FINAL REPORT ON CLIMATE RISK ASSESSMENT OF [redacted] FACILITES

University of Illinois at Urbana-Champaign Team
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[redacted] **Team**
[redacted]

Executive Summary

[redacted] [redacted] ([redacted]. [redacted] recruited the University of Illinois team to conduct a climate risk assessment (CRA) for 157 of their main facilities. The University of Illinois team holistically analyzed the following climate risk indicators: water stress, drought vulnerability, flood vulnerability, air pollution, energy infrastructure, annual temperature rise, wind, tornadoes, and wildfires. For each climate risk indicator, open-access tools were utilized to source historical, current and projection data to represent the overall climate risk for each facility of a list of facilities provided by [redacted] Geographical Informational System (GIS) software ArcGIS was used to present the climate risk for each location utilizing spatial geographical information. The deliverables of this project include i) a tabulated representation of the climate risk for each facility location across each climate indicator and ii) Map of results within ArcGIS in an easily navigable format, such that panning over an individual site would allow [redacted] to access the risk values for the climate indicators. This deliverable is intended to be a visual representation of the primary deliverable, the table, in order to provide a holistic look at the climate risk. This table and GIS map will be utilized by [redacted] in order to create a climate mitigation plan for their most vulnerable sites. This climate mitigation plan will be implemented by 2030.

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Background

Partner Profile

[redacted] ([redacted] is committed to a sustainable future. [redacted] seeks to alter the environment of buildings and provides building projects, technologies, software and services in order to accomplish this goal. [redacted] invests in the advancement of sustainable practices with their work. [redacted] continually achieves and creates new sustainability goals and environmental risks to impact how sustainable practices are implemented.

Project Description

The University of Illinois team was tasked with providing a Climate Risk Assessment (CRA) for facilities and suppliers of [redacted] In this assessment, nine different environmental indicators were evaluated in order to determine the environmental risk to the facilities. The information provided by the assessment will allow [redacted] to create mitigation plans for facilities that are at a high risk to environmental impacts within the next ten years. A climate risk assessment for [redacted] facilities of this scope has not been conducted before.

Project Definition

Project Objectives and Justification

The objectives for this project were to i) find open-access tools which have historical data, projections to at least 2030, and have GIS Information available, ii) supplement any indicators lacking such open access tools with primary research literature, iii) develop methodology to present the raw data, iv) create a presentation to show results to the [redacted] team and v) provide a table of reliable data for [redacted] to base their climate mitigation plans off of.

In order for [redacted] to create an effective mitigation plan, their facilities must be analyzed with region-specific data for the climate risks most prevalent. Open-access tools are the most accessible way to assess aggregate data; the tools are often based on the research of neutrally inclined research facilities, benefitting from peer-review. Additionally, the open-access tools are created with external use in mind; many have functions which integrate user data needs. For indicators which may not have a fitting open-access tool available with a free public use license, supplementary research was used to create an analysis framework for indicator analysis within realistic boundaries for the timeframe of the project.

Project Scope

The project scope assessed 157 [redacted] facilities across the globe. Most sites are located in North America; however, there are a considerable number of sites in Asia-Pacific and Europe. These sites were analyzed for climate indicator risks for 2030. The University of Illinois team analyzed the following climate risk indicators from September to December 2020 (the timeframe in which the University of Illinois Team was able to perform this CRA): water stress, drought stress, flooding, annual temperature rise, air pollution, power outages, wind, tornadoes, and wildfires. The project scope faced no major alterations, with overall objectives of the project maintained and achieved with relative success. All original aspects of the scope were deemed necessary and vital to the success of the project. The project was conducted in four main phases:

Phase One, or the individual climate indicator open-source database acquisition

Phase Two, or the individual risk synthesis

Phase Three, or the GIS Integration

Phase Four, or the synthesized risk synthesis

Deliverables

The University of Illinois team prepared the following deliverables: i) a table of [redacted] facilities showing the vulnerability of each location for each climate indicator, ii) a final report, in the form of a PowerPoint presentation on the findings and conclusions, iii) a geospatial map allowing for visualization of the data and iv) a methodology report to assist [redacted] in future Climate Risk Assessment (CRA) endeavors, including an appendix with additional resources where relevant, both climate tools at cost and additional research.

Project Barriers and Scope Adjustment

General Project Barriers and Scope Adjustments

Generally, the largest barriers to the project were faced during Phase One, or individual climate indicator open-source database acquisition, of the project. Finding open-access data with data projected to 2030 for climate indicators is quite difficult. From the University of Illinois Team's experience, it is notable that consultancy firms and insurance firms are doing quite a bit of in-house analysis in order to assess a given climate indicator. This means that a large proportion of resources are dedicated to acquiring accurate, comprehensive data. The largest scope adjustments included acknowledging gaps in the analysis pertaining to i) timeline of data collection, ii) unavailable projections of data, iii) inability to access global data, and iv) low granularity for the data, such that analysis existed at a granularity at a country level or less.

Additionally, the exchange of GIS data between the [redacted] team and the University of Illinois Team was exceptionally cumbersome. ArcGIS Online has complicated regulations between sharing permissions and user privileges, making it difficult to privately share data between users from different organizations. This should be considered in future projects where collaboration or consultancy with an external organization occurs.

Water Stress

Water stress was one of the first indicators completed in analysis. Considering that the tool utilized to analyze water stress was comprehensive, open-source, and allowed for individual data input, there were no project barriers or scope adjustment required for this indicator.

