MEASURING BENEFITS OF URBAN HEAT ADAPTATION

CASE STUDY OF THE REVITALIZATION OF IPIRANGA STREAM IN SÃO PAULO/BRAZIL

Tazio Cavalheiro Viadana[1], Alex Abiko[2]

1 Master's student in Urban Engineering from the graduate program in Civil Engineering at the Escola Politécnica of the University of São Paulo.
tazio.viadana@usp.br

2 Professor at the Department of Construction Engineering at the Escola Politécnica of the University of São Paulo.
alex.abiko@usp.br

ABSTRACT:

The unpredictability of climate originated from anthropic changes in the environment, made extreme heatwaves occurrence more frequent and intense in cities. Between 2000 and 2019, global data reported 432 natural hazards, in which the majority were heatwaves. This represents an increase of 332% compared to the previous records from 1980 to 1999. Heatwaves have a negative impact in the environmental and socioeconomic axes. The health of low income elderly people is especially vulnerable to the exposure to excessive heat. The increase in numbers of hospitalizations can lead to an overuse of the health system, affecting the provision of services and the economy. In addition, heatwaves also impacts the road infrastructure with the melting of asphalt making roads unsafe, and unusable. From 2006 to 2015 the city of São Paulo experienced seven heatwaves, with temperatures above 31.6°C, in an interval of 70 days. During this period, 4,879 elderly people died due to circulatory system or respiratory diseases, associated with the heat. To reduce these impacts, it would be necessary to implement resilient actions to heatwaves, which include building urban parks, revitalization of urban waters and investing in green roofs among others interventions. Thus, we aimed to measure the benefits of streams revitalization in reducing the local temperature, and returning part of its ecosystem functions. We used the toll the Heat Resilient Cities tool, developed by C40, combined with a literature review and data collection in the Ipiranga Stream. After application, for a 50-year horizon, we found a reduction of 2 to 17 days with an above-average temperature. Thus, the revitalization of the Ipiranga Stream has the potential to prevent the death of 45,000 to 25,500 people from heat-related diseases, saving from US$ 41,313 up to US$ 27,636, in scenarios of RCP 2.6 and RCP 8.5, respectively.

KEY WORDS

Heatwaves; Impacts; Ipiranga Stream; Revitalization; São Paulo

INTRODUCTION

Heat waves are natural meteorological hazards characterized by a sequence of at least three consecutive days with maximum or minimum temperatures above expectations for the same region and for the same time of the year. Usually, this phenomenon is associated with natural climatic cycles, however, the increase in intensity, frequency and duration are related to the increase in the global average temperature caused by anthropic actions, which is increasingly evident (Guo et al. 2017).

Among the anthropic interferences in the environment, those related to the increase in temperature are: the intensification of the concentration of greenhouse gases in the atmosphere, and the intensification of unsustainable urbanization, such as low concentration of vegetation and a high level of waterproofing impermeabilization and use of construction of low albedo[1], creating conditions for the emergence of urban heat islands, concentrating the heat and increasing the temperature of those areas and the surroundings (Field et al. 2014).

Due to the unpredictability of climatic conditions, largely caused by anthropic actions, heat waves are becoming more relevant, currently the coverage of heat waves reaches approximately 30% of the world population (Mora et al, 2017).

According to the International Disaster Database (EM-DAT), global data indicate the occurrence of 143 heat waves between 2000 and 2019, an increase of 305% when compared to the previous 20 years between 1980 and 1999. Between 2000 and 2019, extreme temperatures caused 13% of all disaster deaths worldwide, 91% of which were due to heat waves. The majority of deaths were registered in the countries of the northern hemisphere and the European continent comprises the majority of deaths (88%). Although, the impacts of high temperatures are more noticeable in places with poor infrastructure with increased mortality and morbidity of vulnerable groups (UNDRR & CRED, 2020).

IMPACT OF HIGH TEMPERATURES ON THE HUMAN BODY

The increase in body temperature triggers peripheral vasodilation mediated by the hypothalamus. This autonomic process leads to an increase in blood flow to more peripheral areas of the body, where heat is more easily dissipated into the environment. Although efficient for controlling body temperature, this mechanism can compromise blood flow to other organs, resulting in a situation of ischemia, and subsequent hypoxia. Another heat-related morbidity is cytotoxicity, which occurs when body temperature exceeds cell thermal tolerance, causing necrosis and disruption of cellular integrity (Counsel, Louis & Bielecki 2017).

The damage caused by chemical injuries, resulting from ischemia, and by thermal injuries caused by thermal cytotoxicity, can compromise the functioning of several organs. These injuries can reduce the effectiveness of heart rate regulation, increasing the risk of cardiac arrest, due to the loss of microfibrillar stretch marks, caused by myocardial fragmentation (Sun et al, 2018).

In addition, dehydration caused by rising temperatures thickens the blood causing vasoconstriction, increasing the risk of coronary thrombosis and stroke. Other examples are loss of brain function, presence of liver endotoxins in the blood, acute tubular necrosis in the kidneys, inflammation in the pancreas, damage to the pulmonary endothelium, resulting in respiratory failure (Rikkert, Melis, & Claassen, 2009).

