Climanosco Research Manuscripts

Collection 5, Entangled forests

The dimensional data of American beech trees in changing climates: environmental data science meets digital art installations in public space

By Blandine Courcot, Gisèle Trudel and Marc-André Cossette, 28 April 2025

Climate change is undoubtedly one of the greatest challenges for humanity to address. The IPCC synthesis report (2023) provides guidance; yet the constant barrage of adverse impacts seems to paralyze citizens who recoil from taking action under the pressure of constant and rapidly approaching “tipping points”, thresholds between two states. Explored through the lens of “dimensional data”, understood as both a measurement and a quality, the data shows the resilience of another living being, the beech tree, which can sustain repeated short but intense periods of drought. The climate science data analysis is culled in the academic research site of a forest near Tiohtià:ke/Mooniyang/Montreal (Quebec, Canada). Grounded in and extending a numerical approach, beech tree thresholds are shared with publics through an art-science collaboration and digital art creativity. From soil water potential and soil temperature sensors compiled from 2017 to 2020, the data reveal the tree’s own dimensional relations to its environment which is subsequently shared artistically in the dynamic visualizations of a large-scale outdoor art installation entitled Beech-Becomings presented in a rural forest in May 2023.

{1}An exploration of the dimensional aspect of data, understood as *both* a physical measurement *and* a quality of a thing or situation, this text is narrated by a scientist and two artists, collaborators in the production and dissemination of an outdoor artwork and its discussion below. We begin with an incursion into climate research about soil water potential, soil temperature and flash droughts of beech trees based on data captured with sensors in environmental science. The second part presents the artistic renderings of beech tree and weather data with special generative software, producing evocative visualizations of data thresholds. The third segment discusses the artwork entitled *Beech-Becomings* (2023) emerging from this climate data science research and presented as the third outdoor installation of MÉDIANE, the Canada Research Chair in Arts, Ecotechnologies of Practice and Climate Change which also conducts semi-directed interviews with publics [MEDIANE, 2023].

{2}Dimensions of beech’s soil water potential, soil temperature and flash droughts within environmental data and science

{3}In this context of global climate change, a question remains central in forest ecology: What will be forests’ spatiotemporal evolution in a *future new climate normal*?

{4}We wondered what would happen in a future climate normality of a sugar maple forest near the northern distribution limit of temperate deciduous forests in Quebec, Canada. Focusing on the temporal evolution of the soil water potential, my research in the DOT-Lab, with Pr Daniel Lemire and Pr Nicolas Bélanger, has evolved at the interface between data science and environmental science [DOT-Lab, 2023]. I have contributed parts of my research as the scientist involved in the art-science collaboration presently discussed.

{5}Considering this shift towards a “new normal”, it seems necessary to clarify the concepts of trends and extreme events. Studying the influence of local parameters has become a central issue, and this is especially true in a globally changing hydroclimatic context where extreme events are indeed more likely, more intense, and longer-lasting [D. Herring, 2020]. However, considering droughts, it has become more challenging to define correctly such an event in a situation where the background is shifting [S. Stevenson et al., 2022].

{6}Each tree species reacts specifically to extreme events depending on its capacity to resist change, i.e., its degree of resilience [C. Holling, 1996]. An analogy can be used here to clarify the concept of resilience in ecology. Think of a ball rolling on a landscape of hills. This ball can be stable and stand in a basin between two hills. If a slight disturbance is enough to move the ball over the hill to another basin, it has a low resilience because its capacity to resist change is small.

{7}Water deprivation for trees is a form of disturbance, and Kögler and Söffker have defined several levels of stress based on the intensity and the duration of a hydric deficit [F. Kögler and D. Söffker, 2020] (Figure 1). A stress can be positive for the tree up to a certain threshold, but after a limit, it becomes harmful and can cause death. This threshold is a *tipping point*, a boundary between two states; the hill’s height for the rolling ball.

{8}The mortality process is complex, and it needs to integrate different types of interactions and dependencies between factors both internal and external to the tree [Nate G. McDowell et al., 2022]. I focus on what happens at the soil level.