Flood & Drought

Flood and drought vulnerability, both packaged together within the same database, were not difficult to acquire. The tool utilized to analyze the flood and drought vulnerability was comprehensive and open source. One barrier to this indicator was that there were no suitable open-access tools which had data available projecting to 2030. As such, the scope adjustment for this indicator included altering the timeline of this indicator to acknowledge the narrower scope of data.

Air Pollution

Air pollution data for PM 2.5 concentrations was found in two forms: live data and historic data. The largest barrier for air pollution was the lack of projections to 2030. The scope for this indicator was adjusted to include use the 2016 average of PM 2.5 concentration rather than projections.

Electrical Supply/Power Outages

There were significant barriers for this indicator. There was no historic or projected data for power outages that was available globally or for only the US. After researching energy infrastructure, quality of electricity supply from 2017-2018 based on the World Economic Forum was chosen as a proxy for power outages.

Annual Temperature Rise

The data utilized was comprehensive, including globally projected data. There was no scope adjustment for this indicator.

Wind

There was somewhat of a barrier while finding data for this indicator. At first, data was found for average wind speeds at 10 meters off the ground globally. This did not provide clear insight into which [redacted] sites are at risk because no sites' average wind speed was deemed dangerous (≥25mph). Scope was then adjusted to average days per year that winds exceed 50 knots. This data was found for the United States based on historical records.

Wildfires

The first dataset on wildfires was found as live data indicating current and recent fires globally. This data was not used because it is unreasonable to quantify risk with such a small sample size. The scope was then adjusted to large wildfire (≥100 acres) probability analyzed from historical data in the United States.

Tornadoes

Tornado data is unique from the other sets of data because not only did tornadoes lack open-source data that had projections, but there was no available historical data. To overcome these barriers, research-based literature was used in order to analyze at risk facilities and regions. Multiple sources were used, including resources from FEMA and the European Severe Weather Laboratory (ESWL).

Methodology

Tool Research

General Tool Research Methods

Each indicator presented different challenges and therefore required individualized methodology for research. Generally, University library resources, Resource Watch, and Google Scholar were utilized to assess the overall data availability and source supplementary literature where necessary. In the future, depending on [redacted] goals, it may prove worthwhile for staff to conduct in-house analysis, or to partner with a consulting firm able to conduct the analysis for [redacted] using a wider net of resources.

Water Stress

For water stress, the tool utilized was Aqueduct Water Risk Atlas. This tool was ascertained through research conducted on the Resource Watch website. This tool was created by Aqueduct, a facet of the World Research Institute. Aqueduct is a fantastic resource for water-related indicators, databases, and research. The functions of the final tool used in analysis included an option to input a spreadsheet (.xlsx) or csv (.csv) file with location information, either through address or GPS coordinates. Therefore, the risk for each site was automatically and entirely assessed by the Aqueduct Water Risk Atlas tool.

Flood & Drought

For flood and drought vulnerability, the tool utilized was the World-wide Hydrogeological Mapping and Assessment Program (WHYMAP). This tool was created by the Federal Institute for Geosciences and Natural Resources of Germany (BGR). The tool was ascertained by research through Google Scholar. This tool did not include a function to input a spreadsheet with location information to receive a tabulation of the analysis results. Therefore, the GIS integration of the tool was utilized to manually assess risks for each site.

Air Pollution

The data utilized was from the NASA Socioeconomic Data and Applications Center. The data included average PM 2.5 concentrations for every year between 1998-2016, the average over this time span, the trend in PM 2.5 concentration over this timespan and hot spot analysis. The data was also gridded to different levels of granularity: country, administrative 1 regions (states, provinces), and 50km hex bins. The data was found as a layer on ArcGIS online and GIS was used to match the sites with PM 2.5 concentration. For this analysis, average PM 2.5 concentration for 2016 was used at the granularity of administrative 1 hex bins. The data for the trend in PM 2.5 concentration and average PM 2.5 concentration over the timespan is also available.

Electrical Supply

The data utilized for this indicator was obtained the World Economic Forum Executive Opinion Survey. In this survey, over 12,000 business executives across different industries were surveyed and asked to evaluate their country's quality of electricity supply on a scale of 1 to 7, 1 being extremely unreliable to 7 being extremely reliable. GIS integration was used to match the country's score to the site.

Annual Temperature Rise

The data utilized for this indicator was found from the Climate Impact Lab, which used data from CMIP5 climate projections to predict temperature rise (deg. C) from historical (1981) to the next 20 years (2020-2039), mid-century, and end of century. This data also included different emissions pathways, RCP 2.6 (low emissions), RCP 4.5 (moderate emissions), and RCP 8.5 (high emissions). For the analysis, the temperature change for the next 20 years was used along with two emissions pathways, RCP 4.5 and RCP 8.5.

Wind

Data for this indicator came from the National Oceanic and Atmospheric Administration (NOAA) National Weather Service, Storm Prediction Center. The data was presented in a map indicating average days per year with wind speeds of 50 knots or greater, as areas in the United States based on historical records of both measured and estimated gusts from the year 1986 to 2015. Each [redacted] site was manually given the value for what area they fell on in the map and entered into a csv.

Wildfires

Data for this indicator came from the United States Geological Survey (USGS) Fire Danger Forecast's Large Fire Probability. Using moderate resolution satellite imagery (375 m^2), fuel conditions such as assessments of the relative greenness, the Normalized Difference Vegetation Index (NDVI), and the departure from the average weekly NDVI, are used to produce a percent probability that a large fire (≥100 acres) will occur. In 2020, each day's percent probability raster GIS files (.tiff) was uploaded to ArcGIS Pro, and the spatial analyst tool *extract multi values to points* was used to take daily values at each site. This data was then exported to a spreadsheet where daily values at each site was averaged to give average risk a fire ≥100 acres occurs.

