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GLOBAL WATER STRESS INDICES: AN EXAMPLE OF THEIR INDUSTRIAL USAGE

Globala vattenstressindex: Ett exempel på industriell tillämpning

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Abstract

The article presents a study assigned by SCA about water stress assessments on basin level for sites where SCA have pulp- and paper mills, paper mills or factories. Four tools were evaluated with the aim to find indices that measure water stress, i.e. lack of water of good enough quality for humans and the ecosystem. Water indices, developed through research, become more accessible when they are in water tools, developed by non-governmental organisations, corporations or financial institutions. Two indices in WBCSD's Global Water Tool and three indices in WWF-DEG's Water Risk Filter totally gave each site five assessments. The study included 96 sites. Both tools gave assessments without showing confidence intervals for the results that are presented. More local knowledge would be required to assess how well the results correspond to reality. That is the case for all indices that are measured on the level of basins or countries.

Key words – water stress indices, global water tools, business water risk, CSR, NGOs, environmental models

Sammanfattning

I uppdrag av SCA gjordes en studie om vattenstressbedömningar för avrinningsområden där SCA har massapappersbruk, pappersbruk eller fabriker. Fyra vattenverktyg undersöktes i syfte att hitta index som mätte vattenstress, d.v.s. bristen på vatten av tillräckligt bra kvalitet för att kunna användas av människor och ekosystem. Vattenstressindex, som tagits fram genom forskning, blir mer tillgängliga när de finns i vattenverktyg, som utvecklats av NGOs, företag eller finansiella organisationer. Två index i WBCSDs Global Water Tool och tre index i WWF-DEGs Water Risk Filter resulterade i fem bedömningar för varje anläggning i studien. I studien ingick 96 anläggningar. Vattenverktygen ger i nuläget bedömningar för stora områden utan att visa konfidensintervall för de resultat som presenteras. Mer lokalkännedom skulle behövas för att utvärdera om resultaten stämmer med verkligheten. Detta gäller för alla index som beräknas på nivån av avrinningsområden eller länder.

1 Introduction

Currently 40 % of the world's population lives in areas of water scarcity (Revenga et al., 2000). In their study, Revenga et al. (2000) also estimated that 50 % of the global population could be affected by water scarcity by 2025. There are reasons for concern that the competition for freshwater will increase in regions with growing water scarcity (FAO & WWC, 2015; Revenga et al., 2000; WWAP, 2015a). The competition does not only involve humans; water is essential to all life on the planet.

Water stress assessment is a method of estimating the availability of water. According to a general definition by Mueller et al. (2015) a water stressed area does not have enough river runoff within the basin to meet human and ecological demands. To avoid water stress there should thus be sufficient amounts of water, of good enough quality, for the population and the ecosystem. By using water stress indices water stress can be measured, although this is not an exact measurement. It is not as straight-forward as measuring the temperature with a thermometer.

Table 1. *Brief presentation of four global water assessment tools.*

Name (Developer)	Description	Purpose of use	Water stress indices	Source
Aqueduct (WRI)	Online water risk assessment tool	Plotting sites on risk maps	YES	(WRI, 2015)
Aqua Gauge (Ceres)	Leader-ship oriented excel-based tool	Developing a water strategy	NO	(Ceres, 2015)
Global Water Tool (WBCSD)	Excel-based water assessment tool	Making water stress assessments	YES	(WBCSD, 2015a)
Water Risk Filter (WWF-DEG)	Online water risk assessment tool	Making water risk assessments	YES	(WWF-DEG, 2015a)

The present paper is a summary of a degree project about measuring water availability in different regions all around the world. It is presented here with the intention to provide an industry perspective on how to assess current water conditions in areas of operation. More information about the project that was assigned by SCA can be found in the master thesis (Wästerström, 2016). SCA is a global hygiene and forest product company with 96 sites in 27 countries at the start of the project. Among the sites there are pulp- and paper mills, paper mills and factories. Currently the total water usage is about 210 million cubic meters per year (SCA Sustainability Report 2014). The aim of the degree project was to describe and compare different indices that could be used to estimate the risk that a given location is experiencing water stress. The main objective was to use suitable indices with the aim to identify SCA sites located in regions with indication of water stress.

2 Literary summary

The following sections include information regarding four global water assessment tools and five selected indices.