{9}

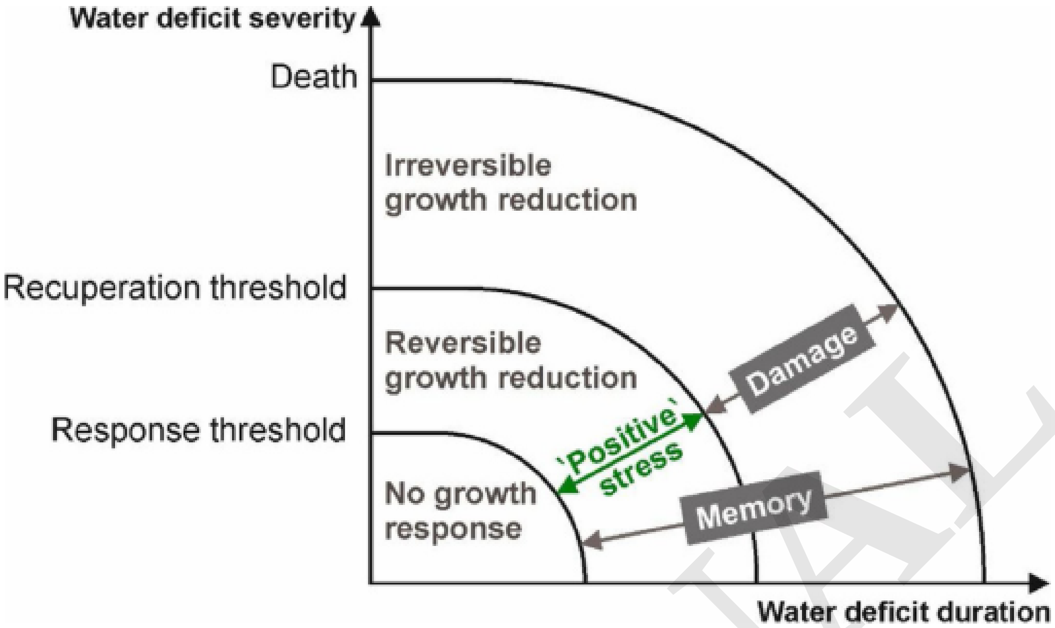


Figure 1: Reprinted from [F. Kögler and D. Söffker, 2020], Copyright (2020), with permission from Elsevier.

{10}Figure 1 can be seen as a tipping point in my dialogue with artists Trudel and Cossette. From this graph emerged the common ground of our collaboration, focusing on the beech's ability to adapt to flash droughts — short periods of intense hydric stress [J. A. Otkin et al., 2018]. During our discussions, we considered this moment as a teaching about resilience from the tree, to be shared with humans through artistic expression. The second band of the graph shows the new dimension of a tipping point, whereby stress can sometimes have positive effects, which is relevant for publics to know in the context of climate change.

{11}The experimental framework for my scientific study is the Pan-Canadian project Smartforests [C. Pappas et al., 2022; Smartforests, 2023], and the site located in Quebec, the *Station de biologie des Laurentides* (SBL) of Université de Montréal in Saint-Hippolyte [SBL, 2023]. Smartforests Canada is also one of MÉDIANE's main collaborators. The experimental field is spread over 32 stations. Each station is composed of similar trees [N. Bélanger et al., 2021]. Three main forest types were identified: mixedwoods (MW), hardwoods (HW), and hardwood-beech (HB). The American beech (*Fagus grandifolia*) is the dominant species of HB stands, and it is the focus of my own research within the DOT-Lab which I bring to my collaboration with the two co-authors of this text.

{12}Each station has sensors to measure soil water potential and soil temperature. Millions of data were collected at the SBL between 2017 and 2020. Weather information was also measured, such as air temperature, soil temperature, precipitations, solar radiance, and soil water content, referred to as soil moisture [B. Courcot, 2023].

{13}Soil water potential, expressed in units of pressure [kPa], allows the characterization of trees' ability to draw water from the soil. When the potential reaches high positive values, the tree faces hydric stress. Considering flash droughts, my study shows a different behavior of the American beech compared to balsam fir and birch trees. Indeed, at the soil level, in a beech-maple forest with a closed canopy, the American beech can regulate the soil temperature and maintain its soil water potential near lower values, as illustrated in Figure 2 and Figure 3 during the second flash drought observed in 2020 [B. Courcot et al., 2023]. This is an asset for beech considering the greater frequency of dry-down periods.

