PORTFOLIO RESEARCH

WATER-RELATED RISKS AND CHALLENGES

A QUANTITATIVE RESEARCH PERSPECTIVE

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Executive Summary

This report sheds light on the growing effects of water scarcity on companies and countries. To address these challenges, investors can use water reporting metrics to identify companies and countries with severe water risk. We further present related water metrics to firm and country characteristics and highlight substantial cross-sectional differences. Our study encourages investors to incorporate water metrics and indicators when constructing their portfolios.

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Key Insights

- Along with flooding and water quality, water scarcity is one of the main water-related challenges of the 21st century. For most of the world's population, Water Stress[2] **has risen considerably over the period 2002-2017** and is projected to continue to rise.
- Worldwide, **from 2002 to 2017, water stress increased by 13%**. Over the same period, Water Withdrawals **increased by 4.9%**, with the agricultural and municipal sectors increasing, respectively, by 15% and 13%. This surge in demand further aggravates the uncertainty of water availability.
- By 2030, about 16 countries are expected to be withdrawing unsustainably from non-replenishable aquifers and surface-level water sources at a national level.
- **Sustainalytics' water metrics**, i.e., water withdrawal, Water Consumption, and Water Intensity, are **tools to gauge the risks related to companies' water use.**
- Only one of ten companies reports information on water usage. Sustainalytics has developed a **proprietary model to predict water metrics for non-reporting companies** and hence, provides our clients with a more comprehensive coverage of water-related risks.
- Our firm-level analysis shows that firms with **high water intensity** display **high ESG risk, high** Return, **high** Standard Deviation of returns, and **high** Downside Deviation of returns. Water intensity, however, **weakly relates to risk-adjusted return**.
- Our country-level analysis reveals that **water stress is inversely related to** Water Use Efficiency and is higher in countries with large populations, a high percentage of irrigated cultivated land, high water withdrawal per capita, and high development indicators.
- **Water efficiency is high** in countries with **small populations**, a low Percentage of Cultivated Land Irrigated, low Total Water Withdrawal per Capita, and **high development indicators.**
- We examine two **country case studies**, **South Africa** and **India**, to illustrate how increased water stress has far-reaching implications for all aspects of society.
- Investors can use water metrics to identify firms with low water intensity and countries with low water stress. Our results show that **reducing exposure to water stress** will go hand in hand with **reducing ESG risk exposure and information asymmetry**.

Introduction

Building a Case for Water Metric Reporting

The importance of water scarcity for economy development

The past two decades have seen a surge in interest in environmental issues, mainly climate change, global warming, and fossil fuels. Yet, another equally important dimension - water scarcity - has thus far remained largely unexamined and is not given adequate importance in the economic development agendas of many countries. Water scarcity is a prominent concern for billions of people worldwide and has a significant impact at the firm and country levels. Water scarcity is also an important type of physical water risk that portfolio managers and investors should consider when building investment strategies. To address this gap, Sustainalytics suggests reviewing water reporting metrics on individual companies. These metrics offer a useful monitoring tool for firm executives, policymakers, governments, institutional and retail investors.

This paper examines the current state of the global water situation and investigates its effects on investment decisions. We further showcase how interested parties can use the newly suggested metrics to set up policies for monitoring water usage and preventing water-related risks.

Sustainalytics' model to predict water metrics for non-reporting companies

Despite the rising importance of water-related risks, reporting on water metrics remains a major challenge. Only one of ten companies reports some information on its water usage. To address this issue, Sustainalytics has developed a proprietary model to predict water metrics for non-reporting companies and hence, offers a more comprehensive coverage of water-related risks.

We expect the number of reporting companies to grow in the future due to increased awareness and the adoption of ESG-aligned reporting frameworks. By reporting on water metrics, companies demonstrate more transparent practices in their water management and reduce information asymmetry. Lastly, with more publicly disclosed information, a company can also attract more investors that may have been reluctant due to the water risk exposure uncertainty.

Next, we conducted an empirical analysis to identify companies that are more at risk of water scarcity and those that are better equipped to circumvent this risk. We find clear evidence that water intensity correlates positively with ESG risk and return standard deviation. There is, however, only weak evidence that water intensity is related to risk-adjusted return, as the correlation is equal to only 1%.

Country-level analysis and two country case studies

We also performed an analysis to identify characteristics of countries that are more at risk of water stress and those that are more efficient in their water use. We find that water stress is inversely related to water use efficiency, and is higher in countries with large populations, a high percentage of irrigated cultivated land, high water withdrawal per capita, and high development indicators.

Lastly, we examined two country case studies, South Africa and India, to illustrate how increased water stress is an important challenge and has far-reaching implications for all aspects of society.

Water – An Increasing Operational Risk

The 20th century was the era of cheap, safe, reliable water supply

Although water plays a vital role in the production and availability of almost all our products and services, many consumers understate its contribution to our daily lives. Indeed, in the 21st century, water has been, most of the time, an abundant, cheap, and safe resource in developed countries.[3]

Water crises make up 9/10 of the worst global risks

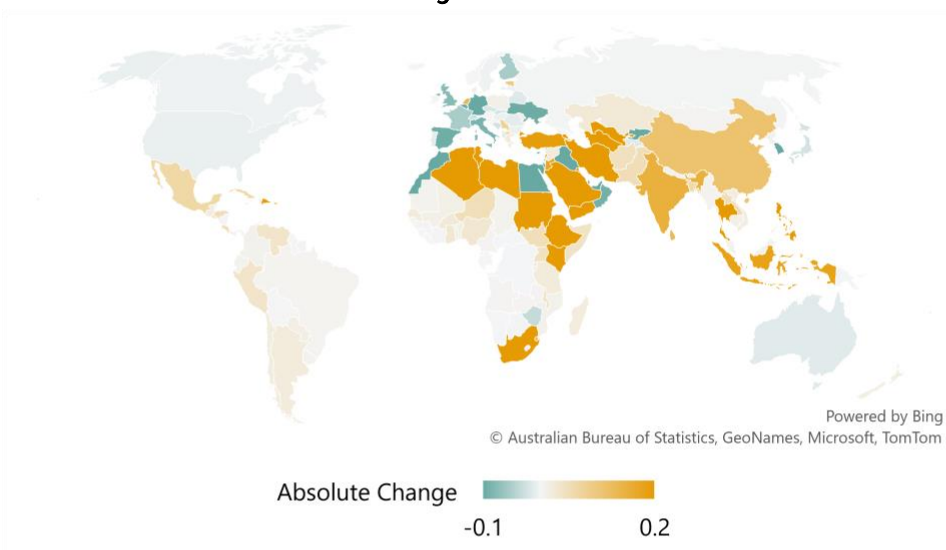
Nevertheless, in most regions of the world, especially those with large populations, both the availability and quality of freshwater are deteriorating (see Exhibit 1). Society contends with over-extraction, poor management of resources, and the continuing loss of wetlands that are directly responsible for biodiversity loss.[4] As a result of human exploitation and mismanagement of water resources, local, regional, and global water use limits are already being exceeded.[5] The importance of water is further highlighted in the Global Risk Report published by the World Economic Forum (WEF) and in which water-related risks represent nine of the top ten worst global risks[6].

A resource not equitably shared yet recognized as a human right

In 2010, the U.N. General Assembly and the Human Rights Council recognized the human right to safe drinking water as part of binding international law[7]. However, in many places, multiple factors such as population growth, socio-economic development, and changing consumption patterns, coupled with inadequate and underfinanced infrastructure, weak governance, and corporate over-use, means the right to water fails to be upheld for many[8]. This imbalance exacerbates poverty, hunger, social exclusion, and poor health for individuals and households, predominantly in rural areas.

