS produced at JISL's Plastic Park. MIS includes drip and sprinkler irrigation equipment and this study addresses drip irrigation only. A water footprint assessment typically involves four steps:

1. Setting goals and scope;
2. Water footprint accounting;
3. Water footprint sustainability assessment; and
4. Water footprint response formulation.

Water footprint accounting was conducted according to the approach outlined in the Water Footprint Manual prepared by the Water Footprint Network (Hoekstra, et al., 2009). This study extends the current methods by incorporating methods under development by the Water Footprint Sustainability Assessment Working Group of the Water Footprint Network. As such, the JISL water footprint assessment is an early test case for the proposed framework.

The total water footprint of a product is equal to the sum of the supply chain water footprint and the operational water footprint.

$$\text{TOTAL WF} = \text{SUPPLY CHAIN WF} + \text{OPERATIONAL WF} \qquad [1.1]$$

A water footprint has three components:

- The **green water footprint** refers to consumption of green water resources (rainwater stored in the soil as soil moisture);

- The **blue water footprint** refers to consumption of blue water resources (surface and ground water);
- The **grey water footprint** refers to pollution and is defined as the volume of freshwater that is required to assimilate the load of pollutants based on existing ambient water quality standards.

Table 1-1 lists the supply chain and operational water uses that were considered in the water footprint calculations.

Table 1-1. Water Uses Considered in the Water Footprint Calculations

COMPONENT	PROCESS STEP	DIRECT WATER USES (COLOR OF WATER)	OVERHEAD (COLOR OF WATER)
DEHYDRATED ONIONS			
Supply Chain	Growing onions	Rain (green) water and irrigation (blue) water to grow onions. Pollutants in runoff or infiltration to groundwater (grey)	(Blue) Water used for building materials, energy, fuel, transportation
Operational	Processing onions into food products	Process water used at the processing plant to wash the onions and to produce product (blue) Water used for cleaning equipment (blue) Wastewater discharged (grey)	(Blue) Water used for hand washing, toilet flushing, drinking, landscaping (Grey) Water from domestic use
MICRO-IRRIGATION SYSTEMS			
Supply Chain	Producing plastics (raw materials)	(Blue) water consumed in the production of plastics from crude oil and other raw materials Wastewater discharged (grey)	(Blue) water used for building materials, energy, fuel, transportation
Operational	Manufacturing MIS	(Blue) water consumed in the production of MIS components Wastewater discharged (grey)	(Blue) water used for domestic purposes such as hand washing, toilet flushing, drinking, landscaping Wastewater discharged (grey)

2 DESCRIPTION OF PRODUCTION SYSTEMS

An understanding of the production processes for dehydrated onion products and MIS is an essential first step in water footprint calculations, to determine the materials flow and identify key information needs. The two production systems are described in this section.

2.1 DEHYDRATED ONION PRODUCTION

Dehydrated onions are processed at the Agri Food Park in Jain Valley, Jalgaon. JISL's dehydrated onion products are produced from white onions. The raw onions are dehydrated and processed at the Food Park into sliced, diced, chopped, granulated, powdered, roasted, and fried products.

Farm production

JISL purchases approximately two-thirds of its onions from contract farmers and on the open market from the regions shown in Figure 2-1. Contract farmers grow onions in six districts including Jalgaon, Dhule, Badwani, Buldhana, Khandwa, and Nandurbar. Approximately 85% of the contract onion farms are located in Jalgaon and Dhule Districts. Open market onion farms are located in Jalgaon, Dhule and Nashik Districts. JISL also purchases onions on the open markets of Gujarat and Madhya Pradesh.

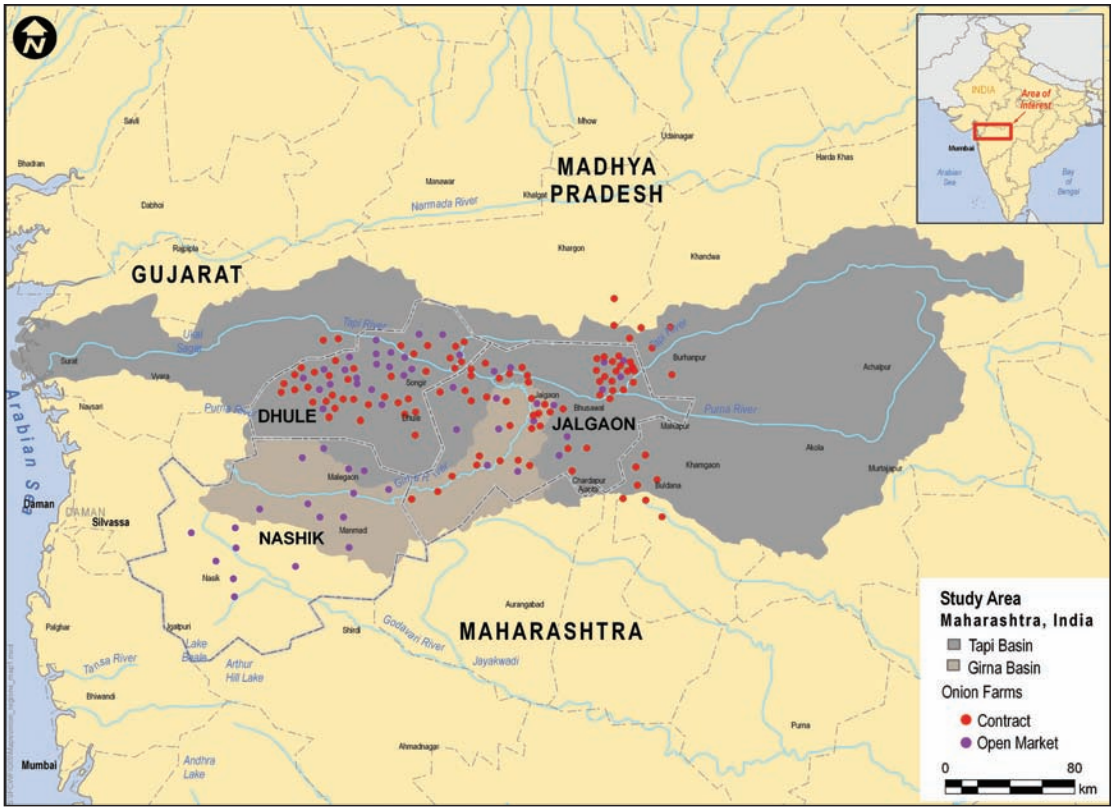


Figure 2-1. Locations of Onion Farms Supplying JISL

Table 2-1 presents the distribution of onions by region and irrigation type. The water footprint calculations described in Section 3 are focused on onions grown in the Jalgaon growing region shown in Figure 2-1. Approximately 18% of the onions sourced from the Jalgaon region are grown under drip irrigation, and 22% are grown under sprinkler irrigation. JISL is targeting a conversion to MIS for the remaining 60% of flood-irrigated crops under contract farming at a rate of 15 – 20% per year.

Table 2-1. Onions Purchased by JISL by Region and Irrigation Type

SOURCING REGION	PERCENT SOURCED BY REGION	PERCENT IRRIGATION TYPE		
		DRIP	SPRINKLER	FLOOD
Jalgaon Growing Region[1] (Maharashtra State)	62%	18%	22%	60%
Gujarat State	35%	3%	7%	90%
Madhya Pradesh State	3%	14%	2%	84%

[1]Defined as onion growing regions in districts of Jalgaon, Nashik, and Dhule as shown in Figure 2-1.

The typical schedule for growing, irrigating, storing, and processing onions is shown in Table 2-2.

Table 2-2. Schedule for Growing and Processing of Onions Grown in Jalgaon

<table>
<tr><th>MONTH</th><th>JULY</th><th>AUG</th><th>SEPT</th><th>OCT</th><th>NOV</th><th>DEC</th><th>JAN</th><th>FEB</th><th>MAR</th><th>APR</th><th>MAY</th><th>JUNE</th></tr>
<tr><td>Season</td><td colspan="4">Hot Wet (Kharif)</td><td colspan="4">Cool Dry (Rabi)</td><td colspan="4">Hot Dry (Jayaad)</td></tr>
<tr><td>Kharif Onions</td><td colspan="2">Planting</td><td colspan="3">Growing</td><td colspan="3">Harvesting</td><td></td><td></td><td></td><td></td></tr>
<tr><td>Rabi Onions</td><td></td><td></td><td></td><td></td><td colspan="2">Planting</td><td colspan="2">Growing</td><td colspan="3">Harvesting</td><td></td></tr>
<tr><td>Irrigation</td><td colspan="4">Protective Irrigation[1]</td><td colspan="7"></td><td></td></tr>
<tr><td>Storage</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td colspan="2"></td></tr>
<tr><td>Processing</td><td></td><td></td><td></td><td></td><td></td><td colspan="7"></td></tr>
</table>

[1]Monsoon rain typically occurs from June - September. Kharif onions are mostly rainfed. However, irrigation water is applied at times when rainfall amounts are not sufficient to meet crop demands.

Onions are grown during the cool dry (Rabi) and hot dry (Jayaad) seasons. These are periods with little to no rain, and high temperatures that peak during the later part of the growing season and during harvest, as shown in Figure 2-2. The figure shows the variations in monthly average rainfall and temperature based on data collected by JISL from 2002-2010. Maximum temperatures occur during the dry harvest months of April and May. Irrigation is a requirement throughout the planting, growing, and harvest periods.

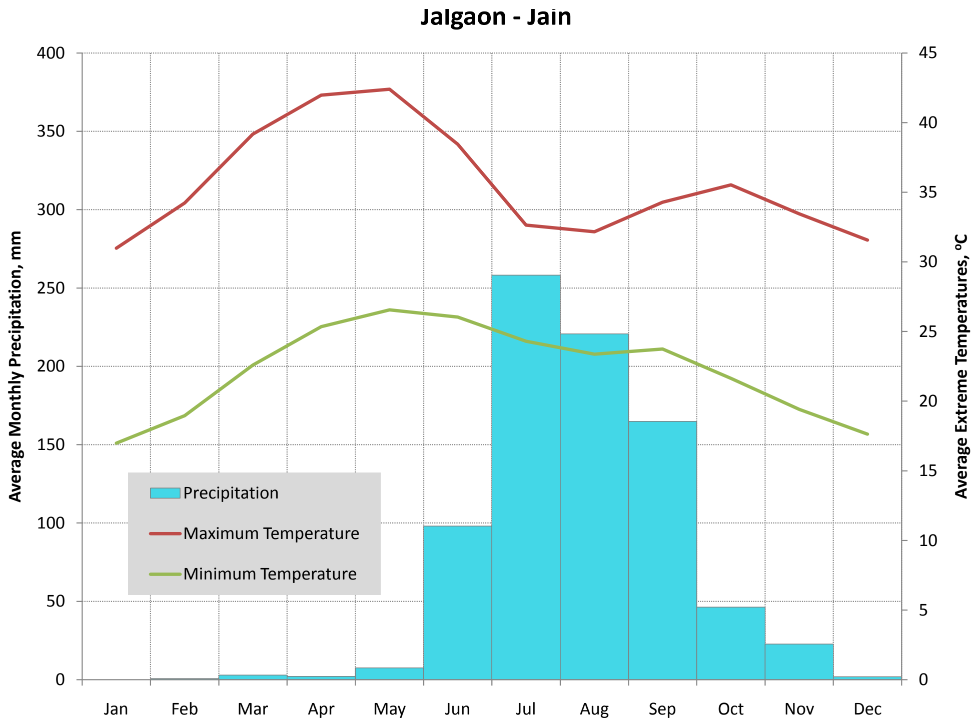


Figure 2-2. Monthly Average Rainfall and Maximum and Minimum Temperatures for Jalgaon: 2002 – 2010.

Food processing

All onions are processed at the Food Park in Jalgaon. Onions are transported from farms to the Food Park via trucks, with an average transport distance of 100 km.

The process steps are outlined below:

1. Reception: Raw onions are cleaned, graded, and sorted.
2. Preparation: Washing, peeling, inspection, and cutting.
3. Drying: Cut pieces are fed to continuous belt dryers.
4. Drying: Hot air evaporates water, which is exhausted.
5. Milling: Dehydrated flakes are milled.
6. Storage: Finished products are stored in cold storages.

After the onions are dried, the weight of dehydrated onions is approximately 14.8 percent of the weight of the raw onions. The remainder of the raw onion is composted on the grounds of the Agri Park and used on-site as fertilizer. The dehydrated onions are processed into seven products, as shown in Figure 2-3.

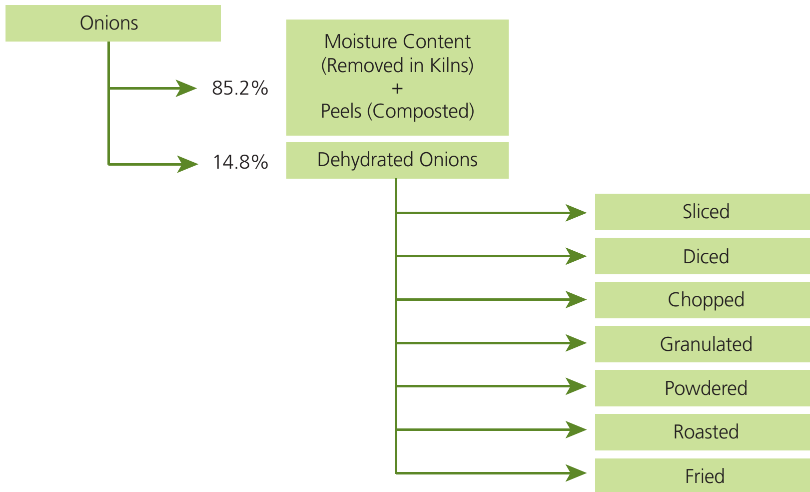


Figure 2-3. Percent by Weight: Dehydrated Onion Products

The source of water used in food processing is groundwater drawn from wells on the plant grounds. Supplemental water is provided occasionally from the Tapi River when local groundwater supplies are insufficient. The local aquifer is recharged through a large-scale rainwater harvesting system known as the "Jain Watershed Project." Covering 207 ha (512 acres), the project involves land and water conservation measures and rainwater harvesting measures by means of dams, barrages and water harvesting structures that capture and store rainwater during the monsoon season for use during the dry season. During a normal rainfall year, approximately 2.5 billion liters of water is gained through these measures (JISL, 2003). The Jain Sagar Dam alone has a capacity of 1.2 billion liters. Since its construction, substantial groundwater recharge has occurred in areas downstream of the dam. Approximately 500 acres of barren land has been transformed to cultivable land due to construction of Jain Sagar (see Figure 2-4).