Tornadoes

The literature used for this data are FEMA Tornado Hazards and Risk in Midwest USA and Southeast USA , MPDI Tornado Risk Climatology in Europe and the European Severe Storms Laboratory Climatology of Tornadoes in Europe. All of these sources use historical data to evaluate climate risk based how many tornadoes of a rating of F2 (Fujita Scale) have occurred in a certain region. FEMA bases the region of risk in a 3,700 square mile region while the European sources both base risks off of a region of 10,000 square kilometers.

Indicator Risk

Water Stress

The Aqueduct Water Risk Atlas algorithm performed the risk assessment based on the geospatial information input by the original researchers; the final result was a tabulated risk assessment specific to the facilities in question. This tabulated result was used in the indicator and synthesized risk analysis. To represent the results on ArcGIS, the data was input into ArcGIS Online in csv (.csv) format on its own layer. The results were then modified to fit a general format of blue/green as lowest risk, orange/yellow as moderate risk, and red as high risk.

Flood & Drought

The WHYMAP was not as comprehensive of a tool as the Aqueduct Water Risk atlas, as it did not allow for the input of a spreadsheet. Therefore, there are two options in order to ascertain the risk values for a site: one, to use the WHYMAP map viewer or two, to use ArcGIS to assess the risk. With option one, the WHYMAP map viewer allows a user to input an individual address to see the risk calculated for the exact location input. However, only one location can be input at a time. With option two, a layer of locations needed for assessment can be uploaded, allowing all locations to be manually assessed in sequence. ArcGIS does not currently support a join-feature for this tool, as the WHYMAP GIS information provided does not have polygon information suitable with the ArcGIS layers utilized for GPS coordinate locations. This indicator analysis was a bit more cumbersome than the water stress indicator, and the system could certainly be refined. Given more time, the original GIS information may have been able to be converted. After analyzing the site risks, the results were then modified to fit a general format of blue/green as lowest risk, orange/yellow as moderate risk, and red as high risk.

Air Pollution

The air pollution data (average PM 2.5 concentration from 2016) required the use of ArcGIS to join the data to the individual sites. The risk cutoffs were assigned based on WHO and US EPA guidelines for annual PM 2.5 concentration, 10 $\mu g/m^3$ and 12 $\mu g/m^3$ r respectively. Low risk was assigned as less than 9.5 $\mu g/m^3$ to allow for a threshold between low and moderate risk. Moderate risk was defined as between 9.5 to 12 $\mu g/m^3$, while high risk was defined as above 12 $\mu g/m^3$. Following GIS integration, an excel file was obtained from the layer and the level of risk was assigned to each site via Excel functions.

Electrical Supply

The quality of electricity supply data was joined to the site locations using ArcGIS. The risk levels were assigned based on the 20th and 80th percentiles of the entire dataset by country. There were no significant natural breaks in the data. Below the 20th percentile was assigned as high risk, with the quality of electricity supply ranging from 1 – 3.7. Moderate risk was between a score of 3.7 - 6.4 and low risk (80th percentile) was between a score of 6.4 - 7. Following GIS integration, an excel file was obtained from ArcGIS Online and the level of risk was assigned to each site via Excel functions.

Annual Temperature Rise

The temperature data was downloaded from the Climate Impact Lab. The 50th percentile of projected (2020-2039) summer and winter temperatures were used to calculate the change from historical temperature (1981) for each country. The summer and winter temperature changes from historical were averaged to determine the projected temperature rise for each country. This was done for both the RCP 4.5 and RCP 8.5 emission pathways. There was no significant natural breaks in the data, therefore, risk levels were assigned based on the 20th and 80th percentiles. For RCP 4.5, low risk was between 0 and 1.3 deg C, moderate was between 1.3 and 1.8 deg C, and high risk was greater than 1.8 deg C temperature rise. For RCP 8.5, low risk was between 0 and 1.5 deg C, moderate was between 1.5 and 2.1 deg C, and high risk was greater than 2.1 deg C temperature rise.

Wind

The data from NOAA shows average greater than 50 knot wind days as <1, 1-2, 2-3, 3-4, 4-5, 5-6, 6-7, and >7 days per year. There are no significant natural breaks in the data; therefore, low risk is 0-3 days, moderate risk is 3-6 days, and high risk is 6-7+ days.

Wildfires

Analysis of data from USGS yielded an average percent probability a large fire occurs at each site, 0% being low and 100% being high. Many sites were found in "unburnable" or agricultural areas; therefore, they were given a value of 0%. All of the sites were found to be less than 40% so the risk values were assigned as follows: extremely low is 0%, very low is 0-20%, low is 20-40%, moderate is 40-60%, high is 60-80%, and very high is 80-100%.

Tornadoes

Data collected by the literature supporting tornadoes needed to be manually inputted into a csv file to use the data in ArcGIS. One common aspect of each source is that they all provide a map of the region of interest that highlights the tornado risk in an area. The coordinates of each facility were referenced to determine which source the risk needs to be analyzed from and assigned risk based on the literature supporting that region. The data risk was separated into five categories ranging from very low: <1, low: 1-5, medium: 6-15, high: 16-25, very high: >25.