Water stress is increasing, for most of the world's population

Exhibit 1: Forecasted Absolute Change in Water Stress - 2002 to 2030



*2002 to 2017 and water withdrawals based on Aquastat data, with forward demand forecasts based on IFPRI Agriculture growth, IMF country GDP forecasts, ourworldindata.org Population Growth.[9]

Source: Aquastat, IFPRI, IMF, ourworldindata.org

Water stress, even without climate change, is becoming more strained

Exhibit 1 depicts forecasts by country of the change in water stress, showing that water stress has continued to worsen worldwide, especially in developing countries. These forecasts may understate the future levels of water stress as they do not consider the additional effects of climate change on renewable water supply.

Further caveats that point to these forecasts of water stress in Exhibit 1 being conservative include irregular and infrequent reporting from countries and straight-lining forecast estimates of withdrawal demand in the source data. Not to mention, larger countries by geographical area may not tell the whole story at the country map level, with regions with increasing water stress offset by other regions with improvements.

Water is a significant input or requirement to all businesses

For companies in many sectors, water is a material input in the production chain and creates a substantial cost increase if the supply chain is disrupted. Water concerns include access to water supplies, operational efficiencies, investor confidence, and consumer perceptions, among other business risks.

The price of water does not reflect the actual value of water

The financial risks related to water scarcity could materialize in terms of increased operational, insurance, and financing costs. The price paid by many different user groups does not reflect the actual value of water. In most cases, the price paid is below the actual cost of water use.[10] It is improbable that the status quo of overly subsidized water costs can persist due to dwindling supplies, increasing demand, and increasing social pressure. Determining a fair price for water is, however, no easy task.

Furthermore, the unstable and unpredictable supply of water can result in production disruption that could impact **Revenues**. Ultimately, adequate water resources management is necessary to reduce business risk, maintain a social license to operate, build long-term access to water, and ensure business continuity and encourage investment.

Sustainalytics Water Metrics

Using different metrics to assess reliance on water

Water metrics are a valuable tool for managers and policymakers to monitor the water-related risks that companies and industries face. One can consider the water withdrawal, water consumption, and water intensity metrics as the key 'starter' metrics to gauge a company's reliance on water.

Limited disclosure on water metrics necessitates the use of prediction models.

Thus far, only a small fraction of companies reports on water withdrawal or water consumption. In fact, only 9.4% (1,041 out of 11,076) of the companies Sustainalytics covers for these metrics report on at least one of the metrics in the 2019 data set. However, we expect this fraction to increase significantly in the foreseeable future due to increased awareness about water-related risks and the adoption of ESG-aligned reporting frameworks.

Filling the gaps in reported water data with predicted values to create more comprehensive water coverage

To address the issue of limited disclosure, Sustainalytics developed a proprietary multi-factor regression model to predict water withdrawal and water consumption for companies that do not yet report such data. The model is based on size-related factors, including revenues, Number of Employees, and Plant, Property & Equipment (PP&E), combined with industry- and country-specific factors (see Exhibit 13 on page 22).

Models can explain the water withdrawal and water consumption relatively well, with an R-squared of 79.8% and 84.0%, respectively

The limited geographic information, coupled with a lack of standardized data across regions and industries, pushed Sustainalytics to adopt a more consistent and generalized approach. Our solution being a multi-factor regression model, which produces an R-squared of 79.8% for water withdrawal and 84.0% for water consumption. These high R-squared values support the approach's relevance, especially given the nature of environmental data and state of water reporting.

Exhibit 2 showcases the percentage of companies with a water-related news incident over the past decade. We distinguish between reporting and non-reporting companies and find that companies that report on water metrics registered more water-specific incidents in the past decade. One explanation is that water-related risk is more material for reporting companies, and hence, these companies are more likely to report it. Yet, another possibility is that it is easier to infer information regarding water incidents for reporting companies and hence, media has a higher uptake on the issue.

Those that report their water intake and use are more likely to have experienced controversy around water use

Exhibit 2: Percentage of Companies with Reported News Incidents

	Large	Medium	Small	Total
Non Reporting Companies	17.6%	4.6%	2.0%	4.4%
Reporting Companies	29.7%	12.2%	8.5%	17.2%

N=10,965 **Source**: Sustainalytics[11]

Interestingly, large firms that report on water metrics are the most likely combination to have historically had an incident surrounding water and 3.5x more likely to have experienced an incident surrounding water than a small company reporting on water metrics.

Water Withdrawal

Water withdrawal includes company usage in all production and service provision

Water withdrawal is the total volume of water withdrawn or diverted by the entity company as required to meet all aspects of production and provisions of services, regardless of whether it was consumed or returned to its source. It can be sourced from surface water (including rivers, lakes, or rainwater), groundwater (aquifers), third-party water supplies (i.e., municipal water supplies), and seawater. Sustainalytics collects water data as reported by companies. Besides converting reported data into a standard unit of measurement (cubic meters), no further data manipulations are made.

The amount of water withdrawal is always equal to or greater than the value of water consumption. It does not include the amount of water used within supply chains.

Water Consumption

Water consumption signals water removed from the local water cycle

Water consumption is the total volume of water withdrawn and consumed for its own purposes, and which is not returned to the same source nor considered useable by others. While companies can use various units to report their water consumption, Sustainalytics reports the data in cubic meters (m^3). The metric is as per reporting, and there is no calculation behind the metric.

Consumption means that this water remains permanently within the boundaries of a company including the water that is locked into the final product. This also includes water that is used for crop production, consumed by employees and livestock, and the water used for operational purposes. Additionally, it includes water that evaporates and transpires throughout production. The water consumed is removed from the local water cycle and is thus no longer available to the ecosystem and other water users, including local communities and businesses.

Water Intensity

Water intensity offers insights into a company's relative water dependency

Water intensity is calculated as the volume of water withdrawal (cubic meters) per revenue unit in millions of U.S. dollars. The higher the metric, the more dependent that company is in using large water withdrawals for its operational model to achieve its expected output. In comparison to water withdrawal and water consumption, water intensity does not necessarily relate to **Market Capitalization** which is why we included it later in our firm-level analysis.

Estimated Growth in Water Withdrawal Demand

Part of the gap has closed, but deficits remain to this day

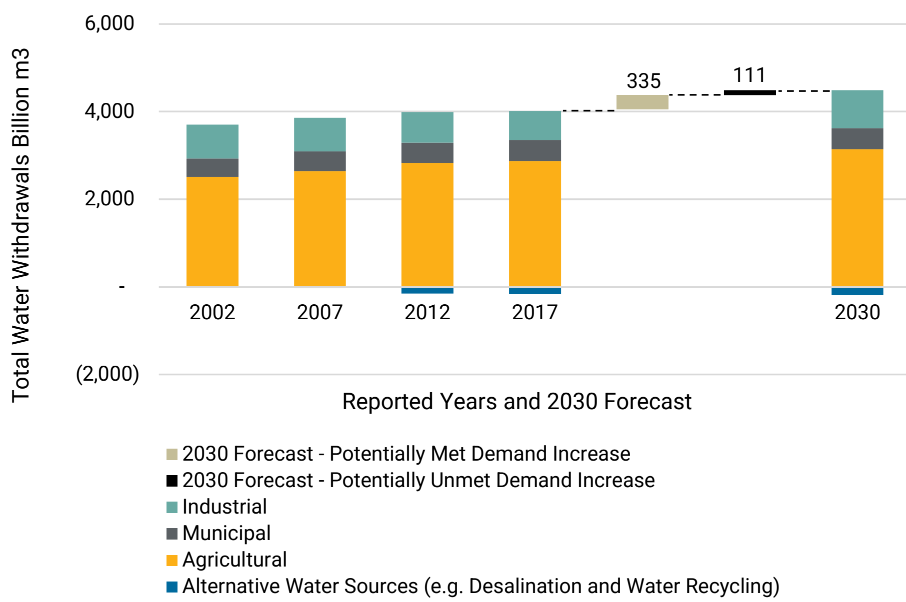
In 2009, the 2030 Water Resources Group released a study that forecasted the aggregated global gap between existing supply and water withdrawals by 2030. Assuming no efficiency gains, the water gap would be 2,700 billion cubic meters of water or 40%[12].