Figure 2-4. Aerial Photograph of Jain Watershed Project

Wastewater from food processing is treated onsite to secondary treatment standards at an effluent treatment plant. The treated water is used for irrigation at the Agri Park, where JISL conducts research and development.

2.2 MICRO-IRRIGATION SYSTEMS

JISL's micro-irrigation systems for drip irrigation are made from more than 1,000 components and over 95% of them are manufactured by the company. In MIS application, water is delivered to the crop using a network of mainlines, sub-mains and lateral lines with emission points spaced along their lengths, as shown in Figure 2-5. The waterlines are made of thermoplastic-extruded polymer pipes and tubes with molded emitters suitably spaced at regular intervals on the tubes, either embedded internally (drip-tube) or mounted externally (polytube). The emitters are designed to release water at preferential flow rates from the drippers. The MIS system operates under low pressure, and according to the precise water requirement of the crop. Each dripper/emitter supplies a precisely-controlled quantity of water and nutrients directly to the root zone of the plant. Nutrients are added with the help of the ventury (see figure), which is installed before the filtration unit in the MIS assembly. Water and nutrients taken up by the plants are replenished almost immediately, ensuring that the plant rarely suffers from water stress. The crops grown under drip irrigation achieve optimum growth and high yields.

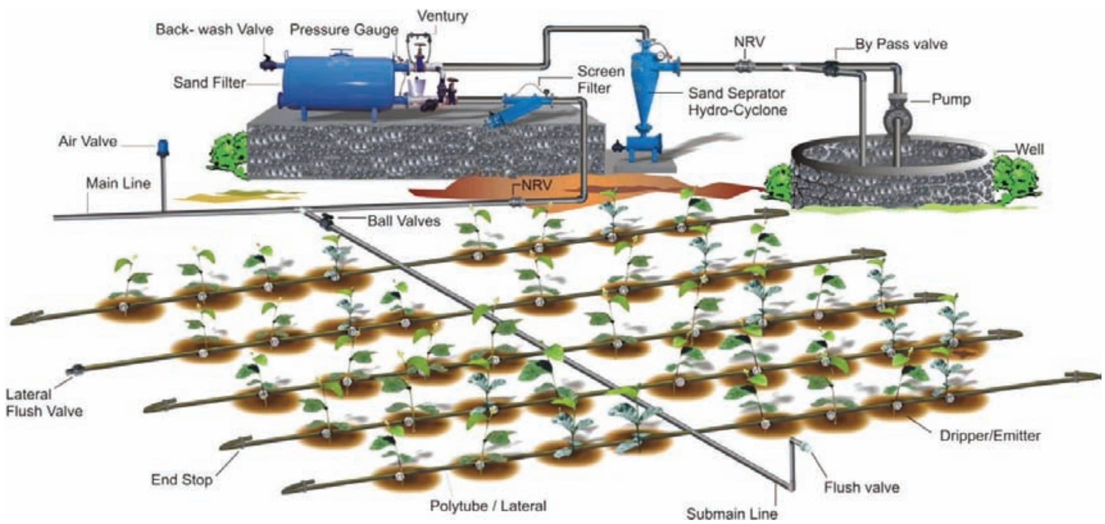


Figure 2-5. Model Design of JISL's Drip Irrigation System

Production of raw materials

The components of JISL's drip irrigation equipment are made from various raw materials, mostly thermoplastic polymers, as shown in Table 2-3. JISL purchases the raw materials from over a dozen major and minor suppliers located in India, Japan, United Arab Emirates, Saudi Arabia, USA, China, and other countries. Materials are transported by sea, road, and rail routes from these locations around the world.

Table 2-3. Raw Materials for MIS Components

COMPONENT	RAW MATERIAL
MIS PVC Pipe	Poly Vinyl Chloride (PVC)
MIS PVC Molded Fittings	Poly Vinyl Chloride (PVC)
MIS Molded Components	Polypropylene (PP)
MIS Poly Tube	Linear Low Density Polyethylene (LLDPE)
MIS Drip Tube	Linear Low Density Polyethylene (LLDPE)
MIS Filter Equipment	Metal fabricated parts purchased from vendors

The category of "MIS Filter Equipment" in Table 2-3 includes fabricated and powder-coated filter tanks purchased by JISL. Some process water is used at JISL's Plastic Park to assemble the tanks.

MIS manufacturing

Most of the MIS components are manufactured with thermoplastic polymer materials. Pipes and tubes components are made by extrusion process, and molded components by injection molding process as indicated in Table 2.4 below.

Table 2-4. Manufacturing Process of MIS Components

COMPONENT	MANUFACTURING PROCESS
MIS PVC Pipe	Extrusion of PVC Resin
MIS PVC Molded Fittings	Injection Molding PVC Resin
MIS Molded Components	Injection Molding Polypropylene (PP)
MIS Poly Tube	Extrusion of Polyethylene (LLDPE)
MIS Drip Tube	Extrusion of Polyethylene (LLDPE)
MIS Filter Equipment	Assembly & testing of fabricated metal parts sourced from vendors

General process flow diagrams are depicted in Figure 2-6 below for extruded pipe, tube and injection molded MIS components.

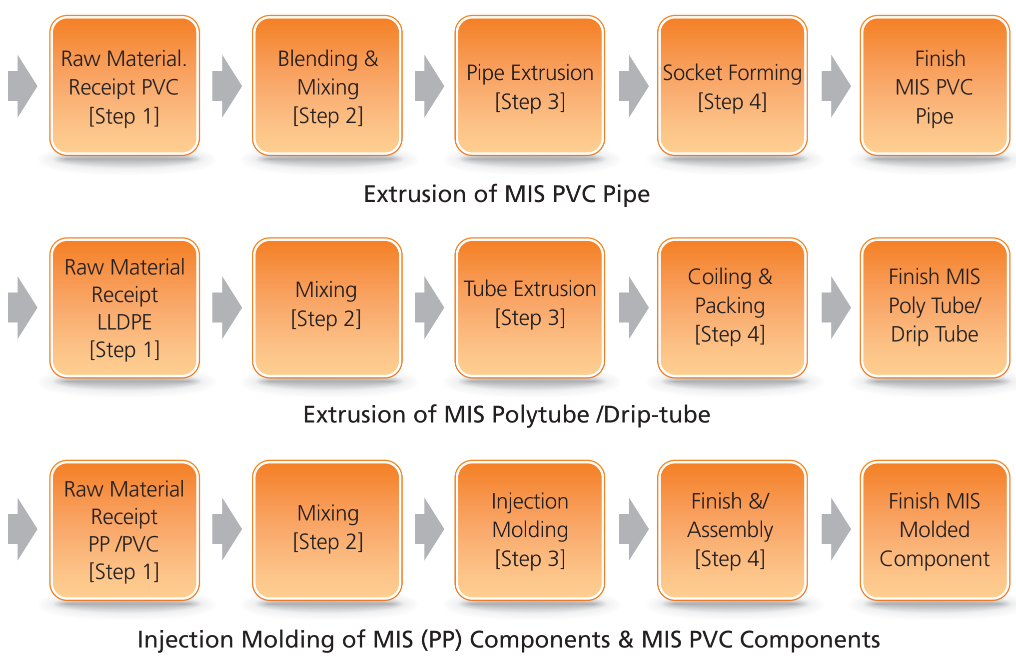


Figure 2-6. Process Diagrams for MIS Components

In the extrusion process, the thermoplastic polymer materials are blended and mixed with certain additives and chemicals before being fed to the extruder machine. The thermoplastic polymer blend is then thermally treated to achieve the desired shape, and cooled for hardening or normalizing. The extruded pipe or tube is then cut to the desired length. The MIS PVC Pipe socket forming operation is done after extrusion of the PVC Pipes. The socket is formed at one end to enable the joining of pipes in field application. Poly-tubes and drip-tubes are then packed as coils of specified length.

The injection molding process involves melting the blended thermoplastic materials in the plasticating unit of the injection molding machine. The injected thermoplastic is cooled down to re-solidify in mold cavities, and shaped in the form of the desired article dimensions. The molded article is ejected out of the mold after cooling.

Both the processes of polymer extrusion and polymer injection molding require water for cooling the equipment, polymer extrudate, or molded material after formation of the desired profile. Recycling of process material waste also requires water as a process chilling media. Water used for process cooling is recycled in a closed loop system. The loss in the volume of water in the circulation system is due to evaporation and spillage. Water is added daily to compensate for losses in the closed loop system of water circulation.

The water source for operations at the Plastic Park is groundwater pumped from bore wells and open wells on the plant property. Total water withdrawal in the Plastic Park is approximately 1.24 million liters per day, of which approximately 0.3 million liters per day is used for MIS manufacturing. Water is consumed in plant operations through evaporation during cooling and washing, and through runoff and spillage. Water is also used in the plant for domestic purposes including drinking water, toilets, washing, and gardening.

JISL has implemented and is currently testing a rainwater harvesting and aquifer recharge system at the Plastic Park. Two methods are being used: rooftop collection; and a percolation pond. Approximately 28 acres or 40% of the rooftop area of the Plastic Park is currently being utilized for rainwater harvesting. Rainwater that falls on the rooftops is collected, filtered, and directed to open wells on the property. The polylined percolation pond drains 40 acres, and another pond is planned to drain an additional 30 – 40 acres of land area. A total of 42.5 million liters is collected annually through these methods (10.5% of annual water withdrawal), with an ultimate target of 88 million liters (23% of annual water withdrawal).

Grey water is generated in small amount from the process, which is only a fraction of total water usage in the plant. The resulting grey water is routed to a central effluent treatment plant which is located on site. Approximately 25% of the treated water is utilized for irrigating onsite lawns and gardens. The remainder is discharged into the local stream. Efforts are underway to reuse all of the treated water.

Water footprints were calculated for dehydrated onions produced by JISL at the Agri Food Park from onions sourced from the Jalgaon growing region. The supply chain water footprint accounts primarily for water consumed in the growing of onions, and the operational water footprint accounts for water consumed in the processing of onions at the Food Park.

Onions are grown and processed mainly during the dry season (November-June), as shown previously in Table 2-2. Monthly production rates for dehydrated onions and monthly water use rates for the factory in 2009 are shown in Figure 3-1. The annual water withdrawal for operational water use in 2009 was 35 liters per kg dehydrated onion product.

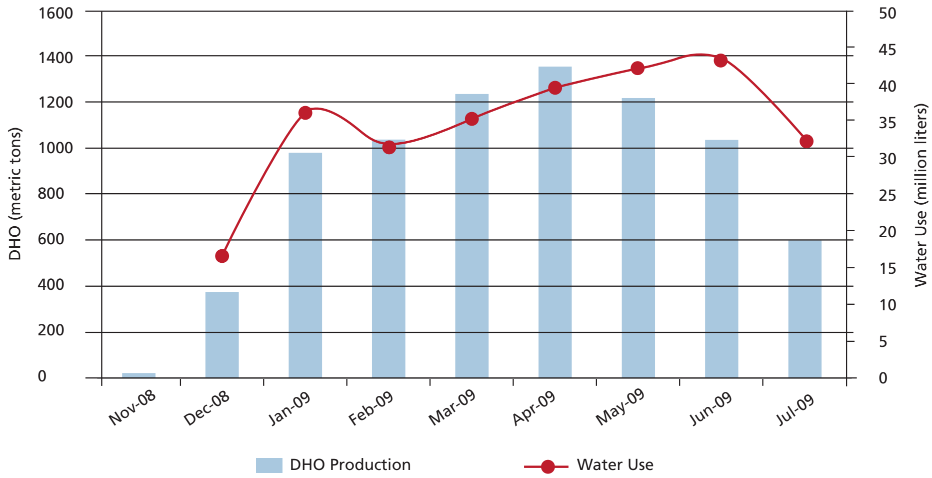


Figure 3-1. Monthly Dehydrated Onion (DHO) Production Rates and Factory Water Use

JISL has made significant efforts to reduce water consumption at the food processing plant. These water conservation activities are reflected in measures of water consumption in recent years. The volume of water withdrawn from wells for use in the plant declined substantially during the four-year period from 2007-2010. Notable efficiency measures include improved recovery of the flash steam and maximum recovery of steam condensate. In addition, significant improvements to the filtration unit in the process line have considerably reduced the frequency and the quantity of water consumption in the plant. JISL continues to implement water conservation efforts at the plant. For example, approximately 100,000 liters of water/day from flash steam are currently wasted, and plans are underway to recover and reuse this water.

3.1 SUMMARY OF RESULTS

The water savings when onions are grown under drip irrigation compared to flood irrigation is estimated to be 129 liters/kg raw onions, calculated as the difference between the consumptive (green plus blue) water footprints for drip and flood-irrigated onions. If 100% of JISL's dehydrated onions were produced from onions grown under drip irrigation (instead of the current 30%), then the annual water savings would be approximately 7 billion liters.

The water footprint results for dehydrated onions expressed as the sum of the supply chain and operational water footprints are presented in Table 3-1.

Table 3-1. Water Footprint Results for Dehydrated Onions

COMPONENT	WATER FOOTPRINT (LITERS/KG, OF DHO)			
	GREEN	BLUE	GREY	TOTAL
a. Supply Chain Water Footprint				
Drip	18	500	13	531
Flood	58	1796	286	2140
Total Supply Chain Water Footprint	76	2296	299	2671
b. Operational Water Footprint	0	33	0	33
c. Total Water Footprint	**76**	**2329**	**299**	**2704**

Approximately 99% of the total water footprint is associated with supply chain water use, and the remaining 1% is associated with operational water use in the processing plant.

The accounting method provides the water footprints for raw onions grown under both irrigations types, and a weighted average water footprint for raw onions purchased by JISL. More detail on the steps involved in the supply chain and operational water footprint calculations are provides in Sections 3.2 through 3.4.