{14}

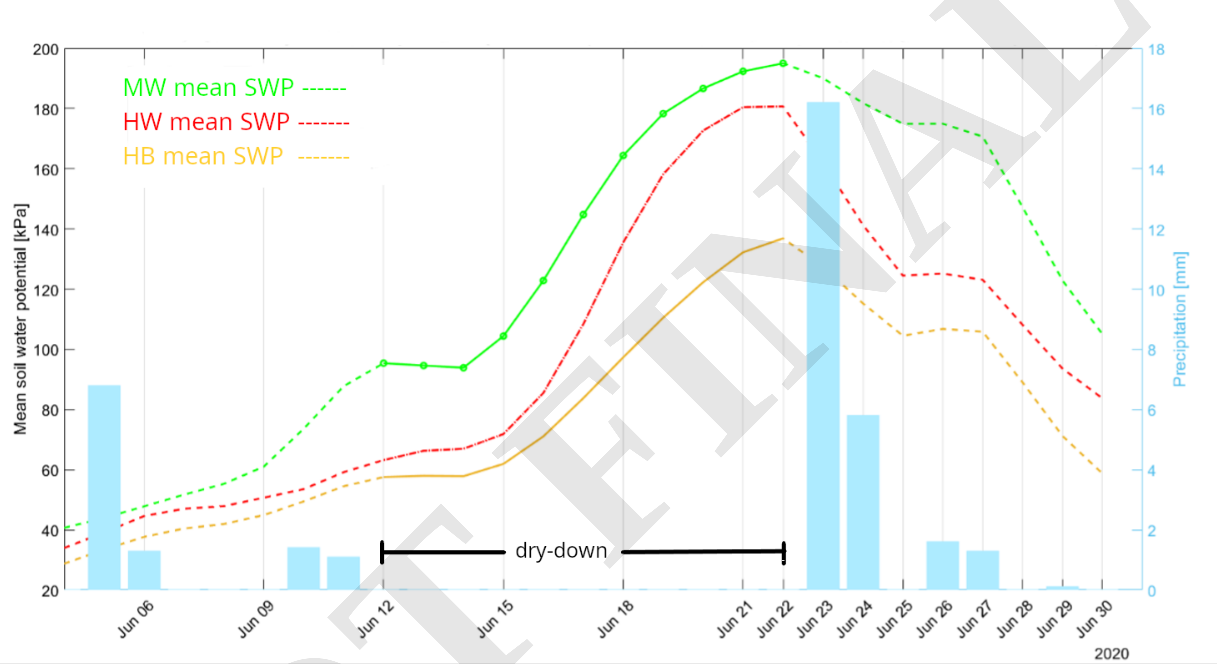


Figure 2: Evolution of the soil water potential [kPa] for maple-fir (MW in green), maple-birch (HW in red), and maple-beech stands (HB in yellow) with daily precipitation in blue.

{15}

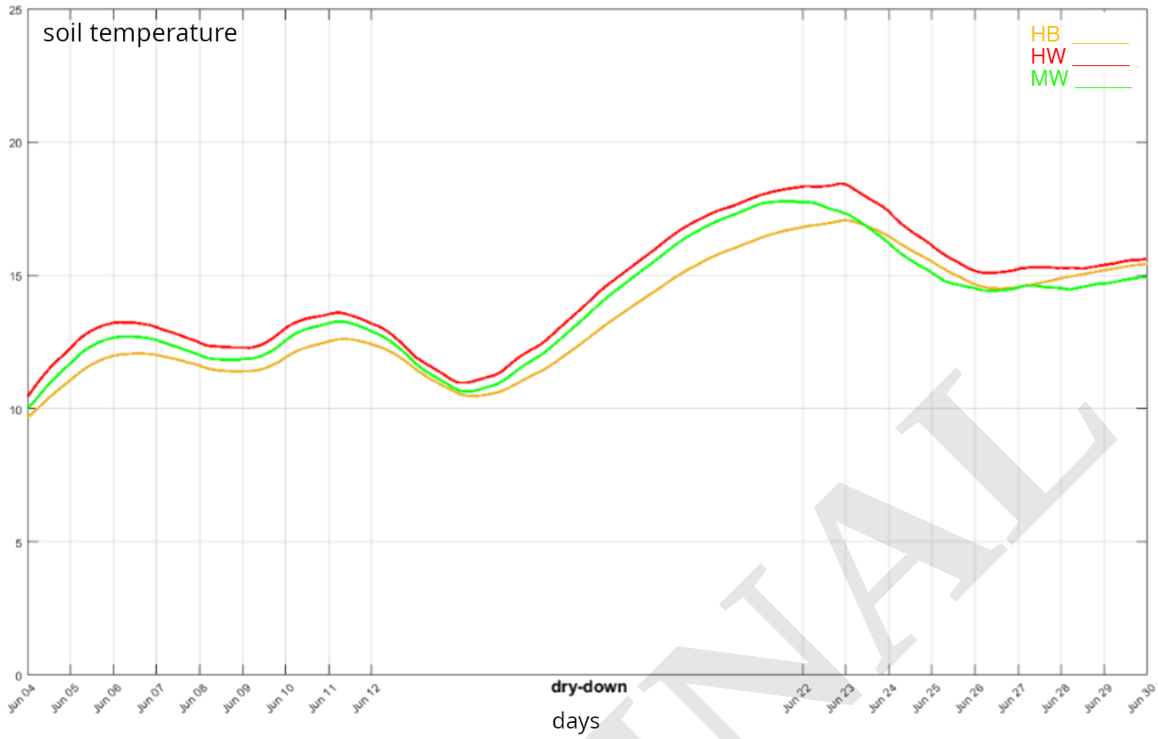


Figure 3: Evolution of the soil temperature [°C] for MW, HW and HB.