Fast forward to 2017, and many countries have made efficiency gains to reduce their water withdrawals. However, other countries still run a water deficit even to this day, withdrawing from non-renewable resources.

Exhibit 3 highlights freshwater withdrawals by relevant sectors over time. Freshwater withdrawal demand for 2030 is forecasted using 2017 Aquastat data as a starting point for each sector. GDP growth, population growth, and agriculture output are used to estimate the industry, municipal and agricultural demands. Annual growth is offset by 1% efficiency gains in industry and agriculture[13] and by 0.5% for the municipal sector.

One quarter of the demand increase expected will not be sustainable at the national level

Exhibit 3: Estimated Total Global Water Withdrawals and 2030 Projection



*2002 to 2017 and water withdrawals for Industrial, Municipal and Agricultural, based on Aquastat data, with forward demand forecasts based on IFPRI Agriculture growth, IMF country GDP forecasts, ourworldindata.org Population Growth.[14]

Source: Aquastat, IFPRI, IMF, ourworldindata.org

National level reporting has limits

One of the model's limitations used in Exhibit 1 (see page 5) and Exhibit 3 is that it reports aggregated information at the national level and does not provide granular information at the water basin level. This is likely to overlook some variations across regions within the same country. For example, the US may have experienced increased water security on its east coast but deteriorating water security in the west. Consequently, the projected 2030 potentially unmet demand will undoubtedly be much higher at the basin level than at the national level.

Having the proper infrastructure and governance matters

On the other hand, some countries such as Israel and Singapore have high-performing water management programs, highlighted by successful governance, innovation, and capital investment policies.

A key missing factor that generates variability

Another limitation is that the 2030 Water Resources Group prediction and our forecasts do not account for climate change impacts on **Total Renewable Water Resources**.

Water gaps are predominately within the middle east

Ultimately, we still see a potentially unmet demand of 111 billion cubic meters for 2030 using national reporting, with about 16 reporting countries projected to be withdrawing unsustainably from non-replenishable aquifers and surface-level water sources needed to support environmental requirements (see Exhibit 3)[15]. These are usually those countries exceeding SDG 6.4.2. Water Stress of 100%.

Industrial Sector is a Bright Spot for Progress

Industrial water withdrawals have declined globally

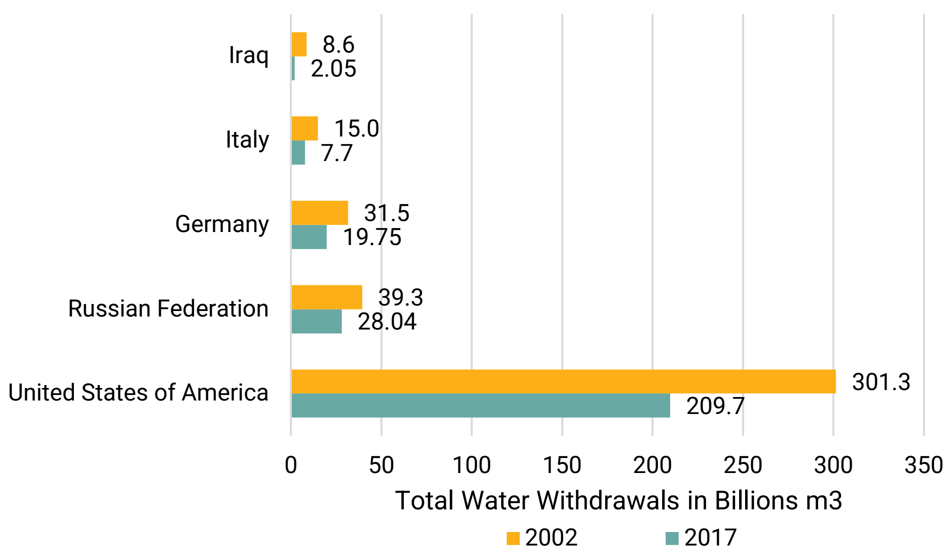
From 2002 to 2017, one of the bright spots in water withdrawals is that the industrial sector water withdrawals declined by 14%, whereas Agricultural and Municipal water withdrawals increased by 15% and 13% across the globe.

Water withdrawal intensity must have improved considerably considering GDP expansion

Between 2002 and 2017, global GDP (in constant 2015 US dollar terms) has grown by 58%, whereas industrial water withdrawals declined by 14%. Consequently, water withdrawal intensity for industrials has improved at 4.0% per year or a 45.7% improvement for this timeframe.

Exhibits 4 and 5 depict countries with the biggest decrease and increase in industrial water consumption, respectively. From an investor's perspective, examining the changes rather than the levels of water withdrawals offers useful insights on future water-related risks.

Exhibit 4: Countries with the Biggest Decrease in Industrial Water Withdrawal



*Note that industrial water withdrawal does not include hydropower. **Source**: Aquastat

Only a few countries are responsible for the major improvement shift

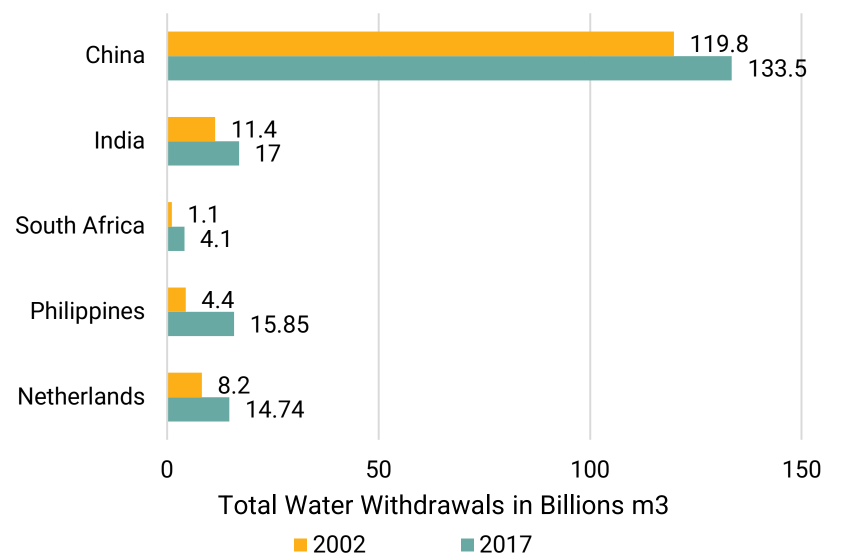
Between 2002 and 2017, the global decrease in water withdrawal of the industrial sector amounted to 112 billion cubic meters, with the US exhibiting a reduction of

92 billion cubic meters. In absolute terms, the United States ranks first with a relative decrease of 30%, followed by Germany down 37% and Russia down 29%.

Enhanced technology in thermoelectric power, wind, and solar have contributed to lower withdrawals

One must also distinguish between the proportion due to outsourcing manufacturing to other nations and improvements in water efficiency. For example, according to one study from the United Nations (UN), the electric utility sector accounted for 89% of the decrease in total water withdrawals from 2010 to 2015 for the United States[16]. Further, economic contraction can play a significant role, as in the case of Iraq.

Exhibit 5: Countries with the Biggest Increase in Industrial Water Withdrawal



*Note that industrial water withdrawal does not include hydropower. **Source**: Aquastat

Increases in industrial water withdrawal appear linked to a fast pace of industrialization

China, India, the Philippines, and South Africa, which all previously experienced fast growth in industrialization, saw growth in water withdrawals of, respectively, 11%, 49%, 258%, and 260%, as shown in Exhibit 5. Interestingly, out of the 5 countries depicted in Exhibit 5, the Netherlands is the only developed country. This increase in industrial water withdrawal may be partly attributed to the substantial growth in the GDP, which almost doubled during the period 2002-2017.