3.2 OVERVIEW OF ACCOUNTING METHOD

The water footprint of dehydrated onions (DHO) is equal to the sum of the process water footprints for all processes in the production chain. There are two process steps in the production of DHO: 1) onion growing; and 2) onion processing. Therefore, the water footprint is calculated as follows:

$$WF_{prod}[DHO] = WF_{proc}[DHO] + WF_{prod}[onions] \,/\, f_p \qquad [3.1]$$

$WF_{prod}[DHO]$ = water footprint of output product (DHO), liters/kg DHO

$WF_{proc}[DHO]$ = process water footprint of processing steps that transform the input product (raw onions) into output product (DHO), liters/kg DHO

$WF_{prod}[onions]$ = water footprint of input product (raw onions), liters/kg onion

f_p = product fraction = quantity of output product obtained per quantity of input product, kg DHO/kg onions

The value fraction, defined as the market value of the product to the aggregated market value of all the outputs products, is not shown in Equation 3.1. There are no byproducts in the production of dehydrated onions, so the value fraction is unity.

The first calculation step accounts for water consumed in the growing of onions, or the supply chain water footprint. The output of this calculation step is the water footprint of raw onions, $WF_{prod}[onions]$. The water footprint of raw onions accounts for:

- Beneficial consumption by crops (evapotranspiration)
- Grey water component
- Water consumed in the production of MIS used on onion fields
- Crop yields
- Overhead

These calculations are described in Section 3.3.

The second calculation step addresses operational water use, and accounts for water consumed in the processing of raw onions into dehydrated onions at the Food Park. This includes water used to wash the onions and clean equipment, as well as domestic water use (overhead). The output of this calculation step is the process water footprint, WF_{proc}[DHO]. These calculations are described in Section 3.4.

The final step is the calculation of the water footprint of DHO according to Equation 3.1. These calculations are described in Section 3.5.

3.3 SUPPLY CHAIN WATER FOOTPRINT

Sixty-two percent of the onions purchased by JISL are grown in the Jalgaon growing region. Approximately 18% of the onions from this region are grown using drip irrigation, 60% are grown using flood irrigation, and sprinkler irrigation is employed for the remaining 22% (see Table 2-1). To estimate the water footprint of onions purchased by JISL, water footprints were calculated for drip and flood-irrigated onions, and then weighted according to the percent grown under each irrigation type. Water footprints were not calculated for onions grown using sprinkler irrigation. It was assumed for this purpose that the onions grown under sprinkler irrigation are split evenly between drip and flood irrigation. Under this conservative assumption, 70% of JISL's onions are grown under flood irrigation, and 30% are grown under drip irrigation.

The method for computing the supply chain water footprint for dehydrated onions also accounts for water consumed in the production of materials and energy used at the Food Park, which is considered supply chain overhead water footprint. The loss of mass in the production process is also accounted for in these calculations. These calculations are discussed in the following sections.

Beneficial crop consumption and grey water footprint

The water footprint of the process of growing onions is the sum of the blue, green, and grey components:

$$WF_{total} = WF_{green} + WF_{blue} + WF_{grey} \quad [3.2]$$

The blue and green water footprints are related to evapotranspiration loss and therefore reflect beneficial crop consumption.

Green and blue water footprints

To calculate blue and green water footprints, crop water use (CWU, m^3/ha) is first calculated for both components. CWU represents water consumed in evapotranspiration. Crop water use is divided by the mass of crop produced per unit area, or yield (Y, metric tons/ha) to compute the water footprint:

$$WF = \frac{CWU}{Y} \quad [3.3]$$

The green and blue components of CWU are calculated separately. Green crop water (CWU_{green}) use refers to the evapotranspiration loss of rain water stored in soil as soil moisture. Blue crop water use (CWU_{blue}) refers to the evapotranspiration loss of surface and groundwater. CWU_{green} is independent of irrigation water supply and depends upon total rainfall and soil characteristics, whereas CWU_{blue} depends upon green water availability and irrigation water required to meet crop evapotranspiration demand.

Crop water use is derived from the crop water requirement (CWR, mm/growing season). The CROPWAT model of the Food and Agriculture Organization (FAO, 2009) was used to estimate CWR under non-optimal conditions, as recommended in the Water Footprint Manual. The model was run using the 'irrigation schedule option' of the CROPWAT model. The timing off irrigation was set to "irrigate at critical depletion' and the irrigation water application was set to "refill soil to field capacity." In this option the model computes a daily soil water balance and keeps track of the soil moisture over time using a daily time step. CWR is calculated as the sum of total crop evapotranspiration (ETC, mm/day), accumulated over the entire growing period.

Different values for the crop coefficients (Kc) used in the CROPWAT model were selected for flood and drip irrigations. Local values for crop coefficients for onions were not available, so the estimates of Kc were based on literature sources. Kc values for flood irrigation were obtained from a study of onions grown in a similar semi-arid region (Lopez-Urrer et al., 2009). For drip irrigation, the Kc values are based on crop coefficients for different irrigation techniques as reported by Allen et al. (1998). The authors report a lower value for Kc for cotton grown under drip irrigation compared to cotton grown under flood and sprinkler irrigations. For this study, it was assumed that the same relative difference in Kc values applies to onions grown in the Jalgaon growing region. The Kc values used in the CROPWAT model for flood and drip irrigation are shown in Table 3-2.

Table 3-2. Crop Coefficient Values Used in CROPWAT for Flood and Drip Irrigation

IRRIGATION TYPE	$Kc_{INITIAL}$	Kc_{MID}	Kc_{FINAL}
Flood irrigation	0.65	1.20	0.75
Drip irrigation	0.50	1.05	0.60

Direct solar radiation, wind speed, ambient temperature, and humidity are some of the most important factors that influence crop evapotranspiration at a given location. As evapotranspiration proceeds, the surrounding air becomes saturated. Wind speed affects evapotranspiration by bringing heat energy and replacing the saturated air mass. Therefore, differences in climate parameters can influence the rate of evapotranspiration between different growing regions.

Climate parameters for the Jalgaon District are shown in Table 3-3. Due to proximity, it was assumed that these climate data are representative of the entire Jalgaon onion growing region. The variability in rainfall and temperature in the Jalgaon District is high, as discussed in Section 1.2.

Table 3-3. Long-Term Annual Average Climate Parameters for the Jalgaon Growing District

PARAMETER	JALGAON DISTRICT
Min Temp (°C)	20.3
Max Temp (°C)	33.8
Humidity %	51.1
Radiation (MJ/m^2/day)	18.6
Wind (km/day)	12.3
Sunshine (hrs/day)	8.5
Rainfall (mm/yr)	822.0

The estimates of CWR (mm/growing season) based on CROPWAT modeling are expressed as crop water use (CWU) in terms of volume per hectare by multiplying by a factor of 10. The water footprint is then calculated by dividing CWU by average yields. The green and blue water footprint of onions is estimated from the CWUs and yields as follows:

$$WF_{green} = \frac{CWU_{green}}{Y} \quad [3.4]$$

$$WF_{blue} = \frac{CWU_{blue}}{Y} \quad [3.5]$$

The yields used in the analysis, and estimated green and blue components of CWR, CWU, and resulting water footprints are provided in Table 3-4.

Table 3-4. Beneficial Crop Consumption for Raw Onions

PARAMETERS	JALGAON REGION	
	DRIP	FLOOD
Crop Water Requirement (mm/growing season)		
Green	31	31
Blue	843	959
Crop Water Use (m^3/ha)		
Green	309	309
Blue	8,425	9,589
Average Crop Yield (tons/ha)	36.1	26.7
Total Water Footprint (liters/kg)		
Green	9	12
Blue	233	359

Onions grown under drip irrigation have smaller green and blue water footprints compared to flood-irrigated onions. The consumptive water saved with drip irrigation is 129 liters/kg raw onions. Much of the difference is due to the higher crop yields obtained for drip-irrigated onions, which are 35% larger than crop yields from flood-irrigated onions. These calculations have relevance to efforts to reduce the green water footprint of rainfed crops, in that they highlight how the green water footprint may be reduced through the use of drip irrigation, which increases crop yields.

Grey water footprint

The grey water footprint (WF_{grey}) relates to the volume of water that is required to assimilate loads of pollutants (fertilizers, chemicals and pesticide) from agriculture lands such that it meets the established water quality standard. The grey water footprint for growing onions was calculated from estimated nutrient loads reaching groundwater supplies or surface water adjacent to onion fields. According to the Water Footprint Manual, it is sufficient to account for the most critical pollutant that is associated with the largest pollutant-specific grey water footprint (Hoekstra et al., 2009). In this study nitrogen is considered as the most critical pollutant because of documented nitrate problems in groundwater in the Jalgaon District (Ministry of Water Resources, 2009).

The grey water footprint is estimated as follows:

$$WF_{grey} = \frac{(\alpha x AR)/(C_{max} - C_{nat})}{Y} \quad [3.6]$$

AR = the application rate of fertilizer (kg/ha);
α = the leaching fraction pollutant entering the water system;
C_{max} = ambient water quality for the pollutant (mg/liter);
C_{nat} = natural concentration of pollutant in the receiving water body (mg/liter); and
Y = the annual crop yield (ton/ha)

The natural concentration of pollutant in the receiving water body (C_{nat}) is assumed to be zero. In the absence of local water quality standards, the USEPA-recommended maximum contaminant level or concentration (C_{max}) of nitrate in drinking water of 10 mg/L was assumed.

Pollutant load information was estimated based on the rate of fertilizer application for onions grown under flood and drip irrigation in the Jalgaon growing region. In the absence of site-specific information for leaching rates and pollutant loads in runoff, a 10% leaching rate was assumed for all locations where flood irrigation is used, as recommended by Hoekstra et al. (2009). A leaching rate of 2% was assumed for drip irrigation, based on the relative quantities of fertilizer required under each irrigation technique and the method of application (JISL, personnel communication).

The estimated grey water footprints for raw onions associated with fertilizer application are:

- Drip irrigation: 6 liters/kg
- Flood irrigation: 57 liters/kg

Grey water footprints from other pollutants in fertilizer and pesticide applications were not calculated because data were unavailable. They are assumed to be smaller than the grey water footprint related to the critical pollutant, but further study would be needed to confirm this.

These grey water footprints are approximations based on the assumptions related to leaching rates and other inputs described above. Further study using site-specific data would be needed to refine these calculations.

Summary of results

The three color components of the water footprints for raw onions grown under flood and drip irrigation are shown in Figure 3-2.

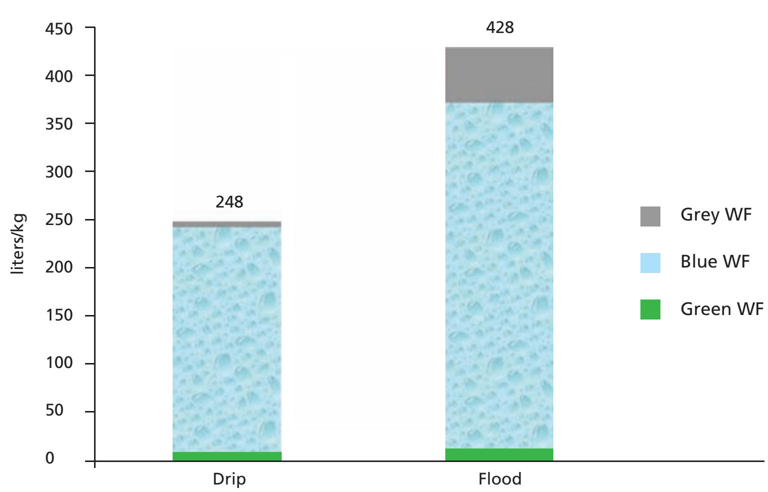


Figure 3-2. Water Footprints for Onions Grown in Jalgaon Region

The results show that onions grown under drip irrigation have a 42% smaller water footprint than onions grown under flood irrigation. The largest component of the water footprints is the blue water footprint, associated with irrigation water. The grey water footprint for onions grown under drip irrigation is almost 90% smaller than the grey water footprint for flood-irrigated onions, reflecting the lower leaching rate when water and nutrients are applied at the roots of the plants.

Water consumed in MIS manufacturing

The water footprints calculated for each of the primary MIS components (see Section 4) were used to estimate the water footprint of MIS equipment used on a typical onion field. The mass of each component on a typical 5 hectare field was then estimated, and multiplied by the water footprint (liters/kg) to calculate the liters required to produce the mass of each component used on a 5 hectare field. This value was then divided by yield to calculate the water footprint for each MIS component. The results are shown in Table 3-5.

Table 3-5. Calculation of Water Footprint of MIS components on a Typical Field

ITEM	TOTAL WATER FOOTPRINT (LITERS/KG MIS)	WATER FOOTPRINT OF MIS COMPONENTS ON A TYPICAL 5 HA FIELD (LITERS/HA)	CROP YIELD (KG/HA)	WATER FOOTPRINT (LITERS/KG OF ONIONS)
MIS PVC Pipe	10.9	491	36,100	0.0136
MIS PVC Molded Fittings	15.0	44	36,100	0.0012
MIS Molded Components	18.5	31	36,100	0.0009
MIS Poly tube	14.9	812	36,100	0.0225
MIS Drip tube	14.8	11	36,100	0.0003
MIS Filter Equipments	3.0	8	36,100	0.0002
TOTAL	**77**	**1398**	---	**0.04**

The water footprint of MIS calculated using this approach (0.04 liters/kg onions) was found to be less than 0.02% of the total water footprint of raw onions grown under drip irrigation (248 liters/kg onion).

Supply chain overhead

Water consumed in the production of materials and energy used at the onion processing plant (not directly related to production) is considered supply chain overhead. This was considered to be an insignificant source of water consumption. For further discussion of supply chain overhead, see Section 4.3.

Supply chain water footprint results

The supply chain water footprint was calculated according to the following steps.