GIS Analysis

The GIS analysis was mainly utilized to present the data visually and to utilize some simple join features. However, extensive knowledge of GIS software is not required to perform the actions required for this project. ERSI has many guides on the functionality of ArcGIS

Online and ArcGIS Pro. Generally, the join features can be replaced by joining information desired within a spreadsheet, which can then be uploaded as a layer to ArcGIS Online. The map has various options for toggling the presentation of an indicator, including color, shape, fill, size, thickness, transparency, drawing style options (which are automatically provided based on ArcGIS estimation of the best option for data provided), data category nesting options (for example, nesting extremely low and very low under a broad category of low), and more. The map can also be converted into a dashboard app, which allows a user to interact with the results of the map without privileges to edit the map itself. There are various dashboard apps available without

Synthesized Risk Analysis

Risk Values and Normalization

To synthesize the overall risk of each site based on the 9 indicators, the indicator risks were tabulated and normalized to determine the aggregate risk. First, a universal value was assigned to each risk level for all indicators.

- Extremely low: 0
- Very low: 1
- Low: 2
- Moderate: 3
- High: 4
- Very High: 5

Most indicators were ranked on a scale of low/moderate/high, but wildfires and water stress included very high, very low and extremely low (wildfires only). These values for the 9 indicators were summed for each site and normalized based on the maximum risk level that was able to be assigned to each individual indicator (high/very high). If sites did not have data for a specific indicator, that indicator was not included in the calculation. The synthesized risks calculated ranged from 0 to 1.

Unweighted

The unweighted risk was calculated using the above process.

Weighted

The weighted synthesized risk factored in the importance of each indicator to [redacted] Indicators were rated on a low/medium/high scale of importance, with low given a weighting of 1, medium given a weighting of 2, and high given a weighting of 3. The importance of each indicator was determined by [redacted] facility management team.

- Water Stress: Medium
- Droughts: Medium

- Flooding: Medium
- Air pollution: Low
- Energy infrastructure: High
- Temperature rise: Low
- Winds: Medium
- Wildfires: Medium
- Tornadoes: Medium

A similar process was used to calculate the weighted synthesized risk. The weighting was multiplied to each indicator's risk value and then summed. This was normalized based on the maximum risk level that was able to be assigned to each individual indicator (high/very high) and the weightings for that respective indicator.

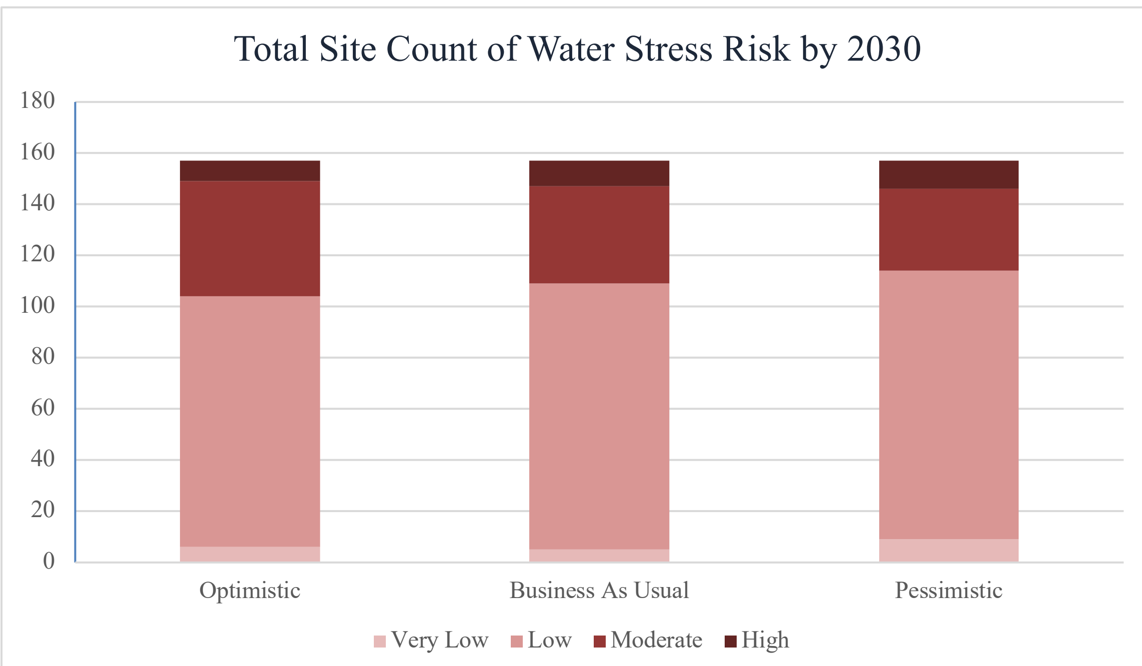
Implications of Findings

Analysis of Research

The following section depicts the results of the indicator risk synthesis analysis. The values are total site count for a given scenario/indicator.