[1] Relationship between the amount of solar radiation reflected by the surface of an object and the amount of incident solar radiation. This relationship varies according to the texture, color, chemical and biological properties of the surface, as well as the wavelength of the incidente radiation (Nery & Carfan, 2013)

Lesions caused by ischemia and cytotoxicity can also trigger the disseminated formation of intravascular clots, which can interrupt the blood supply to vital organs, which can cause haemorrhages (Jilma & Derhaschnig, 2012).
Another mechanism identified is rhabdomyolysis, when cytotoxicity and / or ischemia disrupt skeletal muscle cells releasing myoglobin, which is toxic to the nephrons and can cause acute renal failure (Tan et al, 1995).
Therefore, sudden changes in air temperature and heat waves can lead the body to thermal stress, causing an overload of the cardiovascular and respiratory system of the human body. The elderly population, over 60 years of age, is the most vulnerable group because they have difficulties in cooling the organism due to their weak cutaneous vasoconstriction, limiting the functioning of the lungs, causing rupture of the arteries and greater risk of stroke. of the physiological characteristics of each individual determine the increased risk of death among the elderly, social and economic factors and the conditions of each place are also essential variables for understanding the high risk of death (Kenny et al, 1997 and Vaneckova, Beggs & Jacobson, 2010).

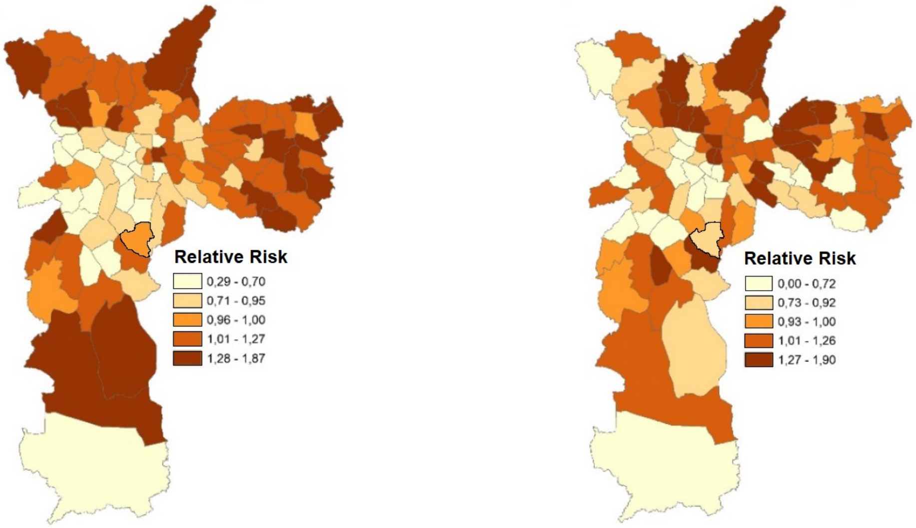
IMPACT OF TEMPERATURES ON INFRASTRUCTURES

Temperatures above 48ºC go beyond the operational safety limit of several types of aircraft, forcing airlines to restrict aircraft cargo capacity, reflecting in increasing flight rates, or even cancelling flights (Wang, 2017).
Depending on the type of material used and the traffic load, high temperatures increase the risk of road pavement deterioration (Daniel et al. 2014). Railway tracks when exposed to temperatures above 32ºC are at risk of warping or buckling, to avoid accidents trains must reduce speed (Margill, 2014).
Fires caused by drought and extreme heat can damage and destroy transmission poles and towers; in addition, high temperatures reduce the electrical transmission capacity and in addition there is an overload of energy plants during periods of extreme heat. The environmental impacts are even higher when the energy source is obtained by burning fossil fuels, degrading the air quality with smog, soot and other suspended particulate substances that associated with the elevated temperature further aggravate the consequences of the public health system. (Davis and Clemmer, 2014; Bartos et al. 2016)

IMPACTS OF HEAT WAVES IN THE CITY OF SÃO PAULO

The city of São Paulo is located in the Southeast region of Brazil, with a population of approximately 12 million inhabitants and has 92 administrative districts. According to Monteiro (1969), the municipality is inserted in two climatic regions: Humid Tropical Altitude and subtropical climate, these regions characterize the climate by alternating seasons, hot and rainy summers and cold and less rainy winters. In addition, the relief, proximity to the ocean and anthropic activities interfere with surface heating and thermal sensation (Tarifa & Armani, 2001)
During the 1960s and 1970s, periods of extreme heat did not reach 15 days a year, however, in 2010 the amount jumped to 40 days and 2014 to 50 days (Geirinhas et al. 2017). Between 2006 and 2015 there were 7 heat waves in the city of São Paulo, with maximum temperatures above 30 ° C. During this period 4,879 elderly people died during the heat waves, 3,381 deaths from diseases related to the circulatory system and 1,492 deaths related to the respiratory system, making an average of 48.3 and 21.3 daily deaths (Moraes & Barrozo, 2019).
Due to the diversity of environmental, social and economic characteristics of each area, the impacts of heat waves will be different [Fig.1]. The mortality of elderly people in the peripheral regions is higher, especially in the eastern and northern regions of the municipality, while in the central-southwest portion