STEP 1.
Calculate water footprint of raw onions grown under drip and flood irrigation

The supply chain water footprint of raw onions (liters/kg) is calculated for onions grown under drip irrigation (WF [onions]$_{drip}$) and flood irrigation (WF [onions]$_{flood}$) as follows:

$$\text{WF [onions]} = (WF_{blue} + WF_{green} + WF_{grey}) + WF_{MIS} + WF_{overhead} \qquad [3.7]$$

$WF_{blue} + WF_{green} + WF_{grey}$ = beneficial consumption, liters/kg

WFMIS = WF of MIS equipment used to irrigate onion fields, liters/kg

$WF_{overhead}$ = Overhead WF, liters/kg

STEP 2.
Weight the results

The results from Step 1 reflect onions grown under each irrigation method. The water footprint of all onions purchased by JISL was estimated by weighting the results based on the relative percents grown under each irrigation method (70/30 split) as explained previously:

$$\text{WF [onions]}_{JISL} = (0.30 * WF_{drip}) + (0.70 * WF_{flood}) \qquad [3.8]$$

STEP 3.
Account for product fraction

The final step in the calculation of the supply chain water footprint is an accounting for the mass of input material (onions) that enters the plant and is not incorporated into the finished product. This loss is accounted for in the calculations through the product fraction (f_p), which is the quantity of output product obtained per quantity of input product. The water footprint of the input raw material, WF_{prod}[onions], is divided by the product fraction so that the water footprint is calculated per unit of output product.

$$\text{Supply chain WF (liters/kg output)} = WF_{prod}\text{[onions]} / f_p \qquad [3.9]$$

The product fraction for JISL's dehydrated onion product is 0.14. This was estimated based on raw material feed and DHO production data collected by JISL in 2009.

The water footprint results for raw onions and intermediate calculations are presented in Table 3-6.

Table 3-6. Water Footprints Results for Raw Onions Grown in Jalgaon District

PRODUCT	WATER FOOTPRINT (LITERS/KG)			
	GREEN	BLUE	GREY	TOTAL
Onions grown under drip irrigation:				
Beneficial crop consumption and grey component	9	233	6	248
WF of MIS on typical field[1]	0	0.039	0.0004	0.04
Total Water Footprint	9	233	6	248
Onions grown under flood irrigation:				
Beneficial crop consumption and grey component (total water footprint)	12	359	57	428
Weighted Average for all Onions Purchased by JISL				
Water footprint of raw onions (liters/kg raw onions)	10.7	321	42	374
Supply chain water footprint (liters/kg DHO)[2]	76.3	2296	299	2671

[1]Calculations for water footprint on a typical field are shown in Section 3.3.
[2]Accounts for product fraction of 0.14 kg DHO/kg raw onions

The results indicate that blue water associated with irrigation is the largest component of the total water footprint for raw onions, comprising 86% of the total supply chain water footprint. As expected, the water footprint of MIS on a typical field is a negligible component of the total supply chain water footprint.

The results show that onions grown under drip irrigation have a 42% smaller water footprint than onions grown under flood irrigation. The largest component of the water footprints is the blue water footprint, associated with irrigation water. The grey water footprint for onions grown under drip irrigation is almost 90% smaller than the grey water footprint for flood-irrigated onions, reflecting the lower leaching rate when water and nutrients are applied at the roots of the plants.

These figures reflect the volumes of water consumed in the growing of onions. The relative percentages are consistent with data on water withdrawals under drip and flood irrigation. Available data indicate that approximately 40% less water is withdrawn and applied to flood-irrigated fields compared to drip-irrigated fields (JISL, personnel communication).

3.4 OPERATIONAL WATER FOOTPRINT

This section describes the accounting method and results for process steps that transform the raw onions into dehydrated onions. Water is consumed in the cleaning and processing of onions in the processing plant. Water is also consumed at the plant for domestic uses not directly related to production, such as toilets and gardening.

Wastewater from the processing plant is treated to standards and applied through drip irrigation in the Agri Park. The rate of leaching related to this application and the associated nutrient load is unknown but assumed to be negligible, so the grey water footprint is estimated to be zero. The operational water footprint results are shown in Table 3-7.

Table 3-7. Operational Water Footprint Results

COMPONENT	WATER FOOTPRINT (LITERS/KG)		
	BLUE	GREY	TOTAL
Water Associated with Production	24.6	0.0	24.6
Overhead[1]	8.0	0.0	8.0
Total Operational WF	**32.6**	**0.0**	**32.6**

[1]Overhead includes domestic water use plus water consumed in the plant during non-processing season.

3.5 WATER FOOTPRINT OF DEHYDRATED ONIONS

The water footprint for dehydrated onions is the sum of the supply chain and operational water footprints, as shown in Table 3-8.

Table 3-8. Water Footprint Results for Dehydrated Onions

WATER FOOTPRINT TYPE	WATER FOOTPRINT (LITERS/KG)			
	GREEN	BLUE	GREY	TOTAL
Supply Chain Water Footprint	76	2296	299	2671
Operational Water Footprint	0	33	0	33
Total Water Footprint	**76**	**2329**	**299**	**2704**

The results indicate that water consumed in the supply chain accounts for approximately 99% of the total water footprint of dehydrated onions, and water consumed in operations accounts for approximately 1% of the total water footprint (see Figure 3-3). The green water footprint is small (3% of the total water footprint), reflecting the limited rainfall during the growing season. The blue water footprint accounts irrigation water, making up 87% of the total water footprint. The entire grey water footprint is associated with the growing of onions in the supply chain, and the operational grey water footprint is zero.

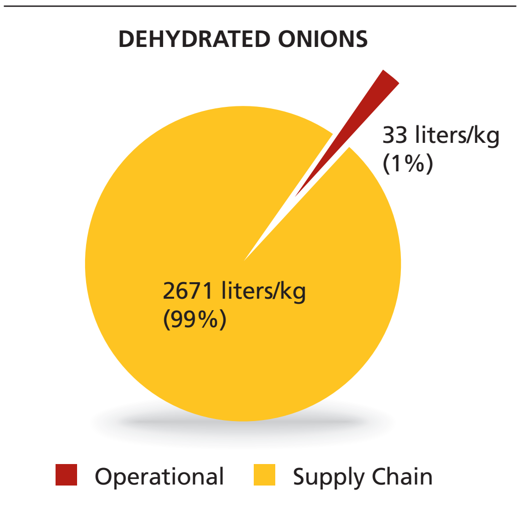


Figure 3-3. Supply Chain and Operational Water Footprints for Dehydrated Onions

4 WATER FOOTPRINT OF MICRO-IRRIGATION SYSTEMS

JISL's micro-irrigation systems for drip irrigation are made up of multiple components manufactured from various raw materials, as described in Section 2. The water footprint of each component was calculated separately, accounting for water consumption in the supply chain to produce the raw materials, and operational water use in the MIS manufacturing process.

A complete drip irrigation system on a typical onion field is primarily made up of six components, which are manufactured individually within JISL's Plastic Park (Figure 4-1). The operational water footprint for each of the six components can be divided into the input and overhead water footprint. The input operational water footprint refers to process water that is directly related to the production of a product. Operational overhead refers to water consumption not directly related to the production of the product, such as domestic waters use and water use in the factory during non-production months.

With regard to the supply chain, the major raw material flows to the Plastic Park are polyethylene (PE), polypropylene (PP), and poly vinyl chloride (PVC). Other raw materials include steel filter components purchased from vendors and assembled to make filter equipments. In addition to raw materials, the supply chain water footprint also includes electricity consumed in each of the six manufacturing units.

A simplified schematic of the flow of raw materials and electricity and the different components manufactured at JISL's Plastic Park is shown in Figure 4-2.

Figure 4-1. Aerial Photo of Plastic Park

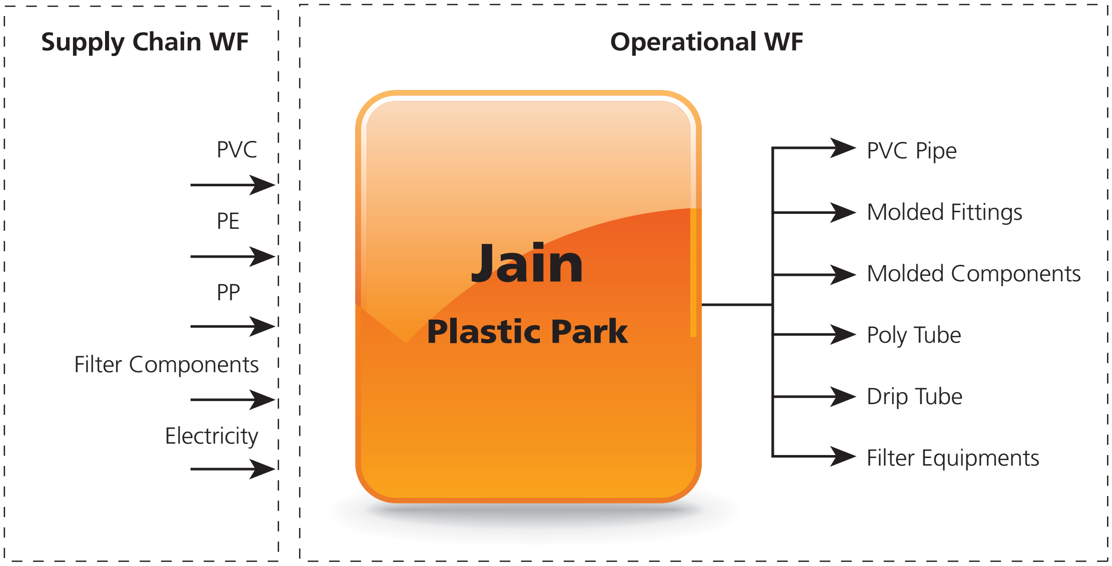


Figure 4-2. Primary Supply Chain and Operational Water Footprint (WF) Components

4.1 SUMMARY OF RESULTS

The water footprint results for MIS components expressed as the sum of the supply chain and operational water footprints are presented in Table 4-1. More detailed steps involved in the supply chain and operational water footprint calculations are described in Sections 4.2 through 4.4.

Table 4-1. Summary of MIS Water Footprint Results

ITEM	WATER FOOTPRINT (LITERS/KG)			
	GREEN	BLUE	GREY	TOTAL
MIS PVC Pipe	0	10.7	0.13	10.9
MIS PVC Molded Fittings	0	15.0	0.06	15.0
MIS Molded Components	0	18.3	0.19	18.5
MIS Poly Tube	0	14.8	0.12	14.9
MIS Drip Tube	0	14.6	0.15	14.8
MIS Filter Equipments	0	3.0	0.04	3.0

4.2 OVERVIEW OF ACCOUNTING METHOD

The water footprint of MIS components is equal to the sum of the process water footprints for all processes in the supply and operation chain. There are two processes in the production of MIS: 1) production of raw plastics materials; and 2) production of MIS components at the Plastic Park. Therefore, the water footprint is calculated as follows:

$$WF_{prod}[MIS] = WF_{proc}[MIS] + WF_{prod}[Raw\ Materials] \,/\, f_p \qquad [4.1]$$

$WF_{prod}[MIS]$ = water footprint of output product (MIS), liters/kg MIS

$WF_{proc}[MIS]$ = process water footprint of processing steps that transform the input product (raw materials) into output product (MIS), liters/kg MIS

$WF_{prod}[Raw\ Materials]$ = water footprint of input product, liters/kg raw materials

f_p = product fraction = quantity of output product obtained per quantity of input product, kg MIS/kg raw materials

The first calculation step accounts for water consumed in the manufacturing of the raw materials, or the supply chain water footprint. The supply chain water footprint of raw onions accounts for:

- Water consumed in the production of raw materials
- Product yield
- Grey water component
- Overhead

The second calculation step addresses operational water use, and accounts for water consumed in the manufacturing of MIS from raw materials at the Plastic Park. This includes water consumed in the production of MIS, as well as domestic water use (overhead). The output of this calculation step is the process water footprint, WFproc[MIS]. Since no rain water is used in production stages in supply chain or plant operations for MIS, the green water footprint is zero.

The final step is the calculation of the water footprint of MIS according to Equation 4.1. All calculations and results are described in the following sections.

4.3 SUPPLY CHAIN WATER FOOTPRINT

The supply chain water footprint is calculated as the sum of the water footprints of all input (raw) materials produced by suppliers and the water footprint of supply chain overhead activities.

Water footprint of raw materials

Geographically-explicit data on the water footprint of raw materials were not provided by suppliers and are not generally available. Therefore, average water footprint estimates for PE and PP were obtained from a recent study published by Borealis Group on water footprint assessments for the manufacturing of polyolefin across all its production sites (Katsoufis, 2009). For PVC manufacturing, water inventory information was obtained from the Environmental Product Declaration (EPD) report (ECVM and Plastics Europe, 2008). The EPD is a standardized method (ISO 14025) of communicating environmental performance of a product or service based on LCA data. The calculated water footprints of raw materials obtained from these different sources are presented in Table 4-2.

Table 4-2. Water Footprint of Raw Materials for MIS

RAW MATERIAL	WATER FOOTPRINT (LITERS/KG)			REFERENCE
	BLUE	GREY	TOTAL	
Polyethylene (PE)	13.7	0	13.7	Katsoufis, 2009
Polypropylene (PP)	13.1	0	13.1	Katsoufis, 2009
Poly Vinyl Chloride (PVC)	10	NA[1]	10	ECVM and Plastics Europe, 2008

[1]Not available

Supply chain overhead water footprint

Water footprint accounting includes consideration of water associated with the production of buildings, machinery, trucks, office equipment and materials, cleaning equipment, working clothes, and other water use not directly related to production of MIS. Water consumed in the production of energy used to power operations at the Plastic Park is also considered to be part of this "supply chain overhead."

Recent efforts by others to calculate the water footprint of overhead have indicated that most components of the overhead water footprint add up to a very small percentage of the total water footprint, and that it is generally not worth the significant effort to compute it. As an example, the water footprints of construction materials, paper, and transportation (vehicles, fuel) were calculated as part of a recent pilot study for a hypothetical carbonated beverage (Ercin, et al., 2009). The results demonstrated that supply chain overhead is less than 0.5% of the total water footprint.

Supply chain overhead was considered as part of this study for the purpose of completeness, and determined to be very small. Only the water associated with electricity was considered, assuming that other components are negligible based on the findings of Ercin et al. (2009). Coal provides approximately 73% of energy generation in the state of Maharashtra and approximately 53% of the energy in India (TERI, 2009). Based on this information, it was assumed that all of the energy for the Plastic Park is sourced from coal. A water footprint for production of coal of 0.59 liters/kWh was used in the calculations, as reported by Gerbens-Leenes, et.al. (2008). Electricity consumed in the Plastic Park (kwh/kg) was multiplied by the water footprint of coal to obtain the water footprint in units of liter/kg of output product. Using this approach, the supply chain overhead water footprint based on energy use was found to be only 0.03 to 1.4 liters/kg MIS.