Water Stress

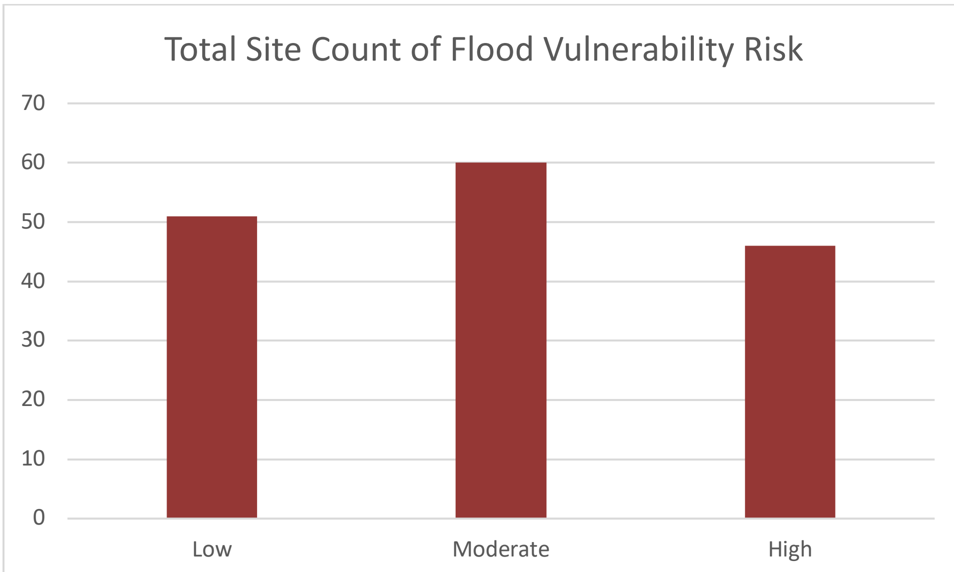
Scenario	Very Low	Low	Moderate	High
Risk Values (Change from baseline)	1.4x decrease ≥ x > 2x decrease	Near Normal ≥ x > 1.4x decrease	1.4x increase ≥ x > Near Normal	2x increase ≥ x > 1.4x increase
Optimistic	6	98	45	8
Business as Usual	5	104	38	10
Pessimistic	9	105	32	11



The site count for water stress risk calculated as the change in water stress by 2030 based on a 2020 baseline according to various scenarios.

Flood Vulnerability

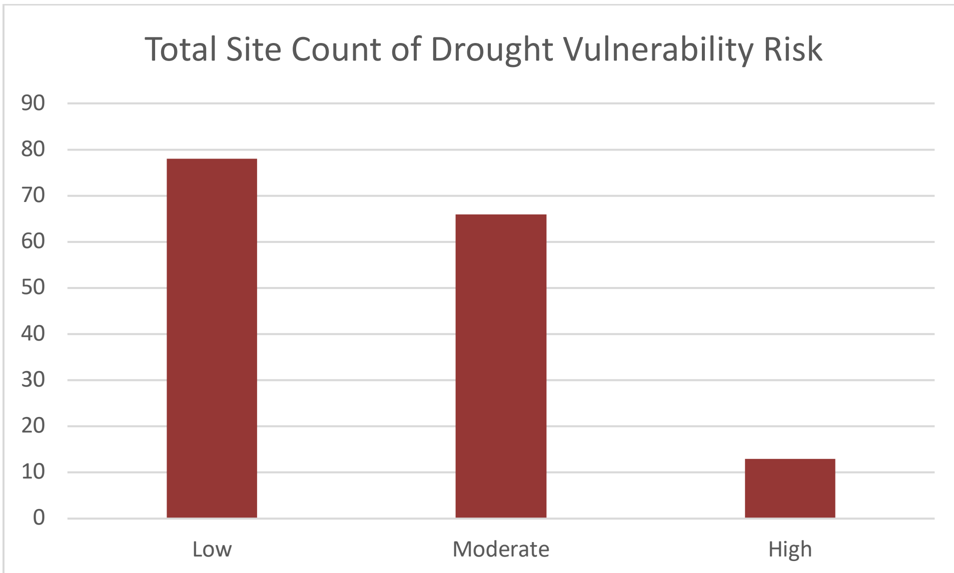
Risk Values (Qualitative measure determined by source)	Low	Moderate	High
Number of Sites	51	60	46



The site count for flood vulnerability risk determined by source.

Drought Vulnerability

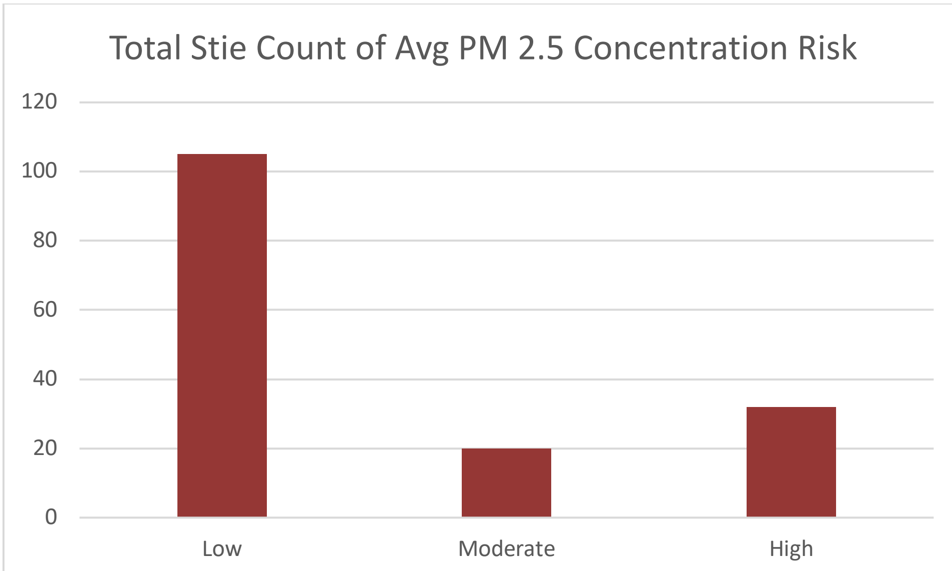
Risk Values (Qualitative measure determined by source)	Low	Moderate	High
Number of Sites	78	66	13



The site count for drought vulnerability risk determined by source.