China shows signals of turning things around regarding water management

Worth of mention is that, during that period, China has made considerable investments into water-related infrastructure while maintaining a real GDP growth of 15% (in comparison to 2015). For example, in 2002, water pollution was a serious problem, with only 29.1% of surface water deemed drinkable if treated. By 2017, this improved to 71.8%[17].

Faster paced growth could mean more risk

Robust Economic Growth in Susceptible Water Stressed Regions

China and India's explosive economic growth and water pollution problems resulting from their fast-paced industrialization is a counseling to those companies that operate in regions of the world with strong economic growth and increasing water stress risk.

Within these regions, water-saving strategies will have a more meaningful impact on the ecosystem and society, as a faster pace of change tends to result in governments playing catch-up in building the required infrastructure and monitoring programs.

Putting the Metrics into Practice

Identifying High Impact Industries

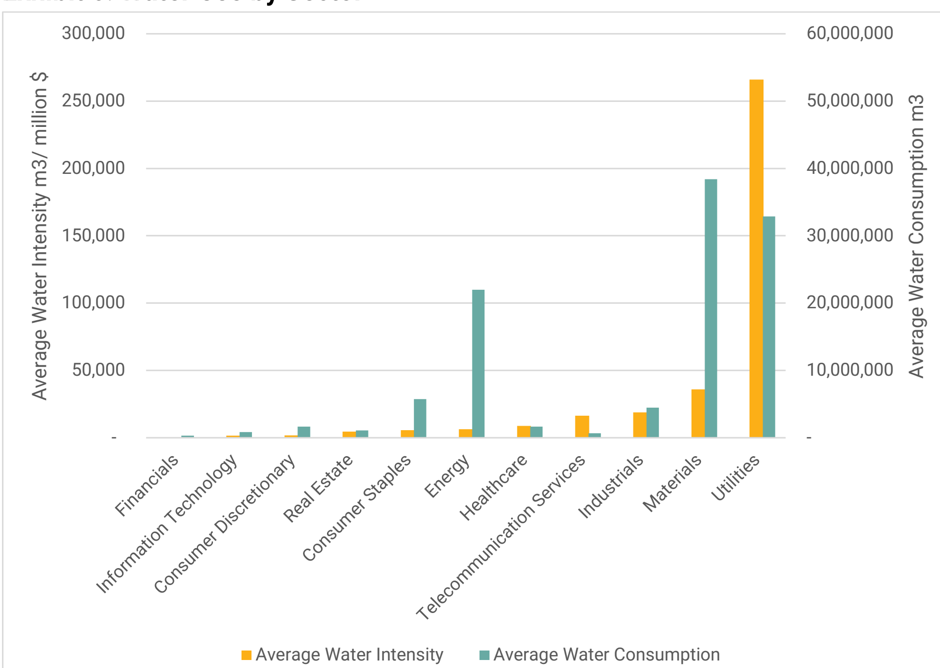
Water consumption, and water intensity are practical metrics to assess industries with high business risk.

Water intensity can approximate potential financial risk. For example, if the company faces increased water input costs, production could become uneconomical, resulting in the closures of facilities and increased unemployment.

Even if licensed for water withdrawal, societal backlash still happens

Water consumption highlights the impact that the company could have on surrounding water systems. In absence of a water sharing agreement or basin planning, if stakeholders consume too much of a share and do not replenish the water system, water scarcity will increase. Heavy water-consuming companies may then be perceived as taking advantage of the resource and causing economic harm to society.

Exhibit 6: Water Use by Sector



*Note that the averages above are inclusive of both estimated and reported numbers.[18] **Source**: Sustainalytics

In Exhibit 6, water intensity and water consumption (in total cubic meters) of sectors are presented. Utilities takes a clear first place for water intensity as water is necessary for many electricity-generating activities, with the Materials and Industrials sectors in second and third, respectively. For water consumption, the Materials sector is the top consumer, driven by high water demanding steel producers and mining companies, with Utilities in second and Energy in third, respectively.

To give context, when compared to the average Utility sector company, the average Financial sector company has water consumption levels of 1/100th and less than 1/1,000th the level in water intensity.

The Energy, Materials, and Utilities sectors are where stakeholders and investors need to assess companies more carefully to determine what water conservation initiatives companies can implement to reduce their water-related risk. In addition to water conservation, companies may also implement water-sharing agreements or basin planning to reduce the uncertainty on their water supply further.

Firm-Level and Country-Level Analyses

Water Metrics, MEIs, and ESG Risk Rating

Water-related metrics contribute to the MEI Resources which itself contributes to the ESG Risk Rating.

An important component of the ESG Risk Rating methodology is the concept of material ESG issues (MEIs). Generally, when constructing an ESG Risk Score, firms are evaluated along different issues (e.g., Business Ethics, Human Capital, Human Rights, Resources, etc.). For each company, only a set of issues that are deemed material are included in the computation. These issues are then called Material ESG Issues (MEIs) as they have the potential to cause a significant impact on the company. Each of these MEIs is itself made of a set of indicators and metrics that captures various dimensions. For example, the MEI "Resources" comprises the following indicators and metrics: Water Intensity, Water Risk Management, Water Intensity Trend, etc. This set of indicators and metrics is also specific to each company and subindustry.

Naturally, all these metrics and indicators directly contribute to their respective MEI and ultimately to the ESG Risk Score. This latter contribution depends on the relative importance of the indicator and MEI for the company or subindustry.

Empirically, we computed the correlation between the Risk Score of the MEI Resource and Water Intensity Weighted Score and found it positive and equal to 27.7%. Next, the correlation between the Risk Score of the MEI Resource and the ESG Risk Score is also strong and positive, 36.4%. Hence, the water-related metrics are an important determinant of the MEI Resources which itself seems to have both direct and indirect impacts on the ESG Risk Score.

Water Intensity and Firm Characteristics

We investigate the determinants of water intensity.

To further improve our understanding of water intensity, we investigate its firm-level determinants using a global sample of 4,914 firms for the year 2020. To examine which firm characteristics relate to water intensity, we include the following variables: **ESG Risk Ratings Score**, return, **Alpha** (i.e., risk-adjusted return), standard deviation, downside deviation, market capitalization, and total revenues. These variables are extracted from Morningstar and Sustainalytics and are further defined in the Appendix.

Exhibit 7: Correlations Between Firm Water Intensity and Firm Characteristics

Firm Variables	Correlations with Water Intensity
Intensity	100%
ESG Risk Ratings Score	27%
Return	10%
Alpha	1%
Standard Deviation	2%
Downside Deviation	5%
Market Cap. (mil)	-16%
Revenue (mil)	-10%

Source: Morningstar, Sustainalytics

ESG Risk and water intensity are positively correlated

Exhibit 7 reports the Spearman correlations between our variables. Of interest are the correlations between water intensity and firm characteristics. Several interesting facts emerge. First, we find that water intensity is strongly and positively correlated with the ESG Risk Ratings score. The high correlation indicates that companies with water intensive business activities face high ESG risks and that water is a systematic factor that has far-reaching implications for companies. Therefore, high-ESG Risk companies may aim to monitor their water-intensity levels and explore ways to ration their water consumption. This decision can be pursued by either optimizing water use or switching to less water-intensive activities. Either way, it seems that reducing water intensity will go hand in hand with reducing ESG risk.

High water intensity accompanies increased returns, but no alpha results

The Markowitz's risk-return framework states that, in theory, more risk should go hand in hand with more return, and hence, the two variables should be positively correlated. Looking at our performance measures, it seems that this is the case, as companies with high water intensity display indeed high returns. Hence, having high-water intensity is perceived as an additional risk and is therefore remunerated by the market. However, once this risk is taken into account using a risk-adjusted performance measure, there is only weak evidence that increased water intensity generates additional value for investors, as evidenced by the weak correlation between water intensity and alpha.