Supply chain water footprint results

The calculation of the supply chain water footprint accounts for the portion of the raw material that enters the manufacturing process and is not incorporated into the finished product. This loss is accounted for in the calculations through the product fraction, which is the quantity of output product obtained per quantity of input product. The water footprint of the raw material is divided by the product fraction so the supply chain water footprint is calculated in terms of liters of water per unit mass of finished output product. The product fraction for all MIS components in the Plastic Park is unity because process material loss is completely recycled in the plant as raw material.

Table 4-3 provides a breakdown of the supply chain water footprint results by component.

Table 4-3. Supply Chain Water Footprint Results

MIS COMPONENT	WATER FOOTPRINT (LITERS/KG)					GREY WF (LITERS/KG)[3]
	WF OF RAW MATERIALS[1]	PRODUCT FRACTION	WF OF MIS COMPONENTS[2]	OVERHEAD WF	TOTAL WF	
MIS PVC Pipe	10	1.0	10	0.18	10.2	NA
MIS PVC Molded Fittings	10	1.0	10	0.99	11.0	NA
MIS Molded Components	13.1	1.0	13.1	1.40	14.5	NA
MIS Poly Tube	13.7	1.0	13.7	0.29	14.1	NA
MIS Drip Tube	13.7	1.0	13.7	0.47	14.2	NA
MIS Filter Equipments	2.4	1.0	2.4	0.03	2.4	NA

[1]Units are liters per kg raw material
[2]Accounts for product fraction; units are liters per kg finished product
[3]Not available

4.4 OPERATIONAL WATER FOOTPRINT

The operational water footprint includes:

- Blue water consumed in the manufacture of MIS components (water used to clean equipment and for cooling) and for domestic water use (overhead); and
- Grey water footprint associated with wastewater discharged from the plant.

Blue water footprint

The blue water footprint is the summation of water consumed in the production of MIS components and domestic water use or overhead, which includes water consumed or polluted related to toilets, cleaning, kitchens, gardening, and laundry. The blue water footprints calculated for each of the primary MIS components, are shown in Table 4-4.

Grey water footprint

The grey water footprint of a process step is an indicator of the degree of fresh water pollution associated with the process step. Wastewater effluent resulting from the manufacturing of different MIS components is collectively processed at an on-site treatment plant. First, chemical characteristics of the treated effluent were evaluated to determine the critical pollutant, which is the pollutant that is associated with the largest grey water footprint. Second, the grey water footprint was estimated as follows:

$$WF_{Grey} = \frac{Effl \times (C_{eff} - C_{nat})}{C_{max} - C_{nat}} \quad [4.2]$$

Effl = effluent volume (liter/year);

C_{eff} = concentration of pollutant in the effluent (mg/liter);

C_{max} = ambient water quality for the pollutant (mg/liter);

C_{nat} = natural concentration of pollutant in the receiving water body (mg/liter); and

Y = MIS production (kg/yr)

Finally, the total grey water footprint was allocated to each of the six MIS components based on effluent discharge.

The critical pollutant considered for the grey water footprint calculations is total dissolved solids (TDS). The natural concentration in the receiving water body is assumed to be zero (C_{nat}). A maximum contaminant level of TDS in drinking water of 500 mg/L (BIS, 1991) was assumed for the calculations. The grey water footprints estimated for each of the MIS components range from 0.04 to 0.19 liters/kg.

Summary of results

A summary of the estimated blue and grey water footprints of different MIS components is provided in Table 4-4. The total blue water footprints ranged from 0.4 liters/kg for drip tubes to 4 liters/kg for PVC molded fittings. Filter equipments have the smallest grey water footprints (0.04 liters/kg), and molded components have the largest (0.19 liters/kg).

Table 4-4. Operational Water Footprint Results

COMPONENT	BLUE WATER FOOTPRINT (LITERS/KG)			GREY WATER FOOTPRINT (LITERS/KG)	TOTAL WF (LITERS/KG)
	MIS INPUT WATER	OVERHEAD	TOTAL		
MIS PVC Pipe	0.24	0.25	0.5	0.13	0.6
MIS PVC Molded Fittings	1.3	2.7	4.0	0.06	4.1
MIS Molded Components	2.3	1.4	3.8	0.19	4
MIS Poly Tube	0.38	0.32	0.7	0.12	0.8
MIS Drip Tube	0.3	0.07	0.4	0.15	0.5
MIS Filter Equipments	0.5	0.09	0.6	0.04	0.6

4.5 TOTAL WATER FOOTPRINT OF MIS

The total water footprint is the sum of the supply chain and the operational water footprints. The proportion of supply chain and operational WF for each of the six MIS components is shown in Figure 4-3.

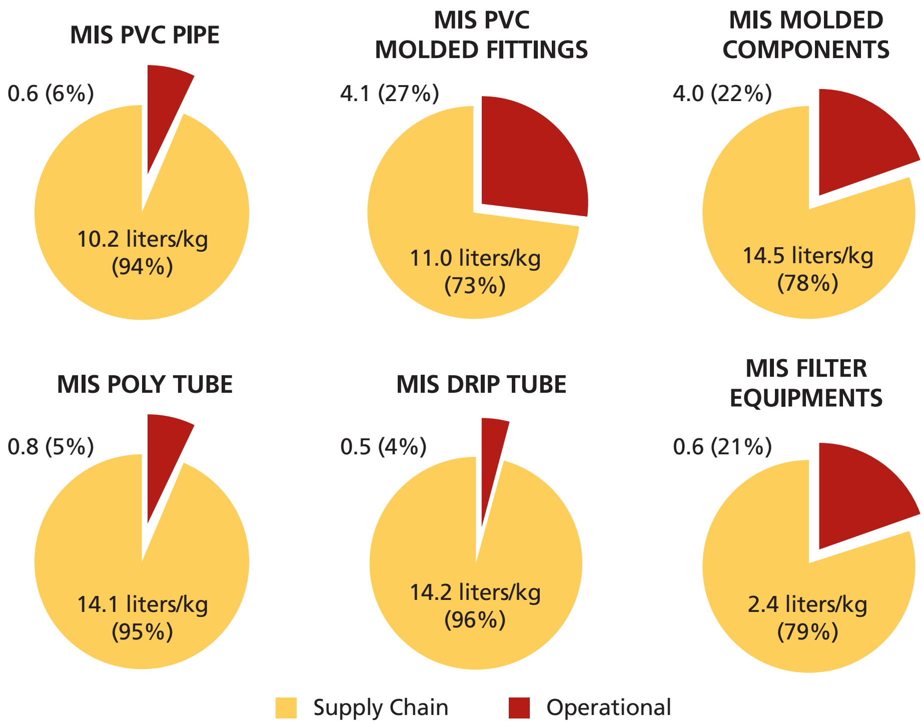


Figure 4-3. Supply Chain and Operational Water Footprints for MIS Components

The water footprints associated with the manufacturing of MIS equipments are generally very small, ranging from 3 liters/kg for filter equipments, to 18.5 kg/liters for molded components. Most of the water footprint for the manufacturing of MIS components lies in the supply chain, accounting for 73% to 96% of the total water footprint. Most of the supply chain and total water footprint is blue water associated with raw material production. Data to calculate the grey water footprint associated with production of raw materials (plastics) were not available, so this component is unknown.

The supply chain water footprints for MIS components are large relative to the operational water footprints because water is used for extraction and refining of oil resources, and petrochemical plants uses large boilers and heat exchangers that consume significant amount of water.

The operational grey water footprint associated with the manufacturing of MIS components is quite small (see Table 4-4). This is due to the fact that most of the process water is used for cooling. The evaporative losses in cooling towers have been minimized by gradually replacing water cooling units with air-cooled chillers. In addition to lowering water consumption, this upgrade has reduced the softening process required for cooling water, which in turn has reduced the wastewater load to the effluent treatment plant.

5 SUSTAINABILITY ASSESSMENT

Sustainability assessment is the third step in a water footprint assessment. The purpose of a sustainability assessment is to gain an understanding of the influence of a particular water user, such as farmers supplying onions to JISL, on local hydrologic systems, and to assess possible ecological, social and economic impacts of that water use. A sustainability assessment focuses on the particular aspects of the water cycle being affected by the water user, such as the water sources from which a company's water supply is being drawn, or the water bodies into which any wastewater or surface runoff is flowing.

Of great pertinence to this assessment for JISL is the sustainability of the groundwater resource that supplies the vast majority of water used in irrigating onions in the Tapi River basin. The farmers interviewed in Shirsoli Village in the Jalgaon District during June 2010 expressed considerable concern about growing groundwater scarcity:

> "Ground water levels have been steadily declining since the 1970's."
>
> "Water levels in the wells are totally rainfall dependent."
>
> "Wells have gone dry during growing seasons in extreme drought years."

These quotes from local farmers provide anecdotal evidence of declining water tables, but their observations are consistent with reports in the literature of steadily declining groundwater levels, as discussed in Section 1.2. To supplement and ground-truth this evidence, considerable groundwater and rainfall data were assembled and analyzed to gain deeper insights into trends in groundwater availability.

5.1 SUMMARY OF RESULTS

A strategic decision was made to focus the JISL sustainability assessment on the potential social and economic impacts associated with the company's use of groundwater (its blue water footprint), with particular emphasis on the possible consequences of groundwater depletion in the Tapi River basin. While other issues such as potential contamination of groundwater with nitrogen fertilizer used in farming (grey water footprint) or the ecological impacts of surface and groundwater use in the area may be deserving of attention as well, those issues are addressed here only peripherally, due to time and resource constraints and lower priority.

Because the onion farms supplying JISL's production of dehydrated onions are distributed throughout the Jalgaon, Dhule, and Nashik districts, water level data from a large number of groundwater wells located throughout the Tapi River basin were analyzed for this sustainability assessment.

JISL's water consumption in the Tapi River basin takes place in a rich and evolving physical, social, and economic context. The company is but one of many users of water resources in the basin, and the nature and volume of those uses has been changing rather substantially in recent decades. For instance, the total area of irrigated agriculture is increasing, with water-intensive crops such as bananas and cotton accounting for much of this agricultural expansion, as shown in Figure 5-1.

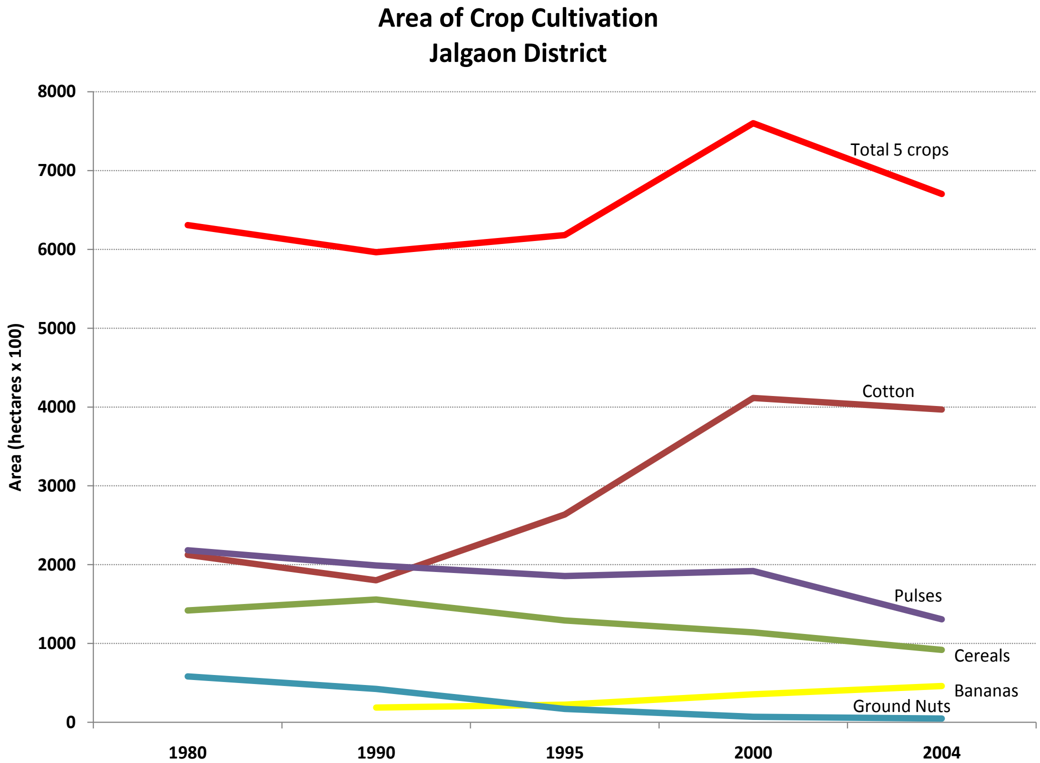


Figure 5-1. Temporal Trends in Area of Crop Cultivation: Jalgaon District

By comparison, approximately 3,500 ha of land were cultivated for onions in Jalgaon in 2000, which is roughly 0.5 percent of the total land area cultivated for these five major crops in the district. Though onion farming constitutes a small percentage of the total area in cultivation, the sustainability of JISL's water use is vulnerable in several distinct ways, each of which suggests a different type of response strategy:

- The overdraft of groundwater due to cumulative uses in the onion growing regions makes JISL's dependence on onions from this area at risk. It also places onion farmers themselves at risk, because any further loss of crop production or associated revenue could cause farmers to shift to other sources of income, including moving to cities. This suggests that response strategies should help farmers reduce their **demand** for water, thereby reducing their risk of shortages and helping to alleviate the regional declines in groundwater levels.
- Given current rates of groundwater overdraft, it may be very difficult or impossible to maintain or increase crop production. Therefore, the response strategies should also find ways to increase the **supply** of water.
- Finally, the complexity brought about by the presence of many different water users suggests that a **community-based, multi-stakeholder approach** to managing the groundwater resource could be of value in ensuring the sustainability of water-dependent livelihoods and in preventing future conflict over water resources.