Air Pollution

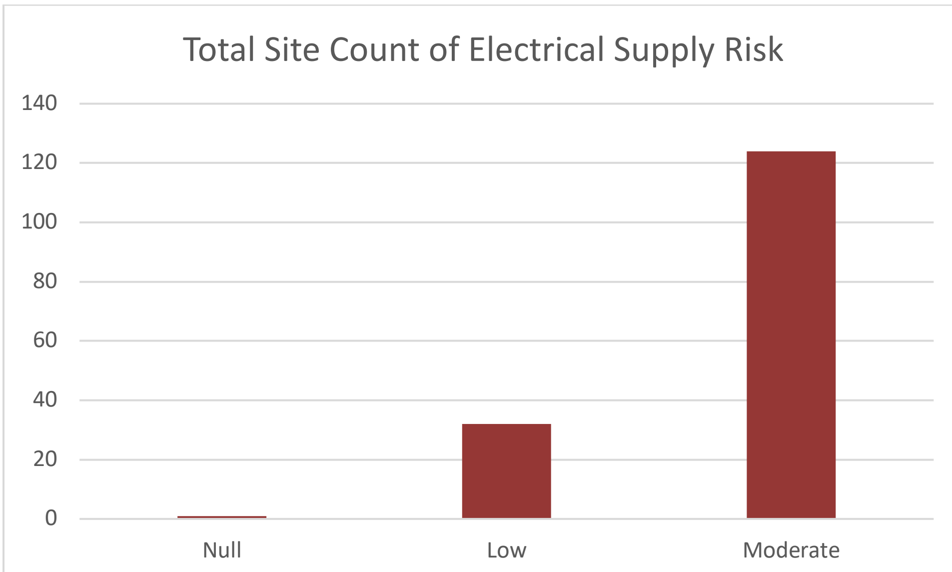
	Low	Moderate	High
Risk Values (PM 2.5 concentration)	< 9.5 µg/m^3	9.5 - 12 µg/m^3	> 12 µg/m^3
Number of Sites	105	20	32



The site count for air pollution calculated as the average concentration of particulate matter 2.5 between 1998-2016.

Electrical Supply/Power Outages

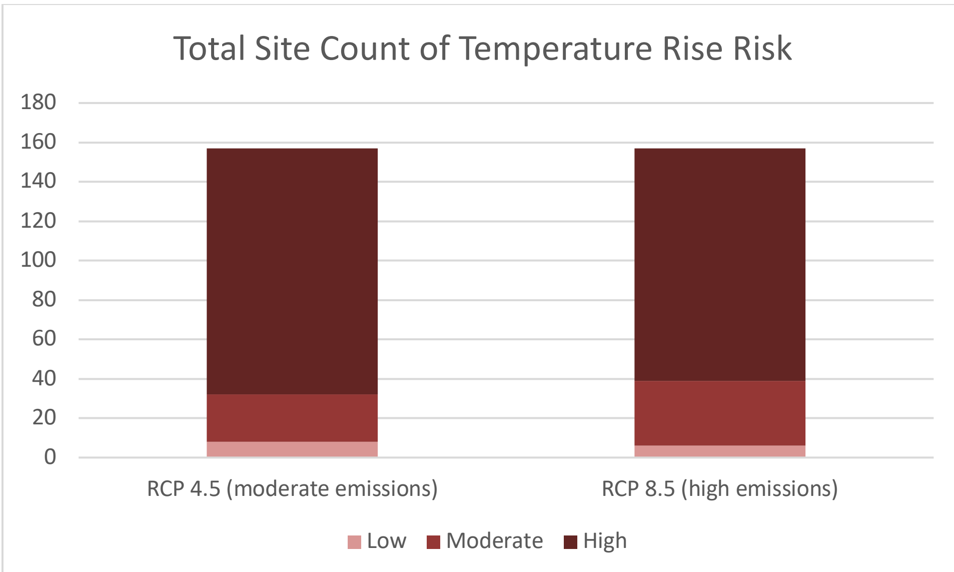
	Low	Moderate	High	Null
Risk Values (scale of reliablility 1-7)	6.4 - 7	3.7 - 6.4	1 – 3.7	No data
Number of Sites	32	124	0	1



The site count for electrical supply risk calculated as a scale of reliability 1-7. 1 being extremely unreliable, 7 being extremely reliable.

Annual Temperature Rise

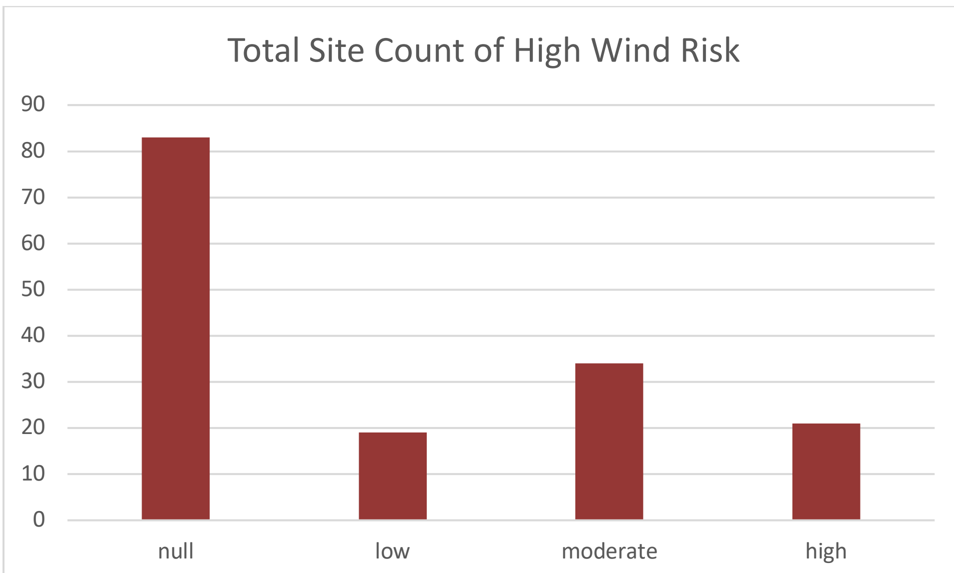
Scenario	Low	Moderate	High
Risk Values (Change in temperature (°C) from historical, 1981)	RCP 4.5.........0 – 1.3 RCP 8.5.........0 – 1.5	RCP 4.5.......1.3 - 1.8 RCP 8.5.......1.5 - 2.1	RCP 4.5............> 1.8 RCP 8.5............> 2.1
RCP 4.5 (moderate emissions)	8	24	125
RCP 8.5 (high emissions)	6	33	118