{16}Keeping in mind the rolling ball of my earlier example, less ecologically resilient species will switch more easily and quickly to new states. However, it is challenging to characterize these new states. The information transmitted by the collected data allows me to extract part of the reality experienced by trees, although they only provide me with a snapshot at a given time.

{17}How to present this dynamic felt by trees to people other than scientists? How can the dimensional phenomena embedded in data be animated more dynamically? How to visualize tipping points between states of the being (namely, the tree) that allow for becoming [M. Igini, 2023]?

{18}Dimensional renderings of environmental data with digital creativity

{19}I write this segment of the text as an artist, musician, programmer and PhD candidate. My contribution to the collaboration is to provide publics with a new sensory experience of scientifically-validated data about climate change. As discussed in the previous section, our scientific collaborator Courcot uses various forms of graphs and histograms in the analysis of extensive data tables in order to identify patterns that would otherwise be challenging to comprehend solely by examining the numbers. This process of creating plots and graphs is a way of transforming abstract cognitive data into a dimensional sensory experience through shapes and colors. How to make sense of data through sensory means, without relying on extensive knowledge and experience of environmental science? Artists can bring these 2D graphs into time-based animations, as a tipping point between two states, adding a new temporal and evolutive dimension to static imagery. By activating the movement inherent to data sequencing, a sensory experience is offered to publics who are unfamiliar with environmental science.

{20}In January 2023 began at Hexagram the initial stage of artistic development using the TouchDesigner software, a specialized program designed to create highly customizable visual synthesis using the Python programming language [Patrik Lechner, 2014; Hexagram, 2023]. I began by parsing the data tables provided by Courcot to extract the data from the Beech tree. As a starting point for our exploration of this new dataset, I crafted, in collaboration with Trudel, simple graphs using 3D lines that could be observed from various angles. To facilitate a closer examination of the graph, I developed the dimensional concept of a “data window” that moves through the data table over time. Additionally, the window moved through the different stations where the beeches are planted, highlighting the transformation in the data from Spring to Fall. This “data window” can be adjusted in terms of both its width and speed. This novel method of “zooming in and out” of the data and observing its spatiotemporal movement offers a fresh perspective on the tree’s experience in relation to soil temperature and water availability. It reveals how soil and trees behave in their own dimensional context. Consequently, it formed the foundation of our sensory visualizations.

{21}Throughout multiple iterations, we refined this technique for visualizing the data and presenting the behavior over time and in movement, akin to a choreography: the tree’s dance with(out) water and variations in soil temperatures. Our conceptual focus shifted from the specific value of each data point to their transformations, relations, tipping point, thus highlighting new patterns within and between the data tables: moments of stability and abrupt shifts, as well as recurring patterns over specific time spans.

{22}As the project development progressed until April 2023, we questioned each other about the relevance of the visualizations themselves, and whether they could serve as a key to experiencing the nature of the collected and analyzed data, but without relying heavily on labeling and textual indicators. A pivotal aspect of our creative process was to explore graphical forms and colors, which are often chosen arbitrarily by scientists, and therefore lack inherent meaning for laypeople. In the software, we experimented with diverse visualizations, such as rotating circles, visual feedback, colored lines and dots, simulated cell replication, particle systems, and fractal algorithms. These animations conjured images of tree trunks, microscopic leaf cells, heat and water, tree branches, and roots. In each instance, the numerical data from within the selected data window (period and speed) were employed to control specific system parameters, imparting each visualization with imagery evoking the visualized data.

{23}For the definitive artwork, we selected eight distinct designs by linking them with pertinent data. For example, soil water potential is portrayed using rotating circles with visual feedback to simulate dots moving as a tree trunk and tree-rings (Figure 4), while soil moisture is depicted through a fractal rendering evoking downward-extending roots (Figure 5).