2.2 Global water assessment tools

Many indices have been developed in the last 20 years for measuring water scarcity and water stress (Brown and Matlock, 2011). A large number of indices have been incorporated into so-called global water assessment tools. These tools make the indices available to the public and companies. The water tools presented in the following sections were developed by NGOs in collaboration with financial organizations.

Four global water assessment tools were evaluated as part of the study to provide information of different types of tools. The evaluated tools are presented in Table 1 to give a short description of each tool and what was found to be the most suitable use for the tools. The table lists the developers WRI (Water Resources Institute), Ceres, WBCSD (World Business Council of Sustainable Development) and WWF-DEG (World Wide Fund for Nature and Deutsche Entwicklungsgesellschaft). Other organisations were also involved in the development.

In order to carry out the assessment in this study it was important to find at least one tool that could be used to measure water stress indices on a basin level. In fact two tools, Global Water Tool and the Water Risk Filter, were found to be suitable and were used in the study. In short, the main condition for a tool to be selected was that the tool had indices that could be used to measure water stress on a basin level worldwide.

2.3 Selected water stress indices

This section includes information about the indices that were measured in order to make the water stress assessments that were the aim of the project. Table 2 shows the name of the indices and which tool they were measured in.

2.3.1 Annual Renewable Water Supply per Person – 1995

Annual renewable water supply per person – 1995 is an index that gives a quantitative measurement of water availability. Experts in a worldwide survey gathered the data that is used to calculate the index in 2000. To cal-

Table 2. *Selected water stress indices.*

Global Water Tool	Annual Renewable Water Supply per Person – 1995 Baseline Water Stress
Water Risk Filter	Risk of Scarcity Risk of Pollution Risk of Ecosystem Threat

Table 3. *Score and assessment-scale of Annual Renewable Water Supply per Person – 1995.*

	Score (m^3/pers/yr)	Assessment
Level 1	> 4000	Abundant
Level 2	1700 – 4000	Sufficient
Level 3	1000 – 1700	Stress
Level 4	500 – 1000	Scarcity
Level 5	< 500	Extreme Scarcity

Table 4. *Score and assessment-scale of Baseline Water Stress.*

	Score (%)	Assessment
Level 1	< 10	Low stress
Level 2	10 – 20	Low to medium stress
Level 3	20 – 40	Medium to high stress
Level 4	40 – 80	High stress
Level 5	> 80	Extremely high stress
	Arid & low water use	Scores as high stress

culate the index on a basin level the estimated runoff value for a river basin (1995) is divided by the population in the basin (1995). World Resources institute (WRI) provides datasets to calculate a value at a basin or country level (WBCSD, 2015b). The datasets are rough-grid and not updated but they cover most countries and basins in the world.

The index can be used to estimate whether there is sufficient amount of water per capita. It can be measured in the Global Water Tool. Stress is defined as "a situation where disruptive water shortages can frequently occur" (Revenga et al., 2000). A site is described as stressed if the water supply in the basin is less than 1700 m^3 per person per year. It is the third level of the scale used by this index, see Table 3.

The level for water stress can be compared to China's per capita water footprint 1071 m^3/person/year (Mekonnen and Hoekstra, 2011).

2.3.2 Baseline Water Stress

Baseline Water Stress is another index that gives a quantitative measurement of water availability. The index can be used to express how much water is taken out of a river basin compared how much water there is in the basin (Reig et al., 2013). It is calculated by dividing an estimated value of total water withdrawal (2010) by the estimated mean annual blue water (1950 – 2008). WRI provides datasets to calculate a value at a basin level. The calculation method relies on estimations by WRI of total water withdrawals (i.e. water removed from freshwater sources for human use) and an estimate of total blue water from a publication by NASA in 2012. The NASA analysis covered the years 1950 – 2008. The datasets are still rough-grid but cover most parts of the world. (Reig et al., 2013)

The index can be used to identify regions experiencing water stress since it gives an estimate of how much water is available for human use. It can be measured in two tools, Aqueduct and the Global Water Tool.

Stress is not defined as a special situation in Baseline Water Stress like it is in Annual Renewable Water Supply per Person – 1995. Instead stress is defined on a scale from low stress to extremely high stress, see Table 4.

In this index there is a special category for arid areas (e.g. deserts) and areas with low water use (e.g. largely uninhabited) but these areas score as high stress areas. Baseline Water Stress can be illustrated on maps and then arid, or low water use areas, are shown in grey to separate them from water stressed areas (yellow, orange, red).