Higher water intensity could indicate a higher downside risk

Worth of mention is that water intensity is mainly an operational risk while the risk metrics we consider, standard deviation and downside risk, are essentially market-based measures of risk. It is interesting to examine such a relationship and see how market players incorporate operational risk in valuing and trading stocks. Our empirical findings show that downside standard deviation and standard deviation are both positively related to water intensity. Hence, higher water intensity is an indication of potentially higher total and downside risks.

Large firms showcase economies of scale in water efficiency

Next, the correlations between water intensity and firm size proxies, i.e. market capitalization and total revenues, are largely negative. Large firms are then better equipped to manage water use or, perhaps, engage in less water-intensive activities. In all cases, a large size allows for better management of water-related risks.

Finally, we estimated Model 1 in which we included all the explanatory variables and found that the R-square is equal to 8%. Hence, the variables chosen showcased significant explanatory power for water intensity. Yet, an even more important portion remains unexplained by firm characteristics, and hence, this adds another layer of uncertainty to water intensity and should therefore be further researched.

Model 1:

$$Water\ Intensity = \beta_0 + \beta_1 * Firm\ Characteristics + \varepsilon$$

Water risk is a non-negligible source of operational risk

Overall, the current section brings a simple message to the investment community. First, water intensity is an important metric that investors and company managers should pay attention to. Second, water intensity is related to several measures of risk, and hence, this lends credence to the idea that water risk is a non-negligible source of operational risk that may have implications on the stock market and the company itself. Third, large firms seem to exhibit lower levels of water intensity and hence, are better equipped to manage water-related risk and possibly are engaged in less water-intensive business activities.

Water Stress, Water Use Efficiency, and Country Characteristics

We now examine the country-level determinants of Water Stress (**SDG Indicator** 6.4.2) and Water Use Efficiency (SDG Indicator 6.4.1) using a global sample of 200 countries for the year 2017. To examine which country characteristics relate to water stress and water use efficiency, we include the following variables: **Total Area**, **Total Population**, percentage of cultivated land irrigated (harvested crop), total water withdrawal per capita, and two indicators of country development, **GDP per Capita** and **Human Development Index (HDI)**. All these variables are further defined in the Appendix and are all collected from Aquastat (see page 23).

Oil-rich nations make up the most water-stressed nations in the world

Exhibit 8 reports the top 5 countries as sorted on their water stress. Unsurprisingly, all of these countries are located in the arid region of the Middle East. Fortunately, these countries have a high GDP per capita and a high HDI and therefore can overcome issues related to water stress. In addition, they may also have enough financial means and knowledge to align with more efficient water-use policies. Nonetheless, the tremendous economic and demographic growth observed in most of these countries may worsen the water stress levels and present an important challenge in the upcoming years. It comes as no surprise that all these countries are currently exploring various ways to desalinate sea water. Lastly, the reported levels of water stress in these countries may only represent the visible tip of the iceberg, as these countries are also big importers of agricultural products with high water footprints.

Exhibit 8: Top 5 Countries Sorted by Water Stress

	Water Stress (%)	Water Use Efficiency (US$/m3)	Total Area (1000 ha)	Total Population (000's)	% of Cultivated Land Irrigated	Total Water Withdrawal per Capita (m3/year)	GDP per Capita (US$/inhab)	Human Development Index (HDI)
Kuwait	3851%	102.4	1,782	4,056	100%	308	28,897	0.8
United Arab Emirates	1708%	92.8	7,102	9,487	67%	421	40,180	0.9
Saudi Arabia	883%	28.3	214,969	33,101	26%	705	20,905	0.9
Libya	817%	3.8	175,954	6,581	20%	886	3,941	0.7
Qatar	432%	191.6	1,149	2,725	66%	335	63,249	0.8

Source: Aquastat

First world European countries make for the most water-efficient nations

Exhibit 9 reports the top 5 countries as sorted on their water use efficiency. Interestingly, all of these countries are located in Europe, and all have a high GDP per capita. Hence, it seems that abundant water and solid financial resources are needed to achieve a high level of water-use efficiency. Furthermore, these countries also have a low percentage of irrigated cultivated land compared to the group of countries with high water stress.

Exhibit 9: Top 5 Countries Sorted by Water Use Efficiency

	Water Stress (%)	Water Use Efficiency (US$/m3)	Total Area (1000 ha)	Total Population (000's)	% of Cultivated Land Irrigated	Total Water Withdrawal per Capita (m3/year)	GDP per Capita (US$/inhab)	Human Development Index (HDI)
Luxembourg	4%	1,221	259	592	0%	77	110,003	0.9
Switzerland	7%	391	4,129	8,456	9%	205	80,221	0.9
Denmark	20%	369	4,093	5,732	10%	129	57,454	0.9
Ireland	4%	350	7,028	4,753	0%	181	70,493	0.9
United Kingdom	14%	320	24,361	66,727	2%	126	40,287	0.9

Source: Aquastat

Exhibit 10 reports the Spearman correlations between our variables. Of interest are the correlations between water stress, water use efficiency, and country characteristics. The first aspect to examine is the sign of the relationship between water stress and water use efficiency. If water stress is mainly driven by a lack of efficiency in water use then a negative relationship is expected between the two variables.

Conversely, water stress may drive water use efficiency, and hence, one would observe that countries with high water stress are those adopting efficient water-use policies. In this case, a positive correlation between water stress and water efficiency may be observed.

Exhibit 10 Correlations Between Water Metrics and Country Characteristics

	Correlations with Water Stress	Correlations with Water Use Efficiency
Water Stress	100%	
Water Use Efficiency	-21%	100%
Total Area of the Country	1%	-25%
Total Population	26%	-23%
% of Cultivated Land Irrigated	60%	-31%
Total Water Withdrawal per Capita	50%	-36%
GDP per Capita	18%	68%
Human Development Index (HDI)	23%	60%

Source: Aquastat

A negative correlation points to a lack of water use efficiency as a material component driving water stress

With a negative correlation of -21%, our empirical results show that water stress and efficiency are moving in opposite directions. This lends credence to our first conjecture, which states that a lack of water use efficiency may have a significant and negative impact on water stress.

The total area of a country does not correlate with water stress

Next, looking at the size of countries, there is stark evidence that large countries in terms of population exhibit high water stress. However, total area seems weakly related to water stress, thereby indicating that both small and large countries alike may face water-stress risk.

Implementation of efficient water use policies is inhibited by the larger total area of a country, and populations

Interestingly, large countries in terms of area struggle with adopting efficient water-use policies. Demographic weight, as captured by total population, seems also to further impede the implementation of efficient water-use policies. Hence, large countries seem to have more abundant water resources, providing fewer incentives to adopt efficient water-use policies.

Countries with high % of cultivated land and water withdrawal per capita have less water use efficiency and greater water stress

Next, we examine indicators that assess the relative importance of water use in a country. Of interest is the proportion of irrigated cultivated lands which traditionally demand much of the water resources of a country, especially those that are semi-arid and arid. Countries with either a high percentage of cultivated land irrigated or high total water withdrawal per capita have high water stress. Because of the intensive use of water, these countries are unable to reach high water-use efficiency. Hence, the correlations between water-use efficiency and the percentage of cultivated land irrigated and total water withdrawal per capita are robust and equal to -31% and -36% respectively.

Higher wealth and human development are highly correlated to water use efficiency

The last measures relate to indicators of development. Developed countries are expected to be more aware of the water stress issue and should have enough financial resources to improve their water use efficiency. The second part of the statement is validated empirically, as the correlations between water use efficiency and development indicators are indeed positive. We find a 68% correlation between water use efficiency and GDP per capita, and 60% between water use efficiency and human development index.