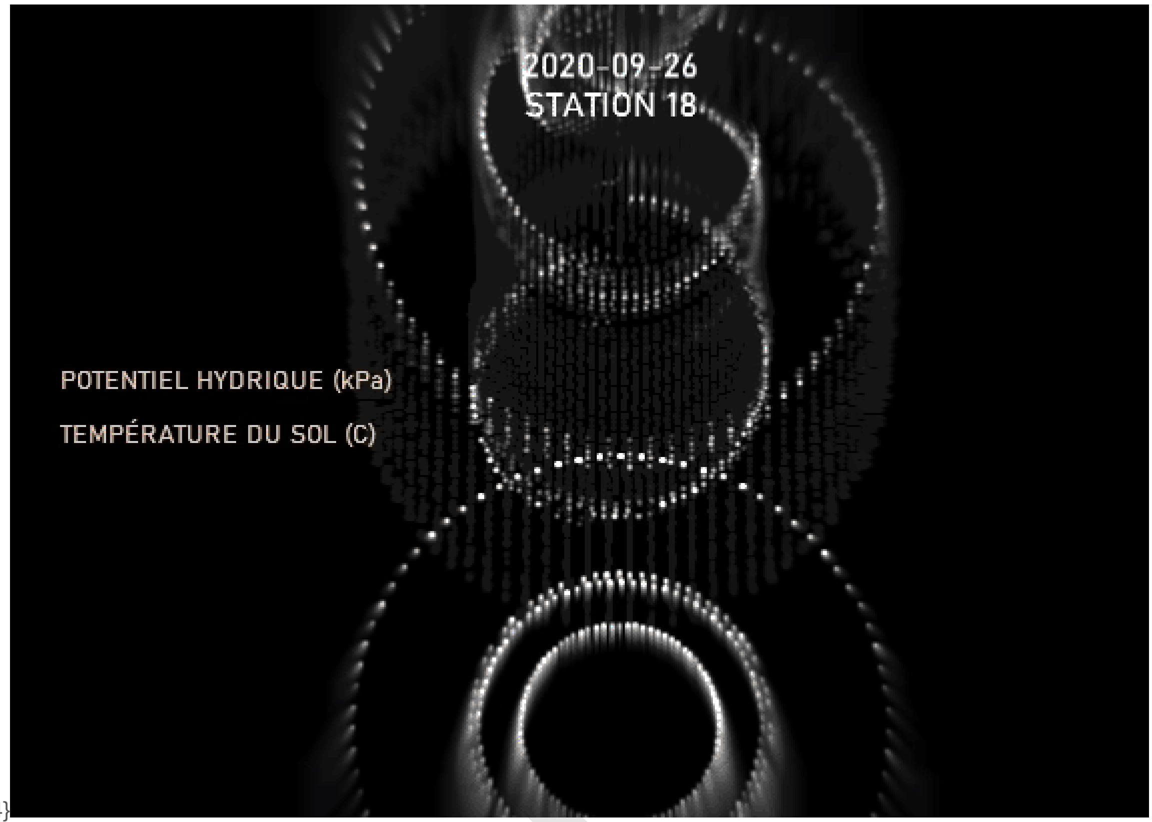
{24}


Figure 4: Ælab and MÉDIANE (2023). Devenir-Hêtre [excerpt from Touch Designer software]. Image sequence shows the particle system as the relation between soil temperature and soil water potential. Credit: Visual programming by Marc-André Cossette.

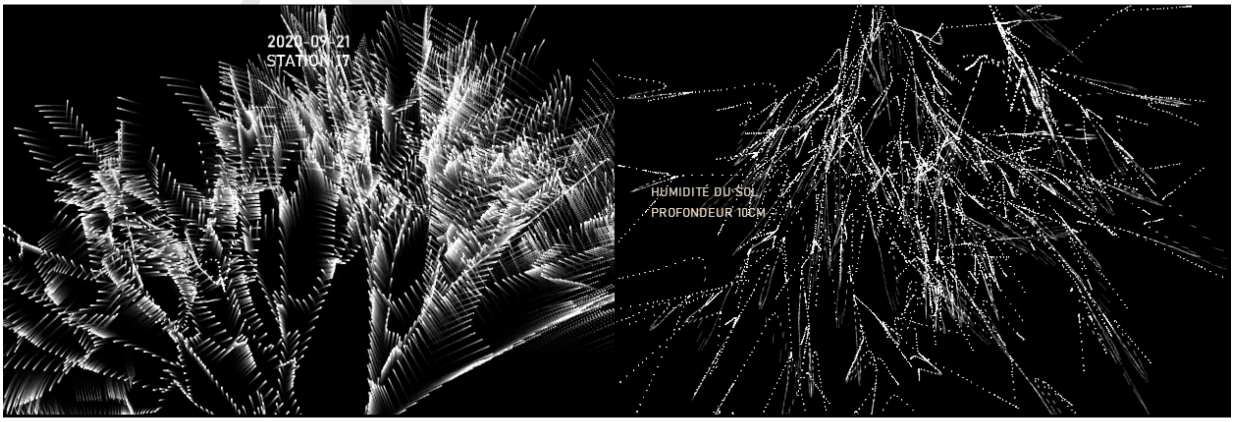
{25}


Figure 5: Ælab and MÉDIANE (2023). Devenir-Hêtre [screen grab from Touch Designer software]. Credit: Visual programming by Marc-André Cossette.