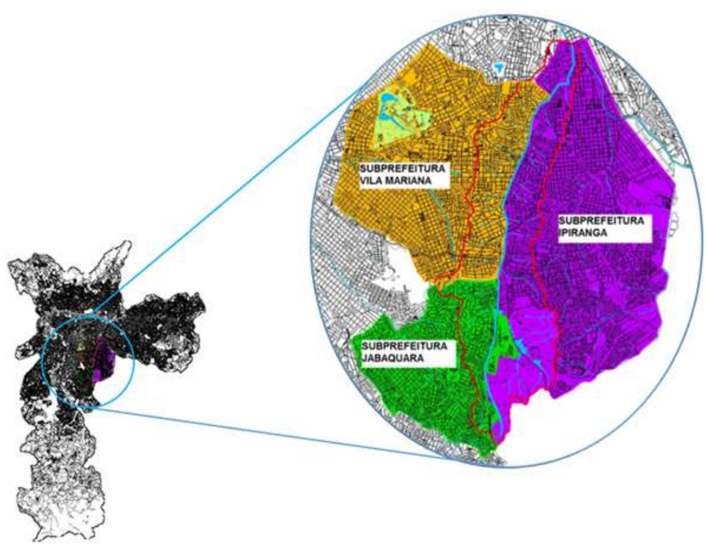
it is much lower. This is because the most vulnerable socioeconomic regions are the east and north, while the southwest axis presents the areas with the best socioeconomic indexes



[Fig.1] Spatial distribution of the relative risk of mortality in the elderly due to diseases of the circulatory system (left) and respiratory system (right), during heat waves in the city of São Paulo from 2006 to 2015. Jabaquara district highlighted (Moraes & Barrozo, 2019).

MOTIVATIONS FOR REVITALIZING THE IPIRANGA STREAM

The Ipiranga Stream has its springs located in the Fontes do Ipiranga State Park, a natural reserve of Atlantic forest, the stream has a length of 9km and flows through the districts of Jabaquara, Vila Mariana and Ipiranga until it's the mouth in the Tamanduateí River [Fig. 2].



[Fig.2] - location of the hydrographic basin of the ipiranga stream and the districts that comprise it.

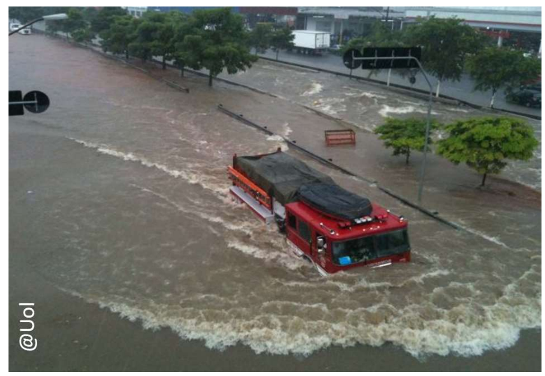
Like most water bodies in the municipality of São Paulo, the Ipiranga Stream has its water quality compromised by pollution, as it receives high amounts of industrial and domestic waste along its path. The basic sanitation company in the state of São Paulo intends to make available approximately R$ 12 million to guarantee the cleanliness of the stream in 2022, the bicentenary year of Brazilian independence and when the Museum do Ipiranga will be reopened (SABESP, 2019).

The revitalization of the stretch upstream of the Ipiranga Stream would serve as a continuation of the revitalization of the Pirarungáua Stream, a tributary of the Ipiranga Stream, located in the interior of Jd. Botanical Garden of São Paulo. The work to revitalize the Pirarungáua Stream was completed in 2007. Previously, the stream ran through an underground channel built in 1940, with brick walls and covered by a slab where the Fernando Costa lane was located. With the removal of the pavement from the mall, the underground channel was removed and the recovery of the Pirarungáua margins began, allowing the stream to run again in the open. The revitalization of the stream allowed the regeneration of the margins [fig.3] with native vegetation allowing the visitor to learn more about the vegetation of the Atlantic Forest, in addition to collaborating with the recovery of the Ipiranga Stream itself (São Paulo, 2008)

[Fig.3] Revitalization process of the Pirarungáua stream, the only revitalized stream in the city of São Paulo.