5.2 OVERVIEW OF SUSTAINABILITY ASSESSMENT APPROACH

A water footprint sustainability assessment can be carried out at a local, river basin, and/or global scale, and it can address environmental, social, and/or economic sustainability. This assessment considers the social and economic sustainability of JISL's blue water footprint, at the scale of the Tapi River basin.

The JISL sustainability assessment was conducted in accordance with a method developed recently by the Water Footprint Network's (WFN) sustainability assessment working group. The assessment can be broken down into the five steps depicted in Figure 5-2.

STEP 1	STEP 2	STEP 3	STEP 4	STEP 5
Identify the company's area of influence	Determine sustainability boundaries for each affected water body (lake, river, or aquifer)	Assess primary impacts for each affected water body (water quantity, water quality)	Determine the associated secondary impacts (environmental, social, economic)	Estimate the company's share of impacts

Figure 5-2. Steps in a Water Footprint Sustainability Assessment

5.3 SUSTAINABILITY ASSESSMENT

STEP 1:
Identify the company's area of influence

Method

Defining the geographic extent of a company's influence on hydrologic conditions is of utmost importance in conducting a sustainability assessment. The area of influence begins at a point at which the company is extracting or returning (discharging) water; the area of influence emanates downstream or outward from this point of origin. This area of influence defines the spatial boundaries for a sustainability assessment.

Application to JISL

Because the onion farms supplying JISL are widely distributed throughout the Jalgaon, Dhule, and Nashik Districts (see Figure 2-1 in Section 2), this sustainability assessment evaluated groundwater conditions throughout the Tapi River basin, upstream of Padalse (see Figure 1-1 in Section 1). The area of influence encompasses both the Tapi alluvial aquifer and a more widespread but shallower basalt aquifer.

It is important to note that surface waters including the Tapi River and the Girna River, a major tributary in the Jalgaon and Nashik Districts, were not assessed because surface water is not used for growing and producing JISL's onions. Due to the exclusive use of groundwater, ecological impacts associated with onion farming were assumed to be inconsequential in this area.

STEP 2:
Determine sustainability boundaries for each affected water body.

Method

The WFN guidelines for sustainability assessment suggest that for each water body affected by the company, the quantity and quality of water should be maintained within certain limits or "sustainability boundaries" in order to avoid or minimize ecological, social, and economic impacts. The concept of sustainability boundaries is founded on the notion that increasing departures from baseline hydrologic conditions will pose increasing stress on ecosystems and social uses or benefits associated with those systems. Sustainability boundaries are typically expressed as ranges within which hydrologic conditions should be maintained.

The process of determining sustainability boundaries begins by gaining an understanding of the natural or historical ranges of variation in hydrologic (including water quality) conditions within a river, lake, or aquifer – these define the "baseline" conditions. Once the baseline conditions are defined, sustainability boundaries – expressed as ranges or limits of allowable alteration from the baseline condition – can be delineated around these baseline conditions.

For aquifers, sustainability boundaries can be defined by the lowest and highest water fluctuations measured during a time period in which long-term average water levels were fairly steady. In western India, such natural fluctuations would likely be caused by climatic variations such as the strength of monsoon rains or droughts each year. Managing for sustainability would then be assessed by determining whether groundwater levels have remained within the historical boundaries or not. Of particular concern is preventing any long-term trends, such as a decline in water table levels.

Application to the Tapi River Basin

To evaluate whether the groundwater aquifers in the Tapi River basin are being managed sustainably, water level data were obtained for 66 monitoring wells. These data extend back to 1980, providing a reasonably long term (~30 years) basis for examining whether groundwater levels have declined over time. As will be discussed in the next step, groundwater levels began declining immediately following the first water level measurements in 1980. Therefore, it is not possible to know how much natural fluctuation in groundwater levels would have been expected, precluding strict application of the concept of sustainability boundaries in this case.

STEP 3:
Assess primary impacts for each affected water body

Method

To gain insight into the sustainability of a water footprint, a company will need to assess whether the affected hydrologic system(s) are showing signs of stress as a result of the cumulative uses of the system. In the WFN guidance for sustainability assessments, changes in water quantity or quality due to cumulative water uses are referred to as "primary impacts." The objective in Step 3 is to determine how much primary impact has occurred.

For aquifers, the key question is: *Is there a detectable trend apparent in water levels?* The answer here will provide an indication of human-induced impacts. For example, if water levels are declining over time, with no apparent trend in climatic conditions, the volume of water being extracted from the aquifer is presumably greater than the natural replenishment of the water body. If on the other hand water levels have risen over time, it may be an indication that the water body is being artificially augmented in some manner.

Application to the Tapi River Basin

Anecdotal evidence abounds for declining water tables. Interviews with some of JISL's contract farmers indicate that they have observed declining water levels in their wells, and they stated that these observations are consistent with levels in surrounding wells. While they do not monitor their well levels regularly, they report that levels have been declining since the late 1970s or early 1980s. The farmers mentioned that levels started dropping with the introduction of electric pumps (replacing bullocks).

This anecdotal evidence is supported by numerous reports in the literature (Narayanamoorthy, 2010a; Foster, et al., 2007) based on abundant data obtained from monitoring wells in the region. These reports cite expansion of irrigated agriculture and increased groundwater use as the cause of the drop in water table levels throughout the Jalgaon, Dhule, and Nashik Districts during recent decades.

An analysis of data from groundwater monitoring wells was conducted to confirm these reports. Data collected from 1980 to 2009 during the pre and post-monsoon seasons at 66 wells in the Jalgaon, Dhule, and Nashik Districts were analyzed. The well locations are shown in Figure 5-3.

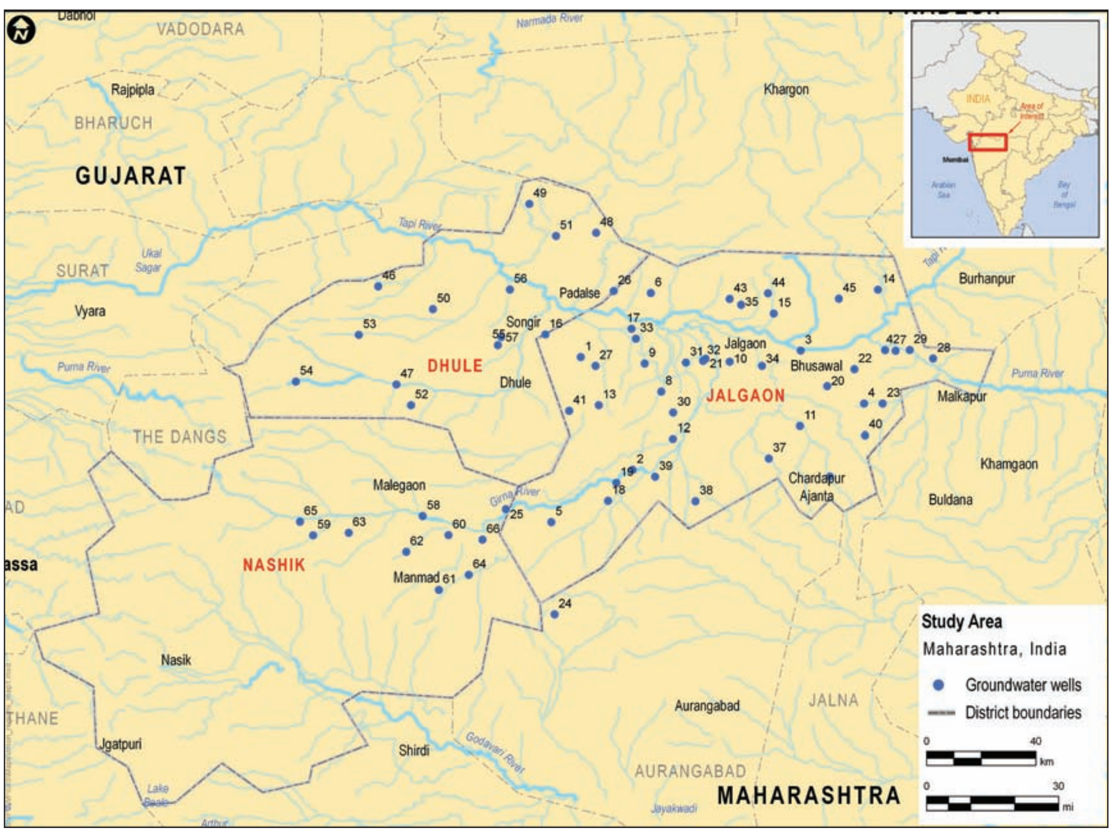


Figure 5-3. Locations of Groundwater Monitoring Wells

Most wells in the basalt areas show some recovery each year during the monsoon season, as shown by differences between the pre-monsoon (May) and post-monsoon (October) measurements in Figure 5-4. However, water tables are dropping to lower and lower levels prior to the monsoon, as depicted in red in the figure. Widespread and progressive depletion of groundwater tables in Maharashtra has become a cause of major concern over the past 10 years; in many locations this has occurred year after year, except for a partial (but temporary) recovery following years of exceptionally heavy monsoon rainfall (Foster et al., 2007).

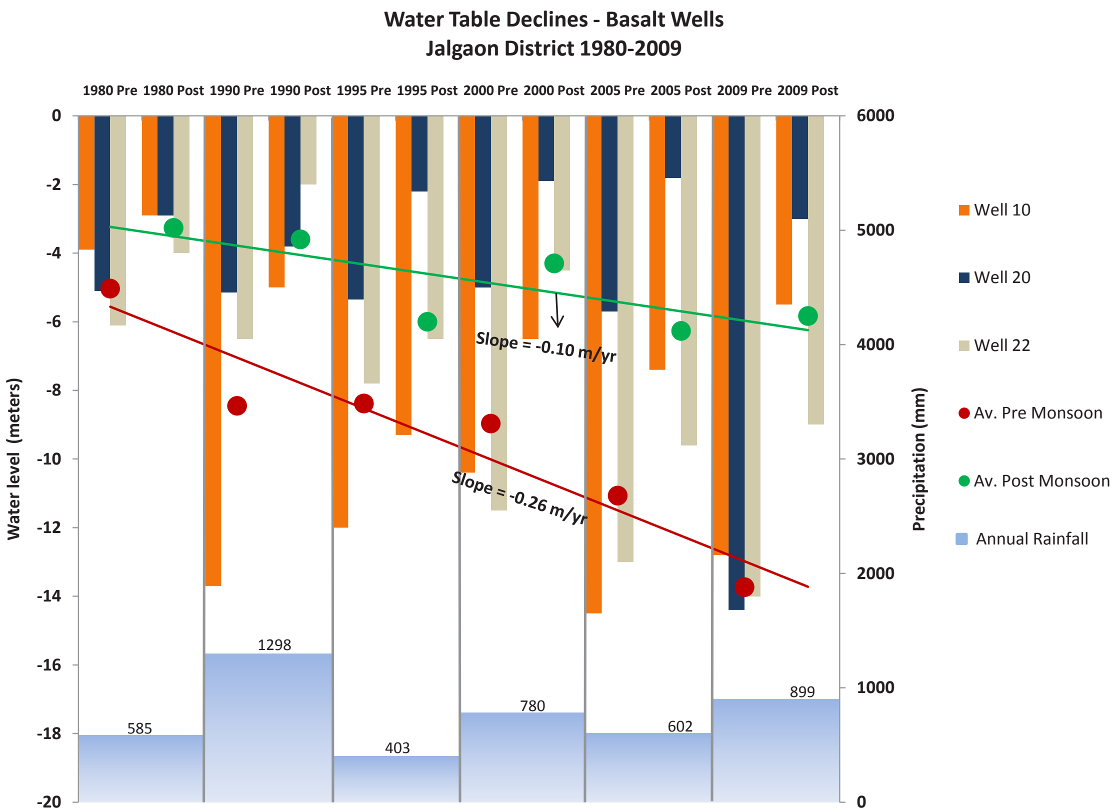


Figure 5-4. Change in Water Table in Basalt Aquifer and Annual Precipitation

(Data Source: Groundwater Surveys and Development Agency, Government of Maharashtra)

While water table levels are much deeper in the alluvial aquifer, these wells do show some degree of rebound during heavy monsoon seasons as well, evident in 2009 (note recovery of approximately 8 meters), as shown in Figure 5-5. Recharge in these wells may be supplemented considerably by infiltration of river flows into the alluvial aquifer.

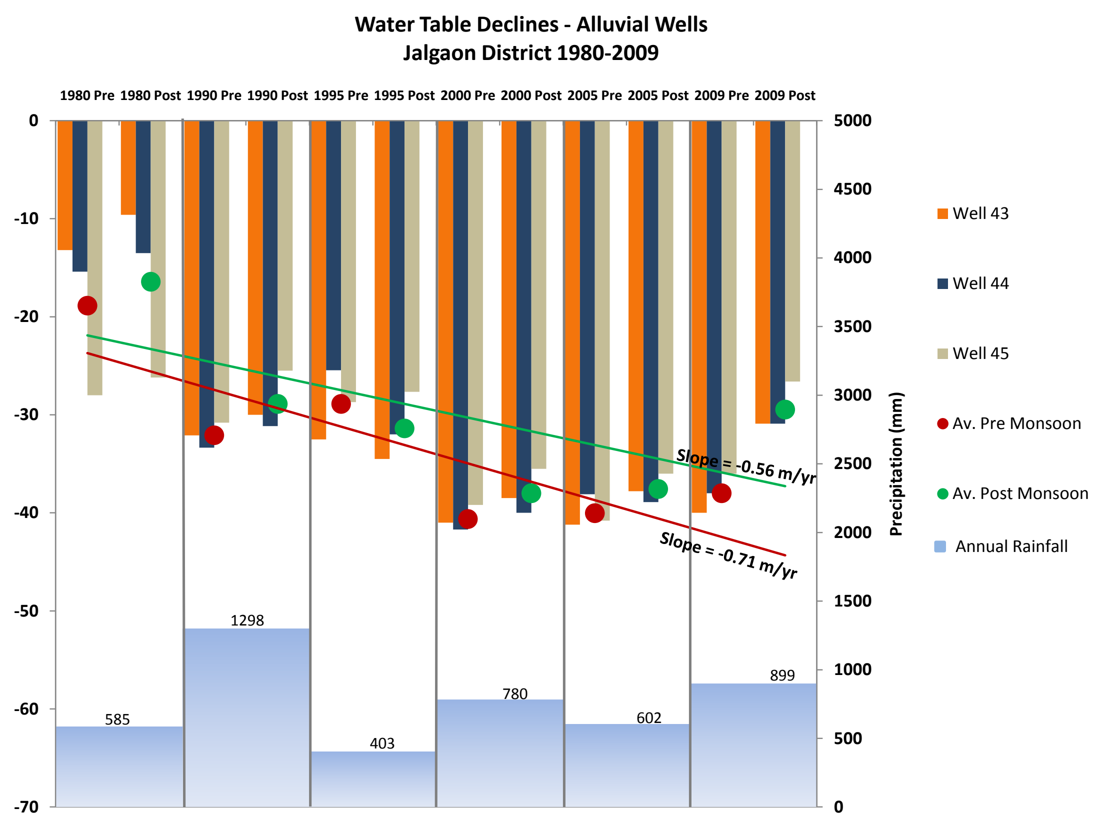


Figure 5-5. Change in Water Table Levels in Alluvial Aquifer and Annual Precipitation

(Data Source: Groundwater Surveys and Development Agency, Government of Maharashtra)

Detailed information on changes in pre-monsoon water levels between 1980 and 2009 in 66 groundwater monitoring wells is provided in Figure 5-6. The bars in the figure indicate the depth of each well. The three colors in the bars indicate: the empty part of the well in 1980 (yellow); the additional drying of the well in 2009 (red); and the water left in the well in 2009 (blue). Declines in water levels between 1980 and 2009 are evident in 58 of the 66 (88%) monitoring wells. The most extreme declines have occurred in the Tapi alluvial aquifer (wells 14, 15, 43, 44). Of considerable concern is the fact that 39% of basalt wells were dry or nearly dry (less than 1 meter water available) prior to the monsoon season in 2009, and an additional 30% had less than 3 meters of available water.