The big surprise comes from the positive correlations between water stress and economic development indicators. This may be explained by the fact that industrialized countries may not all have abundant resources, while at the same time, they may have a high demand for water stemming from both firms and households. Hence, a situation of water stress is observed in some of these countries.

Water stress and water use efficiency are still missing some explanatory factors for making a completed formula…

We also estimated Model 2 in which we included the country characteristics as independent variables to explain water stress and found that the R-squares range between 15% and 30%, depending on which variables are included. Hence, the chosen set of variables has significant explanatory power for water stress. Nevertheless, at the same time, country characteristics cannot fully explain water stress, and hence, water stress remains an interesting issue that should be given further attention in future research.

Model 2:

$$Water\ Stress = \beta_0 + \beta_1 * Country\ \ Characteristics + \varepsilon$$

… yet, the identified factors do provide significant explanatory power

Likewise, we estimated Model 3 in which we included the country characteristics as independent variables to explain water use efficiency and found that the R-squares range between 30% and 50%, depending on which variables are included. Hence, the chosen set of variables has a significant explanatory power for water use efficiency. Although the R-squares found here are higher than those found for water stress, there is still room for further research to better explain water-use efficiency.

Model 3:

$$Water\ Use\ Efficiency = \beta_0 + \beta_1 * Country\ \ Characteristics + \varepsilon$$

In sum, the country-level analysis of water stress and water use efficiency highlights several interesting features. First, water stress affects both large and small countries, and the size of the country does not prevent water stress. Second, water stress is fueled by large populations and the demand in irrigated cultivated lands. The demographic factor and the agriculture sector both aggravate water stress. Lastly, developed countries can implement efficient water-use measures, which, however, entail more financial resources, awareness, and water-related literacy.

Sustainalytics Country Risk Rating, Water Stress Score, and Water Productivity Score

Country Risk Rating, Water Stress Score, and Water Productivity Score

We continue our country-level analysis using now additional measures. For that, we assess the country risk using the Sustainalytics Country Risk Rating and incorporate in our analysis two water-related measures: Water Stress Score and Water Productivity Score.

The correlations between the measures mentioned above provide interesting features. First, we find a positive correlation (4.9%) between Country Risk Rating and Water Stress Score. This result is in line with that at the firm level, in which we also find a positive correlation between firm ESG risk and Water Intensity. Hence, the overuse of water, be it at the firm or country level, is likely to inflate the overall risk of the company and the country. Next, we find a strong and negative correlation between Country Risk Rating and Water Productivity Score (-51.5%). Hence, using water efficiently is likely to improve the country risk. Taken together, the clear connection between water-related measures and country risk rating shows the importance of water risk and further highlights the fact that water risk is a systemic risk with far-reaching implications.

Analyzing High-Risk Regions

From modern-day Syria to the Mayan civilization, droughts precede the fall of many nations[19]

Historically, access to water has been critical in the growth and prosperity of countries and cities. According to the World Bank, worsening water quality already reduces economic growth by a third in some countries.[20] When one looks at events where water has become either suddenly scarce, no longer safe, or inexpensive, one sees large population displacements, a significant reduction in business investment, and adverse economic impact.

Faster paced growth could mean more risk

China's and India's explosive economic growth and water pollution problems resulting from their fast-paced industrialization are a testimony to those companies that operate in regions of the world with strong economic growth and increasing water stress risk.

Within these regions, water-saving strategies will have a more meaningful impact on the ecosystem and society. A faster pace of change tends to result in governments playing catch up in building the required infrastructure and monitoring programs.

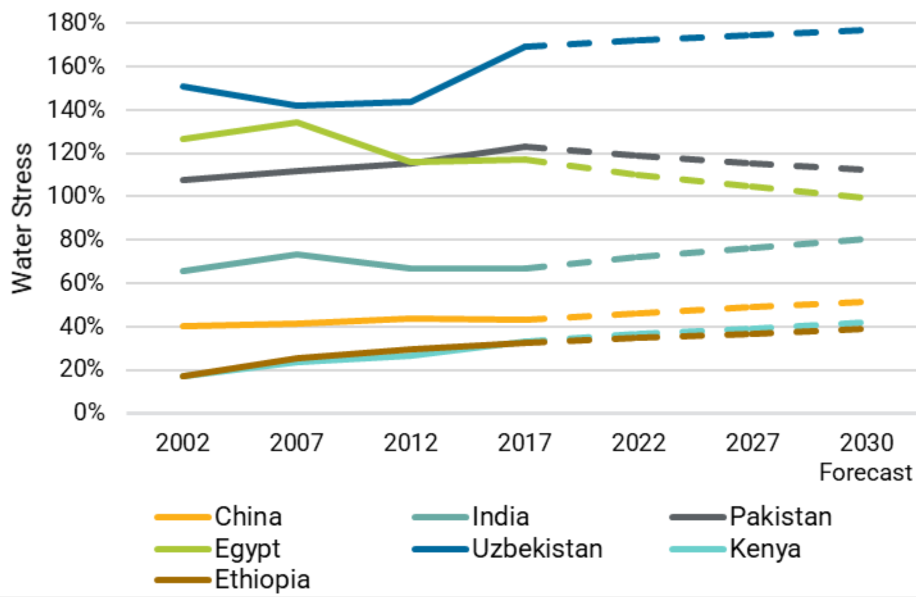
High-growth nations in Africa, along with India, face a concerning trend

Exhibit 11 showcases countries with historically strong economic expansion (GDP growth). For African countries, such as Kenya and Ethiopia, which also have strong agriculture production growth, the growth rate of water stress accelerated considerably from 2002 to 2017.

Unsustainable 'borrowers' of water

Uzbekistan, Egypt, and Pakistan have continually been above 100% of water stress, meaning that at the national level, they constantly extract their water requirements from non-renewable resources in an unsustainable manner and subsequently are regions that are at risk of major water shortages.

Exhibit 11: Water Stress Levels of Countries with High GDP Growth



*The water stress 2030 forecast is the ratio between total freshwater withdrawn by all major sectors and total renewable freshwater resources after deducting environmental flow requirements.[21]

Source: Aquastat, IFPRI, IMF, ourworldindata.org

When Water Nearly Runs Out: The Case of South Africa

'Day Zero' - The day when municipal water supplies would switch off

In spring 2018, Cape Town announced that it was just three months away from running out of municipal water.[22]

According to the 2030 Water Resources Group (2030 WRG), '*The Cape Town crisis stems from a combination of poor planning, three years of drought, and spectacularly bad crisis management. The city's outdated water infrastructure has long struggled to keep up with the burgeoning population.*'[23]

Key industries negatively impacted

Impacts from the near 'Day Zero' event resulted in permanent disruption to the city's core industries and affected other less tangible social and environmental aspects. South Africa is well known for its wine and tourism industry, and these key industries felt the brunt of the drought. Vineyards lost 20% of production,[24] and tourist spend declined 30%.[25]

As Cape Town's dam levels fall, borrowing costs rise

Analysts estimated that the water crisis costed some 300,000 jobs in agriculture and tens of thousands more in the service, hospitality, and food sectors. [26] Many of these job losses were in low-skilled positions.[27] The three-year drought in South Africa, resulted in increases in food prices[28] a surge in inflation, and credit downgrades, which altogether have further aggravated the crisis.[29]

Such rapid change in water withdrawal in South Africa might highlight another piece to the story surrounding Cape Town's water challenges, as it shot past the Water Resource Group's estimate of 3.3 billion[30] for industrial use, the number estimated for 2030, in less than half of the allotted time initially projected.