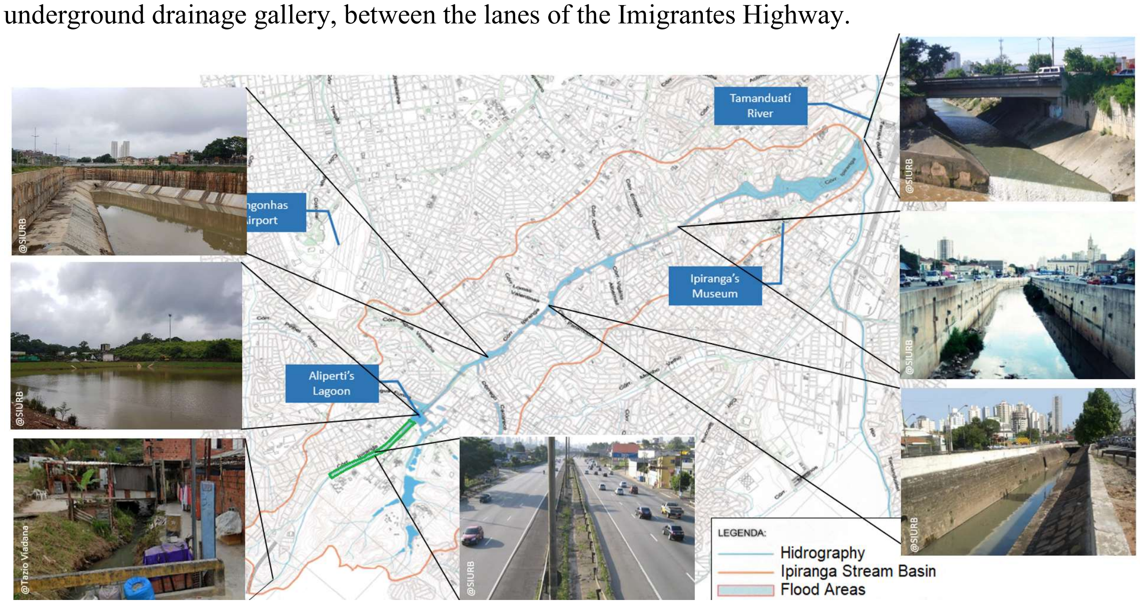
Over the time, the Ipiranga stream has undergone several interventions from its floodplains, subdivisions, implantation of avenues and highways [fig.4], with this the flooding problems worsened [fig.5]. mainly in its middle course and at its mouth, near the Tamanduateí River. In this way, the urban infrastructure department of the municipality of São Paulo, is implementing measures to reduce and control floods in the stream, building 2 reservoirs and works to readjust margins (SIURB, 2015).

[Fig.4] Ipiranga stream inserted in the urban context. margins contained by trapezoidal section in concrete and floodplains occupied by Ricardo Jafet Avenue



[Fig.5] Flooding occurrences in the ipiranga stream in 2019

The construction of two reservoirs aims to reduce and control flooding in the region. Highlighted in green [Fig.6] is the area intended to revitalize the Ipiranga Stream, a stretch where it is inserted in an underground drainage gallery, between the lanes of the Imigrantes Highway.



[Fig.6] Ipiranga Stream Basin presents several types of margin containment, which throughout history have aggravated the occurrence of floods.

According to data from the Department of Urban Development of the Municipality of São Paulo, Jabaquara has 28,900 elderly people, the second district with the largest population over 60 years, second only to the Sacomã district, with 29,220, both located in the south region of the municipality. (SEADE, 2020).
These proposals justify considering the implementation of the revitalization of the stretch of the Ipiranga Stream located in the underground gallery, between the Imigrantes highway. In view of the above, the purpose of this article is to measure the environmental, social and economic benefits of implementing a stretch of the Ipiranga Stream.

METHODOLOGY:

To measure the environmental, economic and social benefits resulting from the implementation of the revitalization of the stretch of Ipiranga Stream, the *Heat Resilient Cities Tool* was used, implemented in the Excel-based program, developed by C40[2] in conjunction with Ramboll[3]. The tool quantifies the impacts related to the health of citizens and the reductions in socioeconomic costs related to certain measures of adaptation to heat, based on a set of social, urban and climatic parameters.
The impacts of adaptation actions are calculated through a combination of multiplying functions based on the data of the action project that is planned to be implemented, population health data and time values for the defined periods, in addition to specific characteristics of the city: location, population density and other input data.
To measure the impacts of the action, the tool calculates the following multiplier items:

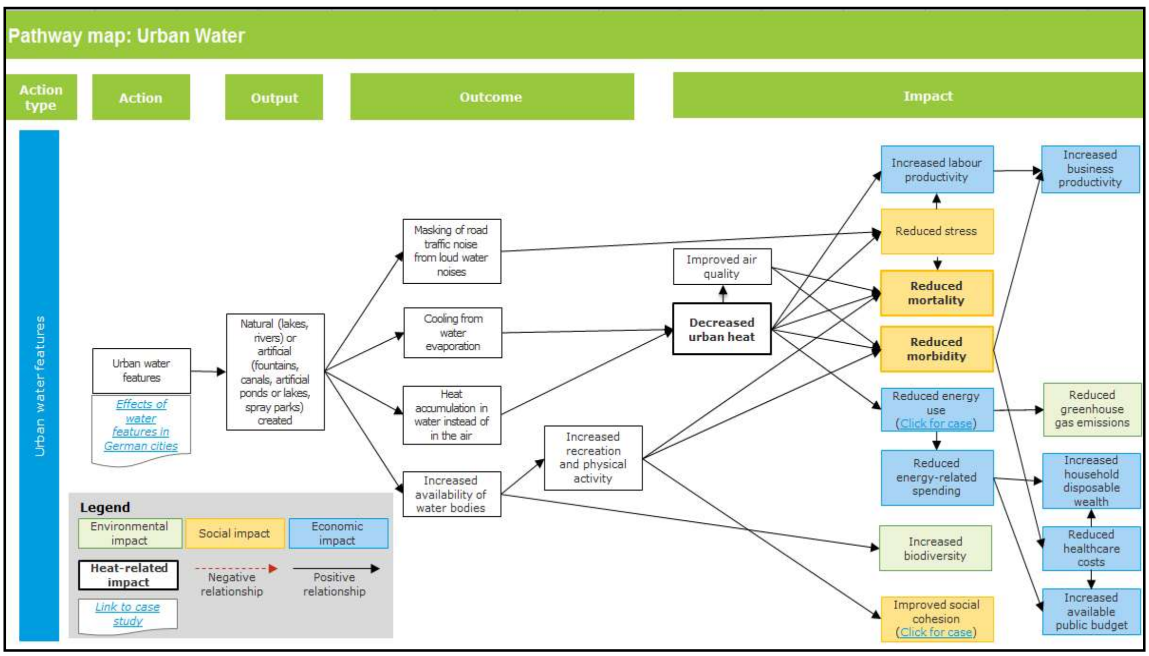
1. The expected temperature change is obtained through the definition of the adaptation action that is intended to be implemented, information on the geographic location of the city and the choice of climatic scenarios (RCP[4]) to be compared;
2. The expected number of days with threshold heat temperatures is calculated based on the input data entered;
3. Additional health risk factor due to heat is obtained through the health multiplier for cases with or without the implementation action, based on the limit temperature value and the selected RCP's;
4. Additional health risk factor is multiplied by the risk of hospitalization, providing an estimate for the heat-related mortality / morbidity risk for each year during the analysed period;
5. The population inserted in the area of influence of the adaptation action is obtained through the population growth of the city and the calculation of the coverage area of the action, multiplying by the population density;
6. Mortality and morbidity risks are multiplied by the number of people within the area of influence of the action for each year considered;
7. The number of lives lost and the occurrences of heat-related morbidity are calculated for each year during the defined period. Mortality is the difference between the number of lives lost

[2] Climate Leadership Group currently connects more than 90 of the largest cities in the world. Its main objectives are to combat climate change and encourage urban actions that reduce emissions of greenhouse gases and other climate risks, increasing health and well-being, creating savings opportunities for urban citizens.
[3] Danish company leader in engineering, design and consultancy, active in the areas of: Buildings, Transport, Water, Environment and Health, Energy and Management Consulting.
[4] Tragetory of greenhouse gas concentration studies adopted by the Intergovernmental Panel on Climate Change (IPCC). The RCPs describe different possible climate futures, based on the volume of Greenhouse Gases (GHG) emitted in the coming years.

between the scenario in which the action is implemented and the current scenario (without the action) for each RCP, multiplied by the statistical value of life. In turn, morbidity is calculated using the product between the cost of hospitalization due to the reduction in hospital admissions expected in the implementation scenario and in the current scenario, without the implementation of the action;

8. Net value of the sum of the cost of each year is calculated using the social discount rate, providing an estimate of the total value providing an equalized basis for comparison in the scenarios with or without the implementation of the adaptation action, for the selected RCP's.

Initially, it was necessary to insert the type of mitigation action to the desired urban heat the impacts of the actions are assessed separately, so it is not possible to carry out a joint analysis with more than one type of action. The possible types of action to be selected are: Urban Parks, Urban Waters and Fresh Surfaces (Artificial or Natural, with vegetal cover). The Urban Water option was selected for this study. On the Pathways tab [fig. 7] the flow diagrams of the chosen action are presented, informing the type of action, the options for applying heat adaptation measures, the results obtained with the implementation of the adaptation measure indicating the relationships and impacts (environmental, social and economic) resulting from these measures, indicating the positive and negative relationships with the results obtained.



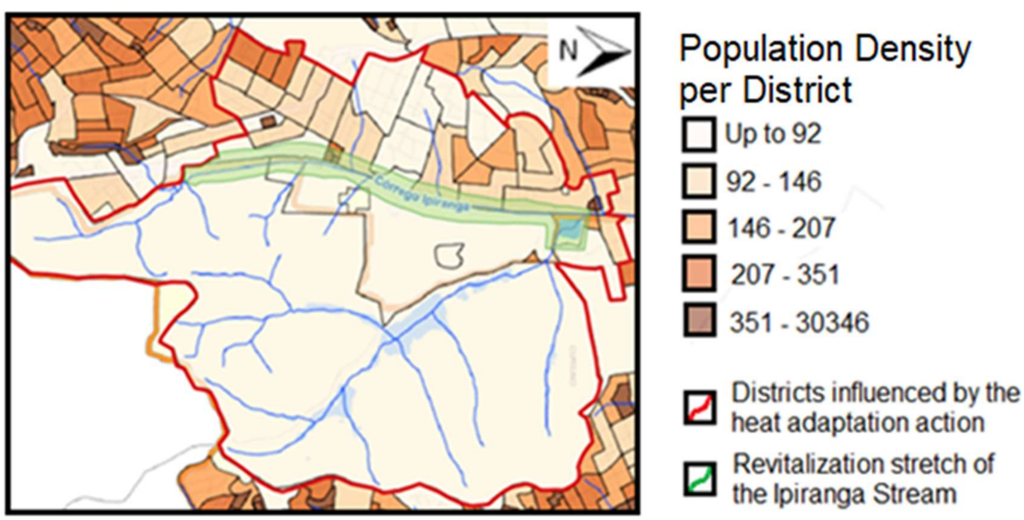
[Fig.7] - Diagram for Urban Waters selected as a heat resilience action.