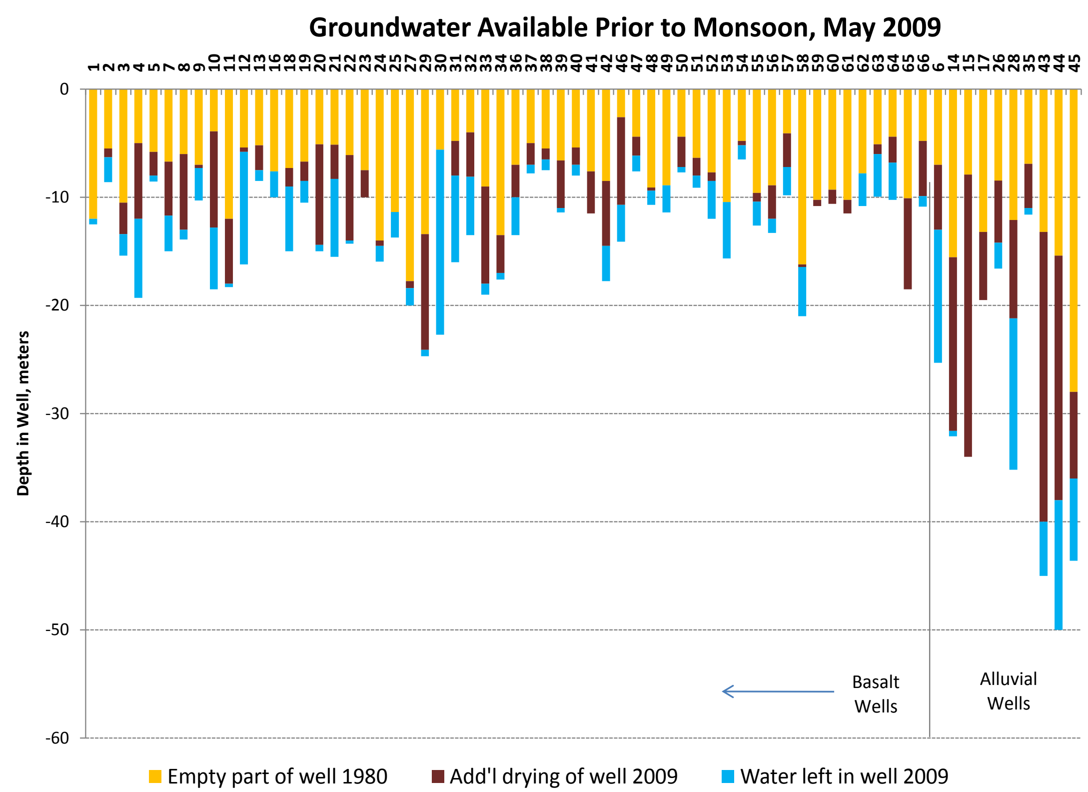


Figure 5-6. Pre-Monsoon Water Levels Showing Declines from 1980 to 2009

(Data Source: Groundwater Surveys and Development Agency, Government of Maharashtra)

The overlay in Figure 5-7 indicates the severity of water level declines in each monitoring well, color coded according to the degree of decline. Two patterns are evident: 1) the greatest declines (red dots) have occurred in the alluvial wells along the Tapi River; and 2) the eastern half of Jalgaon District has experienced widespread declines of 2-10 meters. However, little correlation with rainfall levels can be seen, indicating that the water level decline is related to water extraction rather than rainfall distribution.

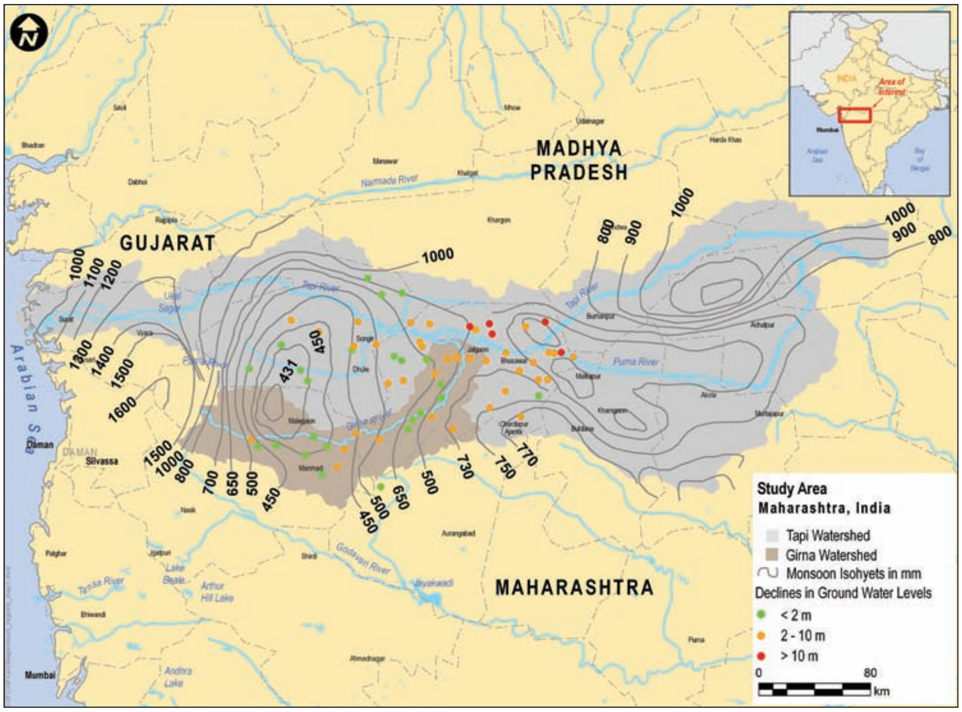


Figure 5-7. Rainfall Pattern and Declines in Water Table from 1980 – 2009

(Data Source: Groundwater Surveys and Development Agency, Government of Maharashtra)

STEP 4:
Determine the associated secondary impacts

Method

This step helps a company understand whether any ecological, social, or economic impacts exist, or are likely to develop, in each area of influence to be examined. These impacts are referred to as "secondary impacts" that stem from changes in water quantity or quality.

It can be very difficult, and in many cases impossible, to ascertain or distinguish which secondary impacts are being caused by a company's own primary impacts on water quantity and quality. In most settings, an individual company's primary impacts are mixed with the impacts of all other water and land users in the watershed. Therefore, it is most sensible to evaluate the secondary impacts resulting from cumulative primary impacts in the area of influence, and then assess what proportion of those primary impacts can be attributed to the company. When impact is assessed in this manner for each area of influence affected by the company's use of water, the company will be able to develop effective response strategies.

Application to the Tapi River Basin

A full social and ecological impact assessment of water consumption in the Tapi River Basin was beyond the scope of this study. As mentioned previously, ecological impacts associated with onion farming are assumed to be inconsequential in this area due to the fact that predominantly ground-water is used for irrigation.

Anecdotal evidence and comments by other analysts provide insight into the social impacts of groundwater consumption in this area. These impacts affect virtually all farmers in the Tapi River basin, not just the onion farmers supplying JISL. For these farmers, water sustainability is of vital importance; a reliable water supply can make the difference between poverty and a more prosperous livelihood.

Many observers have commented on the numerous social disruptions caused by water scarcity in Maharashtra. "There are few 'winners' when [groundwater] exploitation becomes uncontrolled and excessive" states Foster, et al. (2007), and:

- Groundwater declines have financial implications for farmers that have to use more electricity to pump water from deeper levels and/or deepen their wells.
- Groundwater overdraft impacts the poorer farmers first, often putting them in the precarious position of having to purchase water from richer farmers with deeper bore wells or forcing them out-of-business completely. Many migrate to cities in search of other sources of income.
- Even the more prosperous farmers may find themselves having to negotiate larger and larger bank loans in their efforts to deepen water wells to "chase the declining water-table," while simultaneously facing decreased water security and crop yields.

STEP 5:
Attribution of impacts

Method

After a company has assessed the primary and secondary impacts in its area of influence, the company will want to know: *What share of these impacts can be attributed to our activities?*

To answer this question, a company can quantify the magnitude of the cumulative primary impacts (for this analysis, the volume of groundwater consumed, or the amount of change that has transpired in groundwater levels), and compare the size of the company's water footprint to the cumulative primary impacts.

Application to JISL's production of MIS and DHO

The water consumption associated with JISL's production of DHO and MIS accounts for approximately 1% of total groundwater draft in the Jalgaon District (Figure 5-8). This is a conservative estimate because the total groundwater draft would be larger for the entire Jalgaon growing region; only data for Jalgaon District were available for this study (Lamsoge, 2009). Although this suggests that JISL's contribution to the groundwater problem is relatively small, the groundwater declines in this area could affect JISL's business sustainability, as well as the well-being of farmers and other users in the watershed. For this reason, a number of water footprint response strategies are explored in the following section.

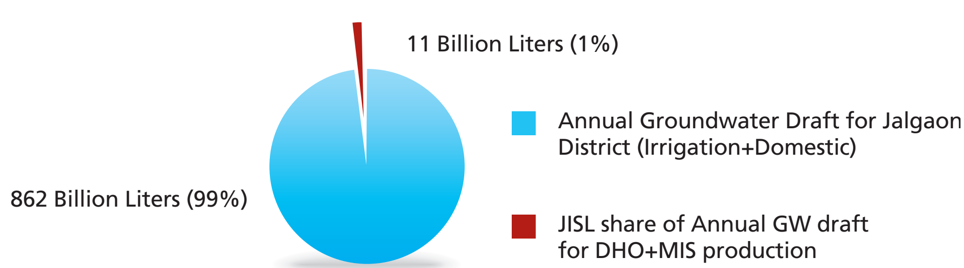


Figure 5-8. JISL's Groundwater Consumption Compared to Annual Groundwater Draft in Jalgaon District

6 RESPONSE STRATEGIES

Water footprint response formulation is the fourth and final step in a water footprint assessment. In this last step, a business can analyze and select measures to reduce water consumption in its operations and supply chain.

As discussed in Section 5, water consumed by JISL for MIS and onion production accounts for only 1% of all water withdrawals in the Jalgaon District. In light of this finding, one may well ask, *Why should JISL adopt water footprint response strategies?*

The answers to this question can be found in JISL's corporate philosophy, "Leave this world better than you found it," and in the company's business interests.

JISL has a very strong corporate commitment to leadership on social responsibility and environmental concerns. This is perhaps best characterized by JISL's transformation, over thirteen years (1995-2008), of dry and barren lands in Jalgaon into fertile land supporting agriculture for over 2,000 families and providing habitat for local flora and fauna (JISL, 2009). Implementing water footprint response strategies is a logical extension of JISL's corporate philosophy of positive change through water management.

From a business perspective, well-designed response strategies that directly address the impacts discussed in Section 5 can help local onion farmers increase their resilience to changes in rainfall and weather patterns, work toward alleviating groundwater overdraft, and ensure a more reliable onion crop as input to JISL's production of dehydrated onions.

The water footprint of onions is relatively small compared to other crops grown in the Jalgaon District, such as bananas or cotton. In the 2005-2006 growing season, less than 0.3 percent of the total area of crop cultivation in the Jalgaon District was under contract farming for JISL's onions, as discussed in Section 5. However, groundwater overdraft appears to be occurring throughout the onion growing region, suggesting that design and implementation of response strategies will likely be required at multiple scales, ranging from individual onion farms to regional water policy initiatives.

The response strategies designed for the Jalgaon District will also be applicable elsewhere in India, and beyond. Drip irrigation was highlighted in as a key vector to addressing the projected deficit between supply and water requirements in 2030 in India in the recent report, *Charting our Water Future* (2030 Water Resources Group, 2009). A water availability cost curve for India includes several agricultural water productivity measures as least cost measures that can increase "crop per drop" through a mix of improved efficiency of water application and crop yield enhancement. Given JISL's unique role as equipment supplier and education provider for farmers, the design and implementation of response strategies in the Jalgaon growing region will enable JISL to gain valuable experience that will help it grow its business elsewhere.

6.1 SUMMARY OF RESULTS

The response strategies formulated for JISL include four different and complementary approaches to alleviating water scarcity and improving the sustainability of water use in the Jalgaon District:

- Through supporting **increased use of drip irrigation by existing onion farmers**, JISL can help these farmers reduce their water consumption and thereby alleviate local groundwater overdraft.