{26}Additionally, daily photosynthesis radiation is driving the replication rate in simulated cells (Figure 6). All these systems moved along with the data window, a condensation of Spring to Fall seasons, six months worth of data transposed into minutes, accelerating the forest's temporal progression to a pace that publics could sense at a human scale.

{27}

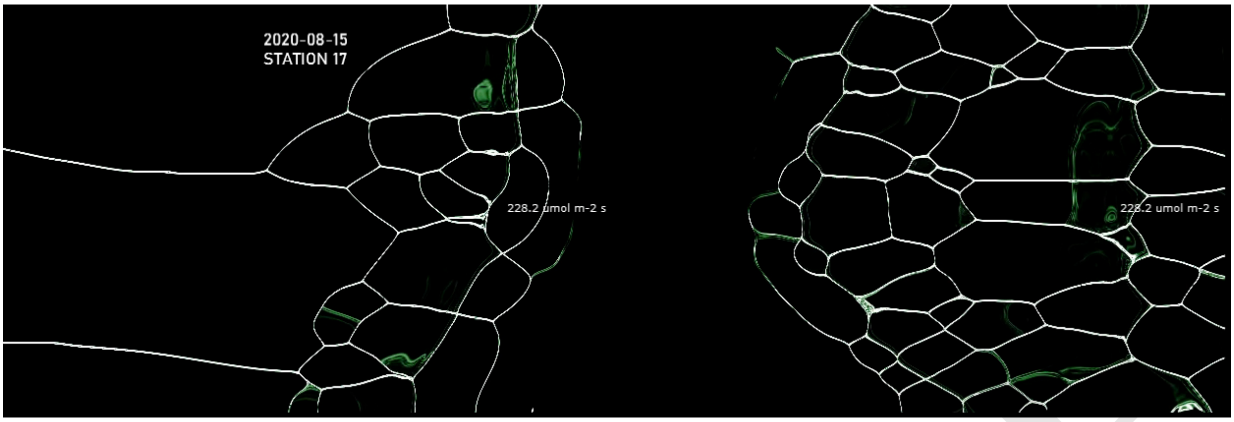


Figure 6: Ælab and MÉDIANE (2023). Devenir-Hêtre [screen grab from Touch Designer software]. Credit: Visual programming by Marc-André Cossette.

{28}Lastly, a temporal pattern within the data described previously as a flash drought, defined by a sequence of 1000 data points below a specific hydric potential, served as a trigger for visual alterations (Figure 7). Through this technique, the art installation became wholly reliant on the temporal dimension of the data at every level, encompassing the motion of each designed graph as well as the overall arrangement of graphs over an extended period.