The next step is the development of multipliers and for that it is necessary to provide input information. To fill in the basic information it is necessary to select the name of the city and the tool itself will identify the Köppen climatic zone where the city is inserted. It is requested to inform the years of beginning and ending of the analysis, for the study the period covered from 2020 to 2050. The social discount rate takes into account the preferences for the monetary value over time and the values vary from 3% to 12 %. A high discount rate means that future monetary values have a higher depreciation. To fill in this information, the rate of 11%, recommended as a standard for Brazilian cities, provided by the tool itself, was used.

About the details of the intended action, it is necessary to present the area covered by the action. After consultation with the project department of the Secretariat of Urban Infrastructure and Works of the Municipality of São Paulo, the area planned for the revitalization of the stretch of the Ipiranga Stream is 8,000 m². Located in the Jabaquara district, between the Imigrantes Highway and the Brazilian Paralympic Committee, Center for Technology and Innovation and the São Paulo Expo exhibition pavilion, up to the height of Aliperti Lagoon, a retention reservoir built in 2020, making a distance of approximately 2,000m.

Regarding environmental data, it is necessary to inform the urban temperature profile above which direct or induced mortality due to exposure to heat may occur. Following specific bibliographic reviews on mortality and morbidity caused by heat in the city of São Paulo, 31.6ºC was adopted. For the purpose of comparing climatic scenarios, the tool provides 4 climatic scenarios: RCP 2.6, RCP 4.5, RCP 6.5 and RC P8.5 and for application in the case study, RCP 2.6 and RCP 8.5 were selected.

Social data was obtained from information contained in two sources. About population data from the Jabaquara district, region of influence of the revitalization of the stretch of the Ipiranga stream [fig.8], such as: quantity, density, population growth and age distribution, were obtained from GeoSampa[5], a geographic information system developed by the Municipality of São Paulo, which gathers georeferenced data from several departments in the city of São Paulo and from the Brazilian Institute of Geography and Statistics (IBGE). For the case study, census districts in the district of Jabaquara were considered close to the thalweg of Ipiranga stream, as they are more likely to be impacted by the action of revitalizing the water body.



[Fig.8] implementation of the revitalization of the upstream stretch of the Ipiranga stream and population distribution of the census districts most likely to be influenced by the action of adaptation to heat.

Data on the health of the population were obtained from TABNET, a generic public domain tab developed by DATASUS, the IT department of the Unified Health System, allowing the organization of health data for the district of Jabaquara. The annual number of hospital admissions and the average cost of hospitalizations on cases of heat-related morbidities are shown in [Table 1], for the statistical value of life, the standard information in the tool, of R$ 330,000.00, was used.

5 http://geosampa.prefeitura.sp.gov.br/

Heat-related morbidities	Annual number of hospitalizations (per 100,000 inhabitants)
Cardiovascular disease	692
Respiratory illness	502
Renal disease (Kidney failure)	64
Stroke (heat related)*	223
Ischemic stroke (heat related)*	162

[Table 1] Information related to the impacts of heat on the health of the population [6]

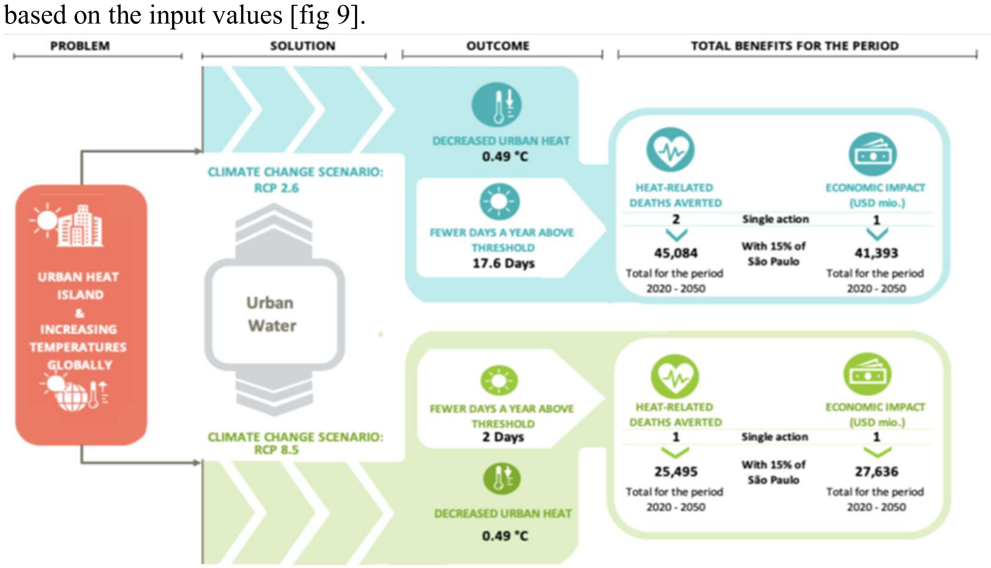
RESULTS

After filling in the basic information, the details of the intended action and the data: environmental, social and economic, the tool returns the expected impacts with the implementation of the revitalization of the stretch of the Ipiranga Stream. For comparison, the results are presented for both climate change scenarios: RCP 2.6 and RCP 8.5.