- Looking more broadly at agriculture in Jalgaon growing region JISL can also support the government's push for **new**, **less water-intensive cropping strategies**, which will reduce overall groundwater consumption.
- On the supply side, JISL can increase the amount of groundwater available by **encouraging rainwater harvesting and aquifer recharge projects**.
- Ultimately, water resource management must be addressed not just by one company, but by all the water users in the Tapi River Basin. JISL is considering supporting or establishing a **Tapi River Basin Water User's Dialogue**, through which representatives of local water stakeholders (including business, government, and NGOs) could work together toward sustainable water resource management.

These approaches address both water demand and water supply. They telescope out from very local applications (for local onion suppliers in Jalgaon) to applications that can make an impact on a regional level (cropping strategies, rainwater harvesting and aquifer recharge, water dialogues). Additionally, JISL's water footprint response strategies provide a strong foundation for resilience in the face of climate change, and for sustainably meeting the growing global demand for food. As such, these approaches are of global importance as examples of a significant corporate response to agricultural water scarcity.

6.2 OVERVIEW OF RESPONSE STRATEGIES

For JISL, as with most businesses, the supply-chain water footprint is much larger than the operational water footprint. The response measures will also benefit JISL's operations which rely on groundwater in the Jalgaon growing region.

To be successful, the response strategies selected will need to show strong positive benefits to three groups. Farmers need to benefit, or they won't adopt the proposed measures. The measures need to be in JISL's business interest. Most importantly, the measures need to have clear positive benefits to society as whole, including both social benefits (job creation) and environmental benefits.

Successful implementation of the response strategies described here will also require that farmers, business interests, and governmental representatives understand that the present use of groundwater in the Jalgaon District is clearly unsustainable (see Section 5), placing livelihoods and businesses at risk. A shared vision of prosperity over the long term will need to drive implementation of these response strategies.

6.3 PROPOSED RESPONSE STRATEGIES

Increase onion suppliers' adoption of drip irrigation

The first response strategy is designed to help JISL's onion suppliers reduce their water consumption, by increasing their adoption of drip irrigation.

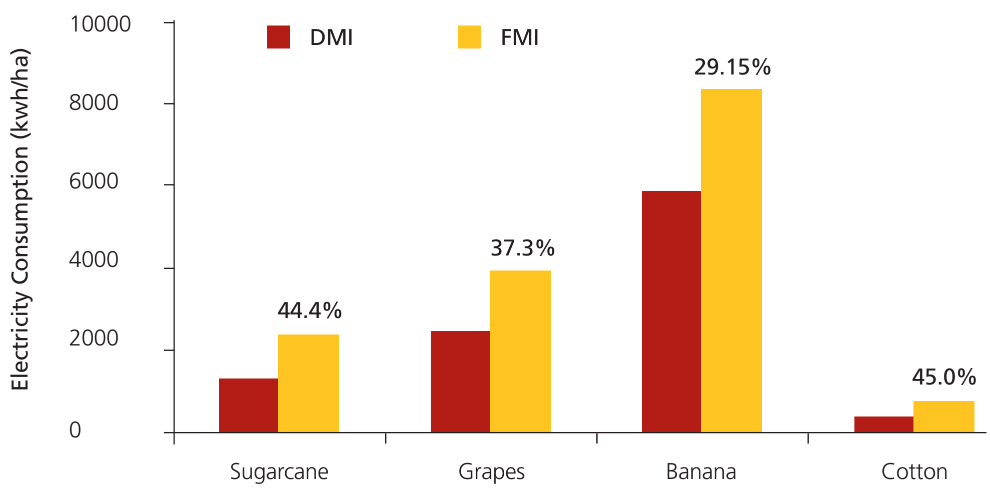
In recent years, Indian citizens have become increasingly aware of the urgency of responding to water scarcity. The government has put in place a series of measures to encourage the use of drip and sprinkler irrigation as a means for addressing this situation. JISL has been supporting the government's efforts through the extensive and well-respected training programs the company provides for farmers, bankers, and the public sector.

JISL has entered into contract farming for onion growing in the Jalgaon growing region since 2001, and promoted the use of MIS for white onions. This has increased the use of drip irrigation to about 18% of JISL's onion suppliers, and sprinkler irrigation is used by approximately 22% of JISL's onion suppliers. Onions grown through contract farming are currently contributing 45-50% of the total raw material input for dehydrated onion production.

JISL will continue to support increased use of irrigation by its onion suppliers. JISL's contract farming team is targeting a conversion from flood irrigation to MIS for contract farming at an annual rate of 15 to 20% (for the 60% of contract farmers who are currently using flood irrigation). These targets do not include the onions that JISL purchases from the open market to manage supply and demand fluctuations, but separate efforts can be made to increase the use of drip irrigation in other markets. JISL also recognizes that some very small farmers cannot afford the investment required to convert to an MIS system.

This expansion of MIS will save not only water but it will result in significant energy savings associated with the electricity required to pump water from the aquifer. Narayanamoorthy (2010b) estimated the electricity savings for different crops in India, and found that electricity savings can range from approximately 30% to 45%, as shown in Figure 6-1. The orange bars show the electricity consumption under the flood method of irrigation (FMI) and the red bars show electricity consumption under the drip method of irrigation (DMI).

Figure 6-1. Savings in Electricity Consumption: Drip vs. Flood Irrigation



Source: Narayanamoorthy (2010b)

To be successful in addressing water scarcity and alleviating groundwater overdraft, the implementation of drip irrigation must be acutely focused on reducing *net water consumption.* In the case of the Tapi River Basin, most crops that utilize irrigation resources use flood irrigation and therefore a shift from flood to drip would reduce net water consumption. However, if farmers were to utilize drip on currently unproductive land, there is a risk that expanded use of drip irrigation could lead to an overall increase in water consumption. There is no question that drip irrigation increases crop per drop, making farming more productive and profitable. However, this usually leads to the production of more crop volume per unit of land, which can result in a net increase in water consumption of water on the same area of land (Molden, et al., 2010; Foster, et al., 2010; Ward et al, 2008). Additionally, farmers who have access to additional arable land that could not be practically irrigated through other means (flood irrigation) are likely to use drip irrigation to increase the area under cultivation, thereby further increasing water consumption. Therefore, to improve the water scarcity issues in the region, the focus first needs to be on converting existing flood irrigation practices to drip irrigation, while at the same time monitoring any increases in converting non-productive land to productive land via drip. These considerations need to be accounted for any plan that involves using drip irrigation to address water scarcity.

Support the adoption of new cropping strategies

This second response strategy looks beyond water consumption in JISL's supply chain, and addresses more broadly the increasing demand for water in the Jalgaon District.

As part of its response to water scarcity in this region, the national government is putting in place incentives to support the planting of drought-tolerant crops of national importance whose water requirements are relatively low, such as pulses and oilseeds. Typically, these crops are grown during the Kharif season to take advantage of the rainy season. However, towards the end of the growing season, the crops can be vulnerable to drought. Farmers are therefore understandably reluctant to switch to growing pulses if the growing seasons' revenue can be compromised by drought.

Drip irrigation can serve as a drought-proofing agent by providing "protective irrigation" which can play an important role in guaranteeing the survival of these vital crops. Protective irrigation involves using irrigation only when necessary to protect a crop when rainfall is insufficient. This gap-filling approach minimizes the use of blue water sources while providing farmers with the necessary flexibility to ensure reliable crop production.

Currently, relatively few farmers are aware of protective irrigation technologies and practices, and of their benefits. JISL, through its training programs, will provide this information to farmers, bankers, and government officials. As a result, farmers will be more likely to switch to pulses and oilseed crops, and agricultural water consumption per unit of land cultivated will decrease.

Encourage water harvesting and aquifer recharge projects

Whereas the first two response strategies addressed the demand for water from JISL's onion suppliers and from other farmers in the Jalgaon growing region, the third response strategy helps increase the supply of water for farms, through rainwater harvesting initiatives. JISL's role in the first two response strategies is that of trainer and equipment provider. In the third strategy, JISL also has the role of design and construction manager.

JISL has undertaken several large-scale water harvesting projects on its own lands and elsewhere. Water used for food processing is drawn from an aquifer that is replenished by a large-scale rainwater harvesting system that captures and stores rainwater during the monsoon season for use during the dry season system (JISL, 2003). A similar approach is used at other JISL locations. Water harvesting can currently provide 10.5% of the annual water withdrawal for the Plastic Park, with an ultimate target of 23% of annual water withdrawal (88 million liters).

JISL has also provided technical know-how (often on a pro-bono basis) and equipment for third-party water harvesting/aquifer recharge initiatives. These are best exemplified by the Village Development Program with National Bank for Agriculture and Rural Development (NABARD), and by JISL's rainwater harvesting project for aquifer recharge at Hindustan Beverages in Wada, Maharashtra.

Village Development Program with National Bank for Agriculture and Rural Development (NABARD)

JISL has a long history of support to farming communities through sustained efforts to provide them with appropriate technology and training on water management, high-tech agricultural practices, and tissue culture plants. JISL recently signed a Memorandum of Understanding with the National Bank for Agriculture and Rural Development (NABARD) to provide support to the Village Development Program. During the current phase, JISL is providing technical advice and training based on practical experience, in partnership with NABARD, local NGOs, and government institutions. JISL is currently training 40 farmers in each of 25 villages on the practical aspects of micro-irrigation systems and farm management.

Specific activities are focused on the needs of the farmers identified through visits and discussions with representative from the communities, local non-governmental organizations (NGOs), and NABARD. JISL is providing training on methods to conserve soil and water including nala bunds (embayment or dike that acts like a percolation tank), farm ponds, recharging of wells, desilting existing ponds, contour bunding, contour trenching, and other measures. JISL is also promoting judicious use of the existing water sources through the use of modern irrigation conveyance and micro-irrigation systems, use of high-tech agriculture, crop rotation, contract farming, and cultivation of vegetable crops under shade nets. JISL is also supporting the introduction of solar and biogas technologies.

Rainwater Harvesting for Aquifer Recharge at Hindustan Beverages: Wada, Maharashtra

JISL provided technical guidance to a beverage facility that was interested in implementing on-site rainwater harvesting techniques for aquifer recharge. After careful study of topographical and hydrogeological conditions, several measures were implemented to capture rainwater and recharge the aquifer. Technologies include a rooftop rainwater harvesting system with underground storage tank used for aquifer recharge, a percolation tank that stores water flowing out from a stream that flows through the premises, a percolation canal that connects and artificially recharges the borewells to increase yields, contour trenches to reduce runoff velocity and increase soil moisture on the property. Approximately 84 million liters of water are harvested per year through these measures. The plant has become a model for neighboring industries and farmers who are interested in implementing similar techniques.

Tapi River Basin Water Users' Dialogue

The last response strategy recognizes that there is a limit to what any single business can do on its own to address water scarcity, and proposes a Tapi River Basin User's Dialogue as a means to engage with other water users.

Thought leaders in the area of corporate response to water scarcity have pointed out that the process of identifying government and corporate risk around water, and then understanding shared risk may enable both parties to find common ground (possibly with civil society) in the very real need to manage water effectively, equitably, efficiently and sustainably (Pegram et al., 2009).

JISL will explore possibilities for setting up a Tapi River Basin Water Users Dialogue. The Dialogue would bring together government, business, and NGOs. Its goal remains to be defined, but the effort would relate to developing a water resource management plan that supports sustainable livelihoods within the river basin.

A possible first step for the Users Dialogue would be to conduct an overall water footprint assessment for the Tapi River Basin. The Water Footprint Network, of which JISL and IFC are both members, is developing a "Water Footprint Assessment Tool" to support water footprint assessments of various types, including assessments at the river basin scale.[2] Importantly, this tool will make it simple to examine alternate scenarios of crop production within a river basin, enabling the evaluation of potential changes in water consumption associated with different scenarios.

Synthesis: climate change resilience, increased food security, and social welfare

JISL's water footprint response strategy provides a strong foundation for increasing farm resilience in the face of climate change, for sustainably meeting the growing global demand for food, and for social welfare.

While it is not yet possible to predict specific local impacts of climate change on hydrology, the recent International Panel on Climate Change (IPCC) presented some general projections for India in its Technical Paper on Climate Change and Water (Bates et al, 2008). The per capita availability of freshwater in India is expected to drop from around 1,820 m^3 (2006) to below 1,000 m^3 by 2025, in response to the combined effects of population growth and climate change. More intense rain and more frequent flash floods during the monsoon would result in a higher proportion of runoff and a reduction in the proportion of rainfall infiltrating into groundwater aquifers. More generally, increases in the frequency of droughts and floods will have a negative effect on local agricultural production.

The response strategies described above can be expected to help JISL build resilience to the impacts of climate change on water availability. The IPCC's list of water-related adaptation options includes expansion of rain-water storage and reduction in water demand for irrigation by changing the cropping calendar, crop mix, irrigation method, and area planted (Bates, et al., 2008); these echo JISL's first three response strategies. The fourth response strategy (dialogues) is also supported by the IPCC, which points out that joint solutions can help address competition for water resources (Bates, et al., 2008).

JISL's strategies are also consistent with recommendations from the Comprehensive Assessment of Water Management in Agriculture, published by International Water Management Institute (IWMI, 2007). The Comprehensive Assessment recommends policies that can ensure that there will be enough water to grow the food we need. Highlights of these policies include the role of rainwater storage, of getting more value per unit of water, and of dialogue between government, civil society, and the private sector, each of which are addressed in JISL's response strategies.

As noted previously, the strategies proposed have several benefits for the smallholder farmers concerned. They increase profit, and they increase crop security, making the farmer less vulnerable to catastrophic crop failure during a drought. These benefits have a profound impact on farmer families, who are usually very poor. Extra revenues allow them to send their children to school, and crop security can stem the tide of migration from farms to urban areas.

The implications of JISL's water footprint response strategies for climate resilience, food security, and social welfare illustrate the strong positive outcome that can result from a water footprint assessment. The scoping (Step 1) allows a company to define the questions it wishes to address. The inventory of volumes of water consumed in operations and in the supply chain (Step 2) helps the company better understand its water usage. It also guides the sustainability assessment (Step 3), which provides insight into vulnerability and impacts linked to corporate water consumption. Formulating response strategies (Step 4) empowers the company to take effective measures to address water scarcity.

[2] A water footprint assessment can be conducted for a product, such as dehydrated onions, but also for an individual, city, region, or country.

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