2.3.3 Risk of Scarcity

Risk of Scarcity, provided by WWF-DEG, is the third among the selected indices that gives a quantitative measurement of water availability on a basin level. The full name of the index is Physical risk – Quantity (scarcity). This index could be described as an indirect water stress index because water scarcity, which generally means a lack of water, is one indication of water stress. The term water stress encompasses water scarcity (Mueller et al., 2015).

The calculation method is to estimate scarcity as a unitless score that is a weighted average of seven indices in in the Water Risk Filter. The three indices with the highest weightings relate actual available water to water-consumption, which shows some similarities with Baseline Water Stress (WWF-DEG, 2015b).

The index is original to the Water Risk Filter, which is the only tool that measures the index. Risk of Scarcity is measured on a five-level scale from score 1 (very limited risk) to score 5 (very high risk), see Table 5. The same assessment scale is used for all indices in the Water Risk Filter.

Table 5. *Score and assessment-scale used for all indices in the Water Risk Filter, including Risk of Scarcity, Risk of Pollution and Risk of Ecosystem Threat.*

	Score (unitless)	Assessment
Level 1	1	Very limited risk
Level 2	2	Limited risk
Level 3	3	Some risk
Level 4	4	High risk
Level 5	5	Very high risk

2.3.4 Risk of Pollution

Risk of Water Pollutions, provided by WWF-DEG, is not a quantitative but a qualitative measurement. It is like Risk of Scarcity original to the Water Risk Filter. The full name is Physical risk – Quality (pollution). A high score in this index indicates that the available water may not be usable. As a consequence, Risk of Pollution is regarded as a suitable water stress index.

The score is calculated as a weighted average of nine indices. Each of the nine indices measures a pollutant that has been known to show a negative effect on water resources or biodiversity (WWF-DEG, 2015b). All nine indices are measured by measuring pollution in grid cells (WWF-DEG, 2015b). The method was developed by Vörösmarty et al. (2010). They divided the global landmass into grid cells, 30' (latitude × longitude), and pollution is measured in each cell based on country data for the area the cell covers.

Just as Risk of Scarcity it is an original index to the Water Risk Filter, and it is only measured in the Water Risk Filter. The assessment scale shown for Risk of Scarcity is used to measure this index as well, see Table 5.

2.3.5 Risk of Ecosystem Threat

Risk of Ecosystem Threat gives an estimate of the quality of the ecosystem. It is the third WWF-DEG index and the second qualitative index used to measure water stress in this study. The full name of this index is Physical risk – Ecosystem threat.

Many ecosystem functions are closely connected to freshwater availability (Brown and Matlock, 2011; WWAP, 2015b). Where the ecosystem is threatened there might be a lack of freshwater and Risk of Ecosystem Threat is therefore regarded as a suitable water stress index.

Risk of Ecosystem Threat is only available in the Water Risk Filter and like all indices in the Water Risk Filter it is measured on the five-level scale shown in Table 5. The score is calculated as a weighted average of four indices in the Water Risk Filter.

3 Assessment methodology

The water stress assessments, which were the primary objective of the project, were carried out by measuring five water stress indices with the help of two global water assessment tools. A challenge of this project was to choose which results should indicate water stress. Because it is not possible to measure water stress directly (Mueller et al., 2015) a choice was made of how to define water stress in each index.

The assessment that a site showed indications of experiencing water stress was given if the site got high enough scores in the selected indices. All indices use a five level assessment-scale, see Table 3–5. Each level corresponds to a water stress assessment, which is not the same for different indices. Scores in level 3, 4 and 5 were used to indicate water stress in this study.

3.1 Measuring indices

Among the four evaluated tools two were selected, WBCSD's Global Water Tool and WWF-DEG's Water Risk Filter. These tools were used to make water stress assessments for 96 SCA sites that were listed in SCA's water data for 2014.

Firstly the location for the 96 sites was entered into each tool. Together with the datasets within the tools the calculations was based on location data (i.e. GPS coordinates). After the location had been entered into a tool a value was calculated automatically for each site and each index. There were many different types of indices in both tools. For this project only the five selected water stress indices were of interest.