India Might Be the Biggest Elephant in the Room

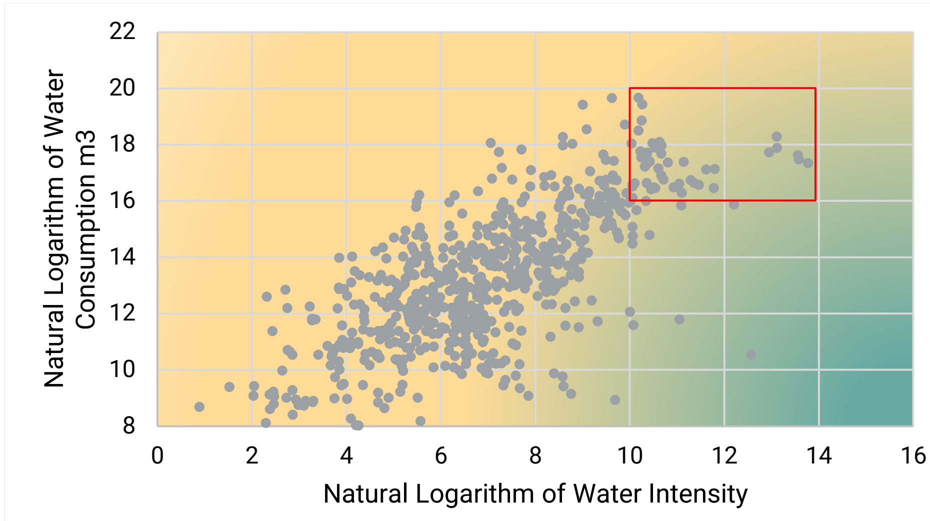
Many companies have operational exposure to India

India is modernizing at a furious pace, accompanied by continued above-average agriculture growth. Many multinational companies have operational exposure to India. We estimate that at least 23% of the companies covered for water metrics have at least 1% of assets or revenues tied to India, suggesting that a significant water shortage in the region could bring about supply chain disruption at the global level.

Exhibit 12 has carved out all companies with either 5% of revenues or 5% of assets tied to India and included all companies with an Indian headquarters. The x-axis contains companies' water intensity, with the y-axis containing the total water consumed by a company.

Companies involved in steel, energy production, and chemicals dominate the red box in Exhibit 12

Exhibit 12: India's Big Water Consumers



N=684 **Source:** Sustainalytics[31]

For those companies in Exhibit 12, 2.2% of companies report water withdrawals, and 8.4% report water consumption. Nevertheless, there is minimal reporting by electric utility companies and a vast list of steel companies with sizeable operations in India. Thus, immediately we have pointed to two subindustries that face considerable water-stress risks.

Water shortages listed as the fifth most common reason for the outage.

In fact, the World Resources Institute (WRI) has pointed out that India's thermal power plants currently run at only 61%, with water shortages listed as the fifth most common reason for the outages. In 2016, 14 terawatt-hours of potential thermal power generation were lost to water shortages, and by 2030, power plants located within water-scarce areas are projected to shift from 40% to 70%.[32] With ambitious policies announced to save 12.4 bn cubic meters of freshwater withdrawal[33], this might be one of the most substantive microcosms in the world to watch when it comes to the impact of water stress, as it is critical to supporting the livelihood of millions.

Conclusions - The Emergence of Water Risk: from Marginal to Systemic

Helping to monitor water-related risks

This paper highlights the importance of water scarcity for firms and countries. It also shows that water stress is on the rise in many regions of the world and is expected to become a critical issue in the near future. To address these challenges and better monitor water-related risks, Sustainalytics has introduced several water metrics.

Predicting water usage for non-reporting companies

In addition, Sustainalytics has developed a proprietary model to predict water usage for non-reporting companies and hence, provide our clients with a more comprehensive coverage of water-related risks. This also circumvents the fact that only a small fraction of companies is currently reporting on their water usage.

Testing the relationship between water intensity and firm-specific characteristics

We further investigated the determinants of water intensity at the firm level and found clear evidence that firms with high water intensity exhibit high ESG risk, high standard deviation and high downside deviation. However, we found only weak evidence of a relationship between water intensity and risk-adjusted return.

Reducing ESG risk exposure

Investors can use water metrics to identify firms with low water intensity. Our results show that reducing exposure to water intensity will go hand in hand with reducing ESG risk exposure and information asymmetry. More generally, investors may also examine companies' business models and assess the relationship between resource dependency and availability.

Two countries, South Africa and India, are used as case studies to illustrate how increased water stress is an important challenge and has profound effects for all aspects of society.

Adding the regional perspective

At the country level, water stress is inversely related to water use efficiency and is higher in countries with large populations, high percentage of irrigated cultivated land, high water withdrawal per capita, and high development indicators. On the other hand, water efficiency is high in countries with small populations, a low percentage of cultivated land irrigated, low total water withdrawal per capita, and high development indicators.

Considering water-related when building investment startegies

Our study shows that water stress has implications beyond the immediate use of water as water stress affects all the aspects of the economy and well-being of society. Therefore, monitoring water usage indicators at the country level and the firm level is an urgent necessity for country policymakers, company executives, and shareholders. For portfolio managers and investors, water-related risks are equally important and should be considered when building investment strategies.

Appendix

Additional Charts & Figures

Exhibit 13: Prediction Model and its Factors[34, 35, 36]

No.	Factors	In Model	Relevance	Data Availabilty and Quality
1	Operating Revenues	*Rev*	Size proxy for the volume of water used in the provision of goods and services	High
2	Number of Employees	*Empl*	Size proxy for the volume of water used in employee's activities	Moderately high
3	Gross Plant, Property & Equipment	*PP&E*	Size proxy for volume of water used during usage of physical, fixed assets (e.g. plants, facilities, machinery)	Moderately high
4	Subindustry	*Subindustry*	Accounts for the subindustry-specific effects and represented as subinustry averages	High
5	Country	*Country*	Country quintile captures country-specific water withdrawal/water consumption patterns, using country indices, which accounted for: a. Country Risk Rating from Sustainalytics b. Baseline Water Stress (by Country) from Aqueduct c. Reputational Water Risk (by Country) from WWF Water Risk Filter d. Regulatory Water Risk (by Country) from WWF Water Risk Filter	Moderately high

$$WW\ or\ WC = \beta_0 + \beta_1 * Rev + \beta_2 * Empl + \beta_3 * PP\&E + \beta_4 * CoR + \beta_5 * Subindustry + \beta_6 * Country + \varepsilon$$

Source: Sustainalytics

Glossary of Terms and Variable Definitions

Alpha	A measure of the difference between a portfolio's actual returns and its expected performance, given its level of risk as measured by beta. A positive Alpha figure indicates the portfolio has performed better than its beta would predict. In contrast, a negative Alpha indicates the portfolio has underperformed, given the expectations established by beta. Alpha is calculated by taking the excess average monthly return of the investment over the risk-free rate and subtracting beta times the excess average monthly return of the benchmark over the risk-free rate.
ESG Risk Ratings Score	Sustainalytics' rating framework that measures the extent to which enterprise value is at risk, driven by environmental, social and governance (ESG) factors. The rating takes a two-dimensional approach. The exposure dimension measures a company's exposure to ESG risks, while the management dimension assesses a company's handling of these ESG risks.
Downside Deviation	A measure that focuses on deviations below a specified benchmark. It is also the denominator for the Sortino Ratio.
GDP per Capita	Gross domestic product divided by population. Unit used in this document: Current USD/inhab.
Human Development Index (HDI)	A summary measure of human development. It measures the average achievements in a country in three basic dimensions of human development: (1) a long and healthy life, as measured by life expectancy at birth; (2) knowledge, as measured by the adult literacy rate (with two-thirds weight) and the combined primary, secondary and tertiary gross enrolment ratio (with one-third weight); (3) a decent standard of living, as measured by GDP per capita. Unit used in this document: Purchasing Power Parity or PPP USD.
Market Capitalization / Market Cap.	An estimation of the value of a business that is obtained by multiplying the number of shares outstanding by the current price of a share. Unit used in this document: Mil USD.
Percentage of Cultivated Land Irrigated / % of Cultivated Land Irrigated	Part of the cultivated land that is irrigated using the total harvested irrigated crop area. Calculation Criteria by Aquastat[37] [% of arable land irrigated] = 100*[Total harvested irrigated crop area (full control irrigation)]/[Cultivated area (arable land + permanent crops)] This corresponds to the Ai component entering in the SDG 6.4.1. calculation. In a few cases, this variable can be above 100%. However, for the calculation of the SDG 6.4.1 it has been capped to 100%. Unit used in this document: Percentage.
Return	A financial return that does not take into consideration reinvestment of dividends. Dividends are treated as a cash payout as of the end of the period. The calculation is point to point using adjusted price at the beginning of the period and the adjusted price at the end of the period incorporating any dividends paid. Unit used in this document: USD.
Revenue	Income that a company receives from its normal business activities, i.e. from the sales of goods and services. Unit used in this document: Mil USD.