Regarding environmental impacts, a reduction in the number of days with high temperatures is expected. For RCP 2.6, a reduction of 17 days, while for RCP 8.5, a reduction of 2 days. Urban areas, located between 100 to 300 m of water bodies, can have their ambient temperature reduced by about 2 - 6°C (Saaroni et al, 2003, Manteghi et al, 2015).

As for socioeconomic impacts, the tool calculates the number of lives saved and the amount saved from hospitalizations and other costs. For RCP 2.6, it is estimated that 45,000 people do not die from heat-related illnesses, resulting in savings of US $ 41 million for the period evaluated. While for RCP 8.5, the reduction in the number of deaths will be 25 thousand people, leading to savings of US$ 27 million.

o facilitate visualization, the Heat Resilient Cities tool returns a summary of the main impacts calculated based on the input values [fig 9].



[Fig.9] Summary of expected results with the revitalization of the stretch of Ipiranga Stream, presented in the results tab of the tool

[6] The public health system - Sistema Único de Saúde (SUS) does not differentiate heat-related ischemic strokes and strokes, in order to avoid overestimating these types of hospitalizations, hospitalization data was used for these morbidities in Mexico, as it is the country of the tool database with characteristics similar to those of the Brazilian population.

Other benefits provided directly by the revitalization of water bodies, but not calculated by the tool, in the environmental conditions of the area are: significant improvement in air quality, reduction of noise level and creation of wind corridors. Regarding biotic conditions, it is worth mentioning the recompositing of favourable conditions for the return of the local fauna and flora (Vermaat et al, 2016).

CONCLUSION

The simple and intuitive interface of the Heat Resilient Cities tool allowed the user to quickly adapt to measure the impacts of actions to adapt cities to heat, presenting the methodology to be adopted, the question-and-answer section and the sources used for the development of the tool.

However, it is necessary to have prior knowledge of the problems and demands of the city. In addition, it is highly recommended to have information on: demographic density, land use and occupation, physical aspects of the city and a database, preferably official, of the health and economy aspects of the city.

The tool can help to predict the impacts caused by climate adaptation actions, in which case the revitalization of the stretch of the ipiranga stream would reduce the number of days with high temperatures, contributing to the reduction of heat waves in the area close to the stream, in addition to reduction in the number of heat-related deaths and savings in hospital admissions.

With the results of the tool, it is possible to motivate technicians, designers and decision makers to consider climate adaptation projects. As in the case of this stretch of the Ipiranga Stream, with the implementation of a sustainable drainage system, instead of conventional plumbing in concrete forms, whose environmental benefits are practically null, or even harmful to the environmental, social and economic issues for the city, can guarantee a more resilient and sustainable city for its citizens.

REFERENCES

Bartos, M., Chester, M., Johnson, N., Gorman, B., Eisenberg, D., Linkov, I., & Bates, M. (2016). *Impacts of rising air temperatures on electric transmission ampacity and peak electricity load in the United States*. Environmental Research Letters, 11(11), 114008. doi:10.1088/1748-9326/11/11/114008

Daniel, J. S., Jacobs, J. M., Douglas, E., Mallick, R. B., & Hayhoe, K. (2014*). Impact of Climate Change on Pavement Performance: Preliminary Lessons Learned through the Infrastructure and Climate Network (ICNet).* Climatic Effects on Pavement and Geotechnical Infrastructure. doi:10.1061/9780784413326.001

Davis, M & Clemmer, S. (2014). *Power Failure: How climate change puts our electricity at risk – and what we can do*. Cambridge, MA: Union of Concerned Scientists. Accessible at: https://www.ucsusa.org/sites/default/files/2019-10/Power-Failure-How-Climate-Change-Puts-Our-Electricity-at-Risk-and-What-We-Can-Do.pdf

Field, C.B., Barros,V.R., Mach,K. & Mastrandrea, M. (2014). *Climate Change 2014: Impacts, Adaptation and Vulnerability.* Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panelon Climate Change. Accessible at: http://www.ipcc.ch/report/ar5/wg2/.