In the Global Water Tool the results were shown in an excel document downloaded from WBCSD's webpage after the site information (i.e. site name and location) had been filled in. As for the results from the Water Risk Filter, these were found on the Water Risk Filter webpage. The online tool was used as follows. Firstly an account was created and site information (i.e. site name and location) was uploaded. Thereafter a full risk assessment was generated more or less immediately. Finally the results could be downloaded by a user of the online account.

After the indices had been measured each site had five assessments, one for each of the selected indices. To get comprehensible results each index score was linked to an assessment according to the assessment-scales shown in Table 3–5.

4 Results

The results show two main findings; firstly the results present the number of sites that show an indication of water stress in each of the selected indices. Secondly the results show that different indices give different water stress assessments. The summary of the results of the measurement are shown in Figures 1–5.

4.1 Annual Renewable Water Supply per Person – 1995

In this index there are 39 sites located in basins that appear to experience at least some indication of water stress. Among the sites below the water-deficit thresh-

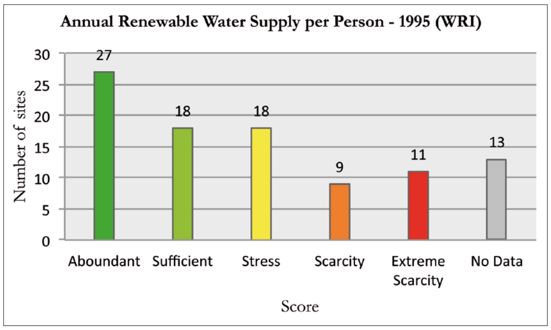

Figure 1. *Number of sites given each assessment on the scale of Annual Renewable Water Supply per Person – 1995.*

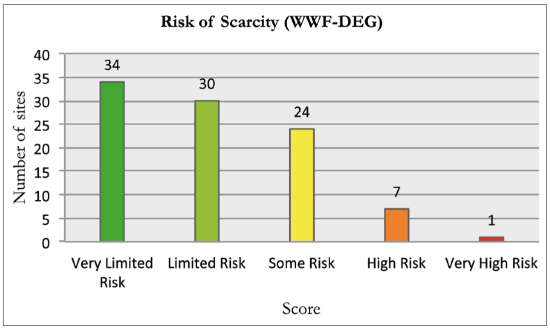

Figure 3. *Number of sites given each assessment on the scale of Risk of Scarcity (Physical – Scarcity/ quantity).*

old, 18 sites get the assessment "stress" (1000–1700 m^3/pers/year), 9 get "scarcity" (500–1000 m^3/pers/year) and 11 get "extreme scarcity" (< 500 m^3/pers/year), see Figure 1.

Finally the results show that all sites did not get a calculated score in this index. The column to the right in Figure 1 shows "No Data" for 13 sites. Consequently, the datasets that were used to calculate the index did not cover all site locations.

4.2 Baseline Water Stress

In Baseline Water Stress the assessment stress is given to 47 sites, see Figure 2. They are located in basins where the calculated value of baseline water stress is above 20 %. There are 15 sites that the assessment "medium to high stress" (20–40 %), 21 sites that get the assessment "high stress" (40–80 %), 10 sites that get the assessment "extremely high stress" (> 80 %). One site gets the assessment "arid & low water use", which scores as high stress.

The measurement of Baseline Water Stress shows that 7 sites cannot be evaluated in this index, see Figure 2.

4.3 Risk of Scarcity

In total there are 32 sites that get medium to very high risk of scarcity, see Figure 3. Here, scarcity is interpreted as an indication of water stress. Sites with scores "some risk", "high risk" or "very high risk" are assumed to show water stress in this study.

The fact that there were gaps in the datasets could be seen in the risk assessment document, which was downloaded from the Water Risk Filter's webpage. The document showed gaps in one or two of the seven indices used to calculate the average score (i.e. Risk of Scarcity). Despite the mentioned gaps, a score of Risk of Scarcity had indeed been calculated in the Water Risk Filter for all 96 sites.