SDG (Sustainable Development Goal) Indicator	The Sustainable Development Goals are the blueprint to achieve a better and more sustainable future for all. They address the global challenges we face, including poverty, inequality, climate change, environmental degradation, peace and justice. The global indicator framework for Sustainable Development Goals was developed by the Inter-Agency and Expert Group on SDG Indicators (IAEG-SDGs) and agreed upon at the 48th session of the United Nations Statistical Commission held in March 2017.[38]
Sustainalytics Country Risk Ratings	Country Risk Ratings help investors to understand the risks to a country's long-term prosperity and economic development by assessing its wealth and its ability to manage its wealth in a sustainable manner. In the context of sovereign bond investing, country risk assessment with an ESG lens can complement traditional credit ratings in order to deepen the understanding of the economic environment and provide insights into areas that are often treated idiosyncratically, in a quantitative and objective manner. While not being a measure of default probability itself, when used alongside economic analysis, it provides a more nuanced assessment of the strength of an economy in the long run.
Standard Deviation (Std. Dev.)	A statistical measurement of dispersion about an average and depicts how widely the returns varied over a certain period of time. Morningstar computes standard deviation using the trailing monthly total returns for the appropriate time period. All of the monthly standard deviations are then annualized.
Total Area of the Country	The total area of the country, including area under inland water bodies but excluding coastal water. Possible variations in the data may be due to updating and revisions of the country data and not necessarily to any change of area. Calculation Criteria by Aquastat[39]: Total area of the country (excl. coastal water) = [Land area]+[Inland Water] Unit used in this document: 1000 ha
Total Renewable Water Resources	The sum of internal renewable water resources (IRWR) and external renewable water resources (ERWR). It corresponds to the maximum theoretical yearly amount of water available for a country at a given moment. Calculation Criteria by Aquastat[40]: Total renewable water resources = [Total renewable surface water] + [Total renewable groundwater] - [Overlap between surface water and groundwater] Unit used in this document: 10^9 cubic meters/yr
Total Population	The present-in-area (de facto) population which includes all persons physically present within the present geographical boundaries of countries at the mid-point of the reference period. Unit used in this document: 1000 inhab
Total Water Withdrawal per Capita	The total volume of water withdrawn in one year on average per capita. Calculation Criteria by Aquastat[41]: Total water withdrawal per capita = [Total water withdrawal]*1000000/[Total population] Unit used in this document: Cubic meters/year per inhabitant
Water Consumption	The total volume of water withdrawn and consumed for own purpose and not returned to the same source or not considered useable by others. Unit used in this document: Cubic meters.

Water Intensity	The volume of water withdrawal per unit of revenue (million USD). Calculation Criteria: Water Intensity = [Total water withdrawal in cubic meters] / [Revenue in million USD] Unit used in this document: Cubic meters/million USD.
Water Productivity	Water productivity, total (constant 2010 US$ GDP per cubic meter of total freshwater withdrawal)[42]
Water Stress (SDG 6.4.2.)	Freshwater withdrawal as a proportion of available freshwater resources. It is the ratio between total freshwater withdrawn by all major sectors and total renewable freshwater resources, after taking into account environmental flow requirements. For a given country, it is considered: Extremely high stress, if the ratio of withdrawals to supply is >80% High stress, if the ratio of withdrawals to supply is 40–80% Medium-high stress, if the ratio of withdrawals to supply is 20–40% Low-medium stress, if the ratio of withdrawals to supply is 10–20% Low stress, if the ratio of withdrawals to supply is <10% Calculation Criteria by Aquastat[43] [SDG 6.4.2. Water Stress] = 100*[Total freshwater withdrawal]/([Total renewable water resources]-[Environmental Flow Requirements]) Unit used in this document: Percentage.
Water Use Efficiency (SDG 6.4.1.)	Value added per unit of water used expressed in USD/cubic meters. Calculation Criteria by Aquastat[44] [SDG 6.4.1. Water Use Efficiency] = ([SDG 6.4.1. Irrigated Agriculture Water Use Efficiency]*[Agricultural water withdrawal as % of total water withdrawal]/100)+([SDG 6.4.1. Industrial Water Use Efficiency]*[Industrial water withdrawal as % of total water withdrawal]/100)+([SDG 6.4.1. Services Water Use Efficiency]*[Municipal water withdrawal as % of total withdrawal]/100) Unit used in this document: USD/cubic meters.
Water Withdrawal	The total volume of water withdrawn or diverted from various water sources, such as groundwater, lake, municipal supplies, etc. (including sea water). Unit used in this document: Cubic meters.

Endnotes

1 The authors would like to thank the following people for their comments on earlier drafts of this report: Clark Barr, Giacomo Bressan, Hendrik Garz, Kata Molnar, Anabel Ng, Cathrine Steenstrup, and Megan Wallingford.

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9 The forecast for withdrawal growth is inspired by 2030 Water Resource Groups exhibit 4, titled Aggregated global gap between existing accessible, reliable supply and 2030 water withdrawals, assuming no efficiency gains. Due to not having basin level data, we subbed in Aquastat sector data as of 2017 as our base information. Note that the model also differs in that it uses total renewable water resources, and not relevant supply quantity. The following inputs are as follows. 2002 to 2017 and water withdrawals for Industrial, Municipal and Agricultural, based on Aquastat data. 2002 to 2017 desalinated water produced, direct use of treated municipal wastewater, direct use of agricultural drainage water based on Aquastat data, with 2030 forecasted created based on the growth trajectory from 2012 to 2017 at the country level. Agriculture growth based on 2030 agricultural production forecast for 2030 from IFPRI, IMPACT Model v 3.3. Industrial growth based on IMF country GDP forecasts and actuals, 2018 to 2026. Municipal growth based on Population growth for countries using 2018 to 2030 actuals and estimates from ourworldindata.org. Agricultural and industrial efficiency improvements from www.2030wrg.org. Municipal efficiency improvements from 2002 to 2017 differential in Aquastat Municipal withdrawals and population growth at the global level. 2017 SDG 6.4.2. Water Stress (%) from Aquastat. Total renewable water resources, environmental flow requirements for 2030 from Aquastat.

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14 The forecast for withdrawal growth is inspired by 2030 Water Resource Groups exhibit 4, titled Aggregated global gap between existing accessible, reliable supply and 2030 water withdrawals, assuming no efficiency gains. Due to not having basin level data, we subbed in Aquastat sector data as of 2017 as our base information. Note that the model also differs in that it uses total renewable water resources, and not relevant supply quantity. The following inputs are as follows. 2002 to 2017 and water withdrawals for Industrial, Municipal and Agricultural, based on Aquastat data. 2002 to 2017 desalinated water produced, direct use of treated municipal wastewater, direct use of agricultural drainage water based on Aquastat data, with 2030 forecasted created based on the growth trajectory from 2012 to 2017 at the country level. Agriculture growth based on 2030 agricultural production forecast for 2030 from IFPRI, IMPACT Model v 3.3. Industrial

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