{29}

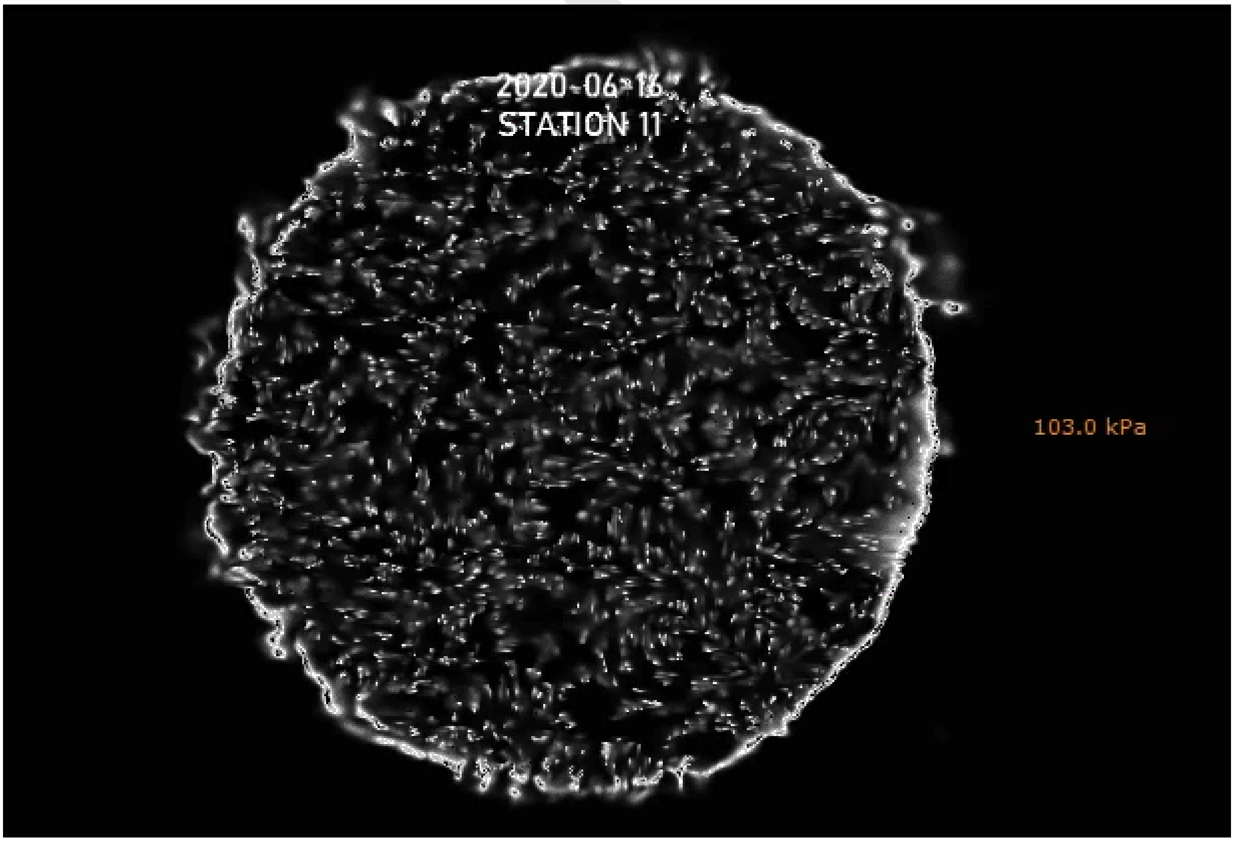


Figure 7: Ælab and MÉDIANE (2023). Devenir-Hêtre [sequence from Touch Designer software]. Image sequence shows the particle system as the relation between soil temperature and soil water potential. Credit: Visual programming by Marc-André Cossette.

{30}Beech’s dimensional resilience experienced in an outdoor art installation

{31}I write this section in my role as artist, professor and principal investigator of MÉDIANE, the Canada Research Chair in Arts, Ecotechnologies of Practice and Climate Change (2020-2025, funded by the SSHRC, CFI, FRQSC). The Chair’s team of researchers, students, artists and professionals conceptualizes, produces and presents the scientific research of the Smartforests Canada group in yearly outdoor art installations. Smarforests research initiatives are part of a global network of connected forest sensor practices [Jennifer Gabrys, 2016]. The audiovisual artworks consist of computer-controlled LED video tiles, immersive sound and tactile sound, modular synthesizers and various sensors, presented outdoors as an “exhibition-laboratory”. The technical equipment is installed in a scaffolding structure whereby cabling and connections are apparent, along with the effects of weather, other trees and plants, wind and forest creatures. These modular tube structures without walls are akin to practices in contemporary architecture and scientific forest experiments (Figures 8, 9 and 10).

{32}The artwork is conceived as a “construction site” open to dialogue about scientific data. This includes the promotion of data literacy [David Spiegelhalter, 2019] in order to question what and how data is shown. Publics are curious about how scientists are contributing to climate research, yet many do not often go to museums or galleries to experience art or science.

{33}

Figure 8: Ælab and MÉDIANE (2023). Devenir-Hêtre [outdoor digital installation]. Fondation

Grantham for the Arts and the Environment, Saint-Edmond-de-Grantham, Quebec. A view of the installation. Photo credit: Gisèle Trudel.