4.4 Risk of Pollution

In total there are 81 sites in basins that show indications of water stress due to pollution. Figure 4 shows that there are 21 sites that get score 3 = "some risk" of pollution, there are 48 sites that get score 4 = "high risk" and 12 that get score 5 = "very high risk". In basins with a high score Vörösmarty et al. (2010) estimated that the

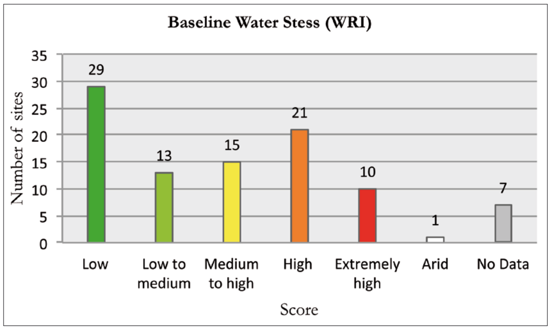

Figure 2. *Number of sites given each assessment on the scale of Baseline Water Stress.*

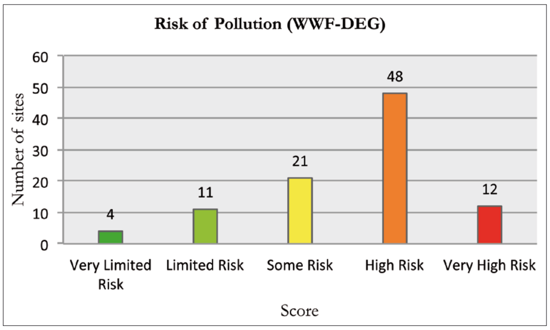

Figure 4. *Number of sites give each score of Risk of Pollution (Physical – Pollution/ quality).*

human population or the ecosystem did not have access to usable water.

As a final remark, there are some question marks with regard to how Risk of Pollution was calculated. In the original Water Risk Filter document, which contains the risk assessment, the scores of many indices can be seen. Both the average score (i.e. Risk of Pollution) and the individual scores of the nine pollutants are included in the document. There are significant gaps in the datasets. 10 sites have an average score but gaps in every index of the nine pollutants. Because of the missing values in the original risk document mentioned above, it appears as if the locations of the above mentioned sites are not covered in the datasets. The final question is thus, how the average score is calculated. What is also remarkable is that the 10 sites with missing values for all pollutants get different assessments.

4.5 Risk of Ecosystem Threat

There are in fact 84 sites that shows at least some risk of ecosystem threat in the basin, which is also used in this study as an indication of water stress, see Figure 5. Among the sites in areas above the threshold 37 sites get score 3 = "some risk" of ecosystem threat, 44 sites get the score 4 = "high risk" and 3 sites gets the score = "very high risk".

5. Analysis

The article presents some results of a water stress assessment, and in addition it gives an example of how to carry out a water stress assessment. In fact, there are many alternative methods to assess water stress. Brown and Matlock (2011) have for instance presented many indices of water stress and scarcity.

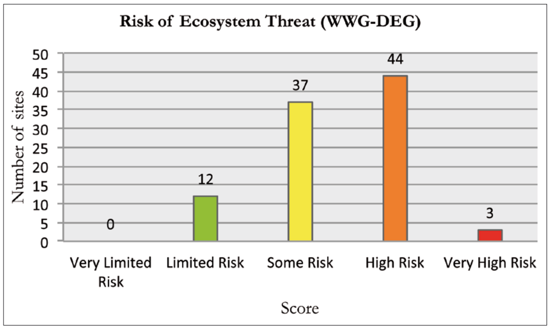

Figure 5. *Number of sites given each assessment on the scale of Risk of Ecosystem Threat (Physical – Impact on ecosystem).*

5.1 Quantitative and qualitative indices

The greatest difference is found between indices that are quantitative in nature (Annual Renewable Water Supply per Person – 1995, Baseline Water Stress and Risk of Scarcity) and the indices that give a qualitative assessment (Risk of Pollution and Risk of Ecosystem Threat). The qualitative indices could be important to complement the quantitative indices.

The three quantitative indices estimated if there were sufficient amount of water in the basins where the sites were located. If the quantitative indices that estimate water availability gave very reliable assessments it would be possible to assume that the same sites should get the same results in different quantitative indices. A close correspondence between the quantitative indices was not shown in this study.

The qualitative indices were used because concepts such as good water quality and a well-functioning ecosystem were considered important to estimate water stress. However, low water quality may not be important for individual sites even if the qualitative aspects are important to estimate water stress. It is possible that a production site that depends on water may not depend on high quality water, e.g. cooling does not require clean water. But water quality may also be connected to water risk. In a polluted area there is a risk that regulations change with the results that the water treatment need to be improved to meet the new demands from the municipality (Maitra and Stuchtey, 2013).