The site count for annual temperature rise risk calculated as change in temperature (°C) from the historical baseline in 1981 according to two scenarios.

Wind

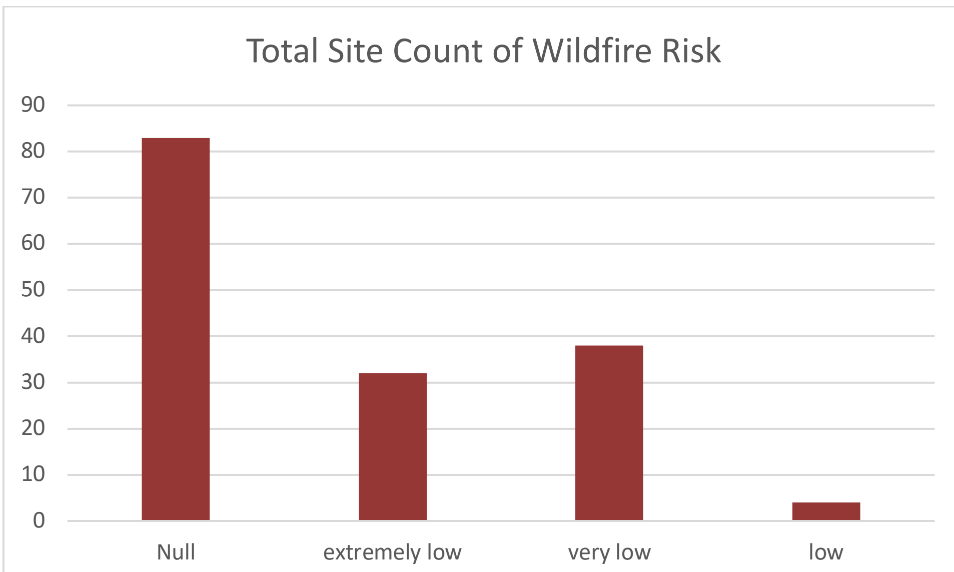
	Low	Moderate	High	Null
Risk Values (mean number of days per year with wind speeds ≥ 50 knots)	0 - 3	3 - 6	6 - 7+	No data
Number of sites	19	34	21	83



The site count for high wind risk calculated as the mean number of days per year with wind speeds of 50 knots or greater.

Wildfires

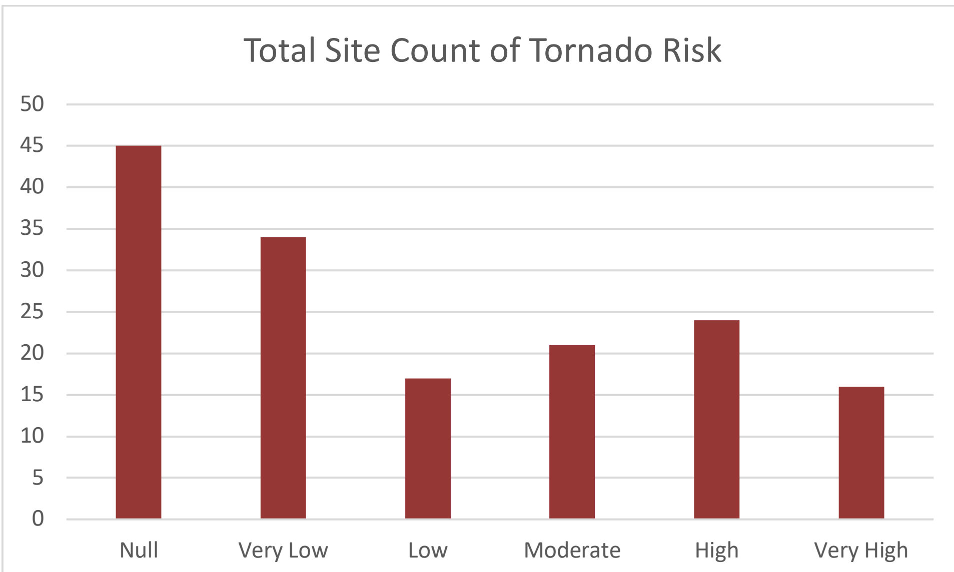
	Extreme-ly Low	Very Low	Low	Moderate	High	Very High	Null
Risk Values (avg. percent chance a ≥100 acre fire occurs)	0%	0 - 20%	20 - 40%	40 - 60%	60 - 80%	100%	No data
Number of Sites	32	38	4	0	0	0	83



The site count for wildfire risk calculated as the 2020 average probability a fire ≥100 acres occurs.