Geirinhas, J. L., Trigo, R. M., Libonati, R., Coelho, C. A. S., & Palmeira, A. C. (2017). *Climatic and synoptic characterization of heat waves in Brazil.* International Journal of Climatology, 38(4), 1760–1776. doi:10.1002/joc.5294

Guo, Y., Gasparrini, A., Armstrong, B. G., Tawatsupa, B., Tobias, A., Lavigne, E., … Tong, S. (2017). *Heat Wave and Mortality: A Multicountry, Multicommunity Study. Environmental Health Perspectives*, 125(8), 087006. doi:10.1289/ehp1026

Jilma, B., & Derhaschnig, U. (2012). *Disseminated intravascular coagulation in heat stroke*. Critical Care Medicine, 40(4), 1370–1372. doi:10.1097/ccm.0b013e31823d785d

Kenney, W. L., Morgan, A. L., Farquhar, W. B., Brooks, E. M., Pierzga, J. M., & Derr, J. A. (1997). *Decreased active vasodilator sensitivity in aged skin*. American Journal of Physiology-Heart and Circulatory Physiology, 272(4), H1609–H1614. doi:10.1152/ajpheart.1997.272.4.h1609

Margill, B. (2014). *"Sun kinks" in railways join the list of climate change's toll*. Scientific American. Accessible at: https://www.scientificamerican.com/article/sun-kinks-in-railways-join-the-list-of-climate-change-s-toll/

MONTEIRO, C. A. de F. (1969) *A Frente Polar Atlântica e as Chuvas de Inverno na Fachada Sul-oriental do Brasil*. *Contribuição metodológica à análise rítmica dos tipos de tempos no Brasil.* 1969. Universidade de São Paulo

Mora, C., Counsell, C. W. W., Bielecki, C. R. & Louis, L. V. (2017). *Twenty-Seven Ways a Heat Wave Can Kill You: Circulation: Cardiovascular Quality and Outcomes*, 10(11), e004233. doi:10.1161/circoutcomes.117.004233

Mora, C., Dousset, B., Caldwell, I. R., Powell, F. E., Geronimo, R. C., Bielecki, C. R., Trauernicht, C. (2017). *Global risk of deadly heat*. Nature Climate Change, 7(7), 501–506. doi:10.1038/nclimate3322

Moraes, Sara Lopes de. Barrozo, Lígia Vizeu. (2019) *Spatial Clusters of the Relative Risk of Elderly People Mortality by Circulatory and Respiratory System Diseases During Heat Waves in São Paulo, Sp*. IX Simpósio Nacional de Geografia da Saúde, Blumenau-SC

Nery, J. T.; Carfan, A. C. (2013) *Glossário de Termos técnicos em Meteorologia e Climatologia*. Jundiaí: Paco Editorial.

Rikkert, M. G. M. O., Melis, R. J. F., & Claassen, J. A. H. R. (2009*). Heat waves and dehydration in the elderly*. BMJ, 339(jul02 1), b2663–b2663. doi:10.1136/bmj.b2663

SABESP. (2019) *SABESP e Prefeitura vão despoluir o Córrego Ipiranga.* Accessible at: http://site.sabesp.com.br/site/imprensa/noticias-detalhe.aspx?secaoId=65&id=8018

SÃO PAULO (2008) *Jardim Botânico de São Paulo comemora 80 anos* Accessible at: https://www.saopaulo.sp.gov.br/ultimas-noticias/jardim-botanico-de-sao-paulo-comemora-80-anos/

SEADE. (2020) *Bairros: onde mais vivem idosos na cidade?* Accessible at: https://www.seade.gov.br/bairros-onde-mais-vivem-idosos-na-cidade/

SIURB. (2015) *Saiba Mais sobre as Obras do Córrego Ipiranga* Accessible at: https://www.prefeitura.sp.gov.br/cidade/secretarias/obras/obras_de_drenagem/corregos/index.php?p=193693

Sun, Z., Chen, C., Xu, D. & Li, T. (2018) *Effects of ambient temperature on myocardial infarction: A systematic review and meta-analysis.* Environmental Pollution 241 - 1106 e 1114, https://doi.org/10.1016/j.envpol.2018.06.045

Tan, W., Herzlich, B. C., Funaro, R., Koutelos, K., Pagala, M., Amaladevi, B. & Grob, D. (1995). *Rhabdomyolysis and Myoglobinuric Acute Renal Failure Associated With Classic Heat Stroke*. Southern Medical Journal, 88(10), 1065–1068. doi:10.1097/00007611-199510000-00013

Tarifa, J. R.; Armani, G. (2001) *Os climas urbanos*. In: TARIFA, J. R.; AZEVEDO, T. R. (Ed.). Os climas na cidade de São Paulo. 4. ed. São Paulo: GEOUSP. p. 199.

UNDRR/CRED (2020). *The human cost of disasters: an overview of the last 20 years (2000-2019).* Accessible at: https://www.undrr.org/publication/human-cost-disasters-overview-last-20-years-2000-2019

Vaneckova, P., Beggs, P. J., & Jacobson, C. R. (2010). *Spatial analysis of heat-related mortality among the elderly between 1993 and 2004 in Sydney*, Australia. Social Science & Medicine, 70(2), 293–304. doi:10.1016/j.socscimed.2009.09.058

Vermaat, J.E., Wagtendonk, A.J., Brouwer, R. et al. *Assessing the societal benefits of river restoration using the ecosystem services approach*. Hydrobiologia 769, 121–135 (2016). https://doi.org/10.1007/s10750-015-2482-z

Wang, A.B. (2017). *It's so hot in Phoenix that airplanes can't fly*. Washington Post, June 21. Accessible at: https://www.washingtonpost.com/news/capital-weather-gang/wp/2017/06/20/its-so-hot-in-phoenix-that-airplanes-cant-fly/