One of the more spectacular results of the study that most sites get high scores in Risk of Ecosystem Threat. Since water stress assessment is in the developing stages it is difficult to know how well an index score correspond to reality. Unreliability is a major drawback of all water stress indices. However, the threat to an ecosystem is assumed to be more difficult to estimate than parameters such as water availability and pollution. According to Brown and Matlock (2011) it is difficult to measure the connection between the reliability of a freshwater system and how well the ecosystem is functioning.

5.2.1 Selection of one tool

The Global Water Tool and the Water Risk Filter are here compared in order to provide information that could possibly be of use in a future water stress assessment. The tools are compared with respect to indices in the tools and reliability.

Water Risk Filter can be used to measure more indices, 33 water related indices are calculated on a basin level in the Water Risk Filter compared to 6 in the most resent update of Global Water Tool. Although relevant water stress indices for this study were easier to find in the Global Water Tool than the Water Risk Filter.

With regard to reliability both tools were found to provide the user with knowledge of water stress on a global scale. With regard to reliability of the actual assessment both tools have a major drawback. Neither of the tools provided any information of the degree of confidence of the score. It would have been very helpful if the scores had been shown together with confidence information (e.g. medium evidence, high agreement), which is the standard of IPCC's climate reporting (Jiménez Cisneros et al., 2014). Without that kind of information it is difficult to know if one tool gives a more reliable assessment than the other. However, in this study both tools have been found to be more or less equal with regard to reliability. The developers of both tools gave sources for all indices and databases, see (WBCSD, 2015b) and (WWF-DEG, 2015b).

Neither of the tools can give highly reliable information due to the large gaps in the datasets of all current water stress indices. The tools did not have access to datasets with the level of detail needed to estimate the water situation at a given location (Reig et al., 2013). The datasets and models needed in order to accurately estimate water availability were not available at the time of this project and IPCC reported that more computing power and research would be needed in order to improve the spacial resolution of environmental models (WWAP, 2015b). Because of the shortcomings of the tools Mueller et al. (2015) concluded that information of the local water situation at production sites would still be essential for companies that use global water tools.

The tools have a difference concerning transparency. The Global Water Tool shows "no data" instead of an assessment for some sites. Water Risk Filter is less transparent; a score could be calculated apparently without any data for some, or all, indices that the Water Risk Filter uses to calculate the average score.

Because the tools are relatively similar the most important factor in the selection of a tool was found to be which indices the tool can measure. In this study Baseline Water Stress was preferred to the other indices because if was found to be most clearly connected to water stress. Therefore WBCSD's Global Water Tool that measures Baseline Water Stress was to some degree preferred to WWF-DEG's Water Risk Filter.

6 Conclusions

There is no absolute definition of water stress, which makes it a difficult subject to discuss and measure. Although the general opinion seems to be that there is no water stress in an area if there is sufficient amount of freshwater of good enough quality for humans and the ecosystem.

Among the five evaluated indices in this study the WRI index Baseline Water Stress is found to be the most suitable index. It is mainly preferred because of the clear connection to water stress. As a result of using Baseline Water Stress 38 SCA sites are located in areas where the estimated level of water stress is moderate to high. That can be regarded as a relatively large number. However, SCA as a global company is likely to be affected by water stress since water stress has been reported to be a global problem. For instance, Revenga et al. (2000) estimated that 40 % of the world's population in 2000 lived in water stressed areas, and that percentage was expected to increase.

All indices in this study were calculated based two types of information. Firstly, the results were based on the GPS coordinates for the sites. Secondly, the results were based on information connected to the GPS coordinates that was available in the datasets of the indices. The GPS coordinates were thus the only corporate information that affected the outcome of the assessment.

The use of this water stress assessment is limited because the results are not site-specific and there are large gaps in the datasets that are required to calculate water stress indices. In addition the results are limited because the water tools used in the study did not provide information such as confidence intervals. The tools could be argued to generate results with a false sense of precision. Therefore it would be necessary to gather knowledge of the local water condition in order to get a more accurate estimate of water stress at a site level.

To conclude, water stress assessment is expected to become more important, and possibly more reliable, in the following years. A potential extension of this study is to estimate business water risk. In that case water stress would be one factor among many factors that are measured to estimate the risk of water related events at the sites.

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