Tornadoes

	Very Low	Low	Moderate	High	Very High	Null
Risk Values (Frequency of tornadoes in a region with a rating of F2 or higher)	< 1	1 – 5	6 – 15	16 – 25	> 25	No data
Number of Sites	34	17	21	24	16	45



The site count for tornado risk calculated as frequency within a region from 1950 – 2005.

Synthesized Risk Results

[redacted]

Implications of Findings

The data for the synthesized risk shows the highest at-risk sites when evaluating unweighted and weighted indicator risk values. The findings reveal [redacted] as highly vulnerable sites for the indicators analyzed. Multiple sites appear to have equal values of synthesized risk, which is why, for example, in the unweighted ranking, 3 sites fall into 2nd place. The implications of this results must be considerate of the indicators represented at each site. 3 of the 9 indicators lack global data (wind, wildfires, tornados) and 7 of 9 indicators lack data projected to 2030 within the database. For example, site 234 in [redacted] and site 100 in [redacted] lack risk values for winds, wildfires, and tornados. This may misrepresent the relative risk across all [redacted] sites analyzed. Future analyses may be more accurate should they be evaluated for synthesized risk based off consistency of data, where site evaluation includes values for each site of a given indicator. An alternative is to analyze synthesized risk regionally, because for the indicators that lack a global scope, the data availability is clustered in regions. For example, wind and wildfire risks have data for only sites in the [redacted], and tornado risk has data for only sites in the [redacted] Evaluating the synthesized risk for these regions separate from other regions would provide greater insight into the overall vulnerability of [redacted] sites.

Analysis of Deliverables

Project Deliverables

The deliverables of this project include i) a tabulated representation of the climate risk for each facility location across each climate indicator and ii) Map of results within ArcGIS in an easily navigable format, such that panning over an individual site would allow [redacted] to access the risk values for the climate indicators. This deliverable is intended to be a visual representation of the primary deliverable, the table, in order to provide a holistic look at the climate risk. This table and ArcGIS map will be utilized by [redacted] in order to create a climate mitigation plan for their most vulnerable sites.

Table of Results

The results of the analysis are tabulated in an Excel file, including the site's location ID, data for each indicator, risk level for each indicator, the unweighted synthesized risk, and the weighted synthesized risk. The data for each individual indicator is also available.

ArcGIS Map

The results can be viewed visually via ArcGIS Online. A free account may be used to view the map. There are layers for synthesized risk, as well as each individual indicator for flexible viewing. The data for individual sites can be accessed further by clicking the site's pin. Additionally, a file compatible with ArcGIS Pro is provided.

Limitations

There are a few limitations for the climate risk assessment. Firstly, most (7/9) indicators do not have projected data to 2030. For those seven indicators (drought, flooding, air pollution, electricity, winds, wildfires, and tornadoes), historical data was used to assess the risk of each facility for those indicators as projected data was not available. For these indicators, the University of Illinois team does not believe the risk will decrease in the next 10 years; however, some risks may be greater than the historical data suggests due to climate change. Further analysis can be done to analyze proxy variables that can be related to these seven indicators as well as datasets that are not open source.

A second limitation is that three of the nine indicators (winds, wildfires, tornadoes) did not include global data. Winds and wildfires included data for the US, while tornadoes included the US and Europe. This means that roughly half of the sites analyzed are missing data for these three indicators. This also affected the synthesized risk analysis. As mentioned in the methodology, the indicators with no value were excluded from the site's synthesized risk. Therefore, the six global indicators (water stress, drought, flooding, air pollution, electrical supply, temperature rise) were weighted higher for sites outside the US in this analysis. This affected the top 10 sites for both weighted and unweighted synthesized risk as both consisted of only sites outside the US and Europe.

The final limitation noted is the use of quality of electrical supply as a proxy for power outages because historical and projected power outage data was not available. This may have particularly affected the weighted synthesized risk because this indicator was weighted high importance, while all other indicators were weighted low and medium. Furthermore, this indicator used data that was at the country-level, which makes the analysis less granular for each specific site.

Recommendations

Indicator Data

The research conducted lacked data for projections to 2030 for 7 of 9 indicators and global data for 3 of 9 indicators. This changed how risk was analyzed for facilities because some facilities did not have information for some indicators. If an assessment of the same scope will be done in the future, there should be an emphasis on researching data that can be projected to 2030. The University of Illinois Team mainly found data for this assessment from open-source tools since there are many resources available. However, this constrained the data accessible. Some sources can be bought that have more data for the indicators. Private consulting agencies, insurance firms, and other private corporations may have their own sources for risk assessments as well. A budget or outreach to one of the aforementioned parties could be beneficial to attaining global data and projections for the indicators that did not have this data. This would help improve the synthesized risk analysis of the assessment because all indicators would have projected data and a risk value for each indicator.

Appendix

Appendix Guide

The final tool utilized in this analysis will be listed in the first position under the individual indicator. Any additional sources that may be helpful in future analyses will be listed in the positions following.

Additionally, this appendix covers an explanation of budget.

Budget

This project had no budget allotted to the University of Illinois Team. However, there were certain advantages conferred due to the team's ability to utilize campus resources. For example, GIS software was provided to students at the university as a provision of student tuition and fees. Additionally, library resources assisted in tool research, which positioning as an academic institution certainly assisted with in terms of access. The team also received use of Microsoft Suite (Word, Excel, and Project) in a manner equal to the GIS Software. Beyond that, no budget was required for the analysis.

In future projects, it may prove helpful to have a budget allotted for consultancy firms to conduct this analysis with a wider range of in-house database analysis and resources. Beyond that, the subscription to ERSI software utilized in this project will be helpful.

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