{34}

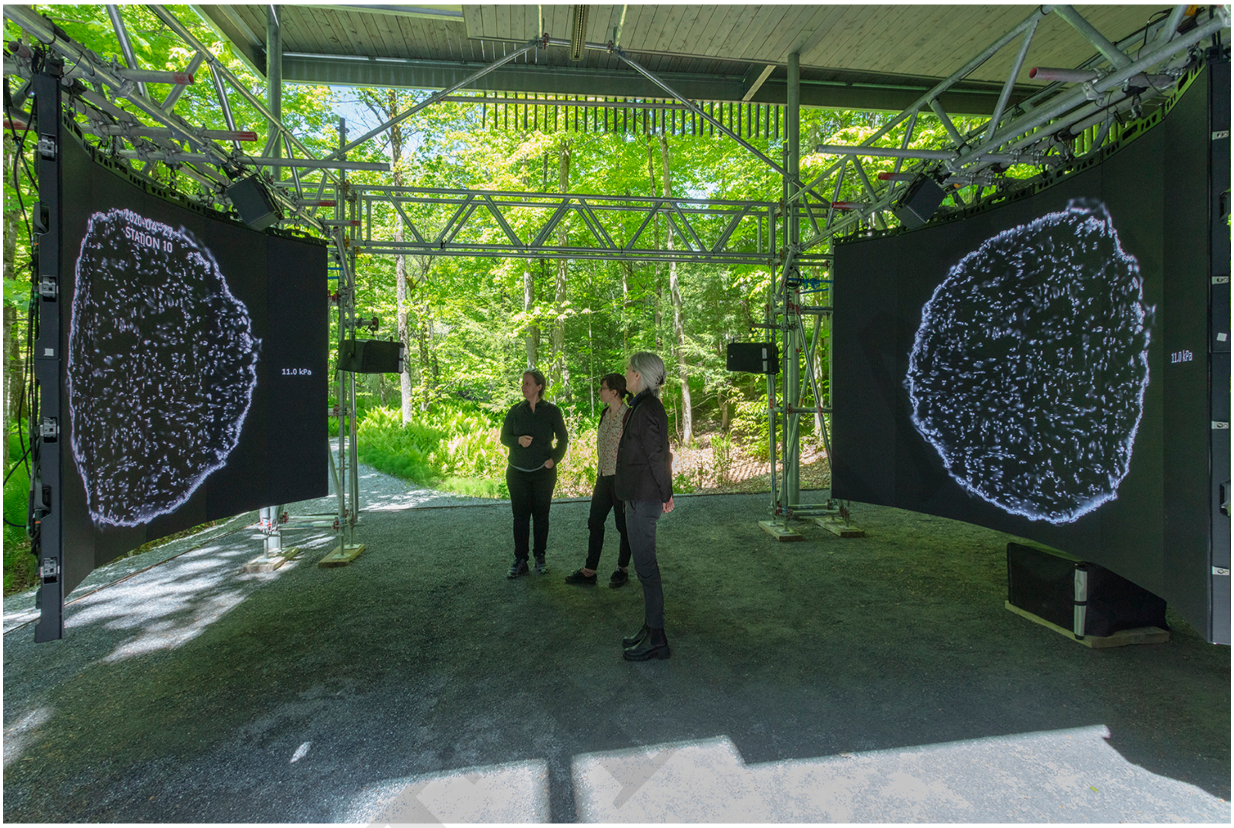


Figure 9: Ælab and MÉDIANE (2023). Devenir-Hêtre [outdoor digital installation]. Fondation Grantham for the Arts and the Environment. The LED video tiles are placed facing in a semi-circle, with surround sound and also a speaker array positioned at the top. Photo credit: Richard-Max Tremblay.

{35}

Figure 10: Ælab and MÉDIANE (2023). Devenir-Hêtre [outdoor digital installation]. Fondation Grantham for the Arts and the Environment. In the foreground is as a component of the installation, the “tactile sound” table where people could sit or lie down and receive a “sound massage” from transducers placed under the platform. Photo credit: Richard-Max Tremblay.

{36}MÉDIANE’s third artwork *Devenir-Hêtre* (in English, *Beech-Becomings*), took place in May 2023 in a forest at the Fondation Grantham for the Arts and the Environment [Devenir-Hêtre, 2023; Grantham Foundation, 2023]. This location resonates with the Chair’s own objective of interacting with different publics about forests and climate change, enabling fruitful and unprecedented conversations to occur freely, without pressure, previous interests or knowledge. It points to the increase in art-science collaborations [M. G. Tosca et al., 2021; N. Li et al., 2023] and contemporary artworks delving into symbiotic relations with trees along with digital media [J. Tingley, 2020-23; R. Smite and R. Smits, 2020; Agnes Meyer-Brandis, 2013].

{37}MÉDIANE’s two previous installations took place in urban settings [bois eau métal, 2021; Orée des bois, 2022], respectively in a botanical garden and in a community garden of a university campus. The Chair’s collaborations are public forums, adding new dimensions to climate data based on sensory experiences with digital art. A tipping point for digital art is the challenge of presenting the installation outdoors for active involvement in changing climates. The artwork is subjected to the same environmental conditions experienced daily by trees in the cold, rain or heat: the demanding yet exquisite dimensionally felt immediacy of being “on location". The scientific data explored was collected at SBL during the first year of the pandemic in 2020, a time of ecological and social collapse. It is presented three years later in another forest, in another time. Each instance of data presenting beech resilience contributes to a dimension of present and future climates, involving publics in new ways to envision, think and live with change, their own and that of another living being.

{38}Encounters with publics foster the circulation of ideas and creative actions, elements gathered on a voluntary basis through semi-directed interviews comprising 7 questions. In May 2023, 300 people visited the installation (Figures 10 and 11), 76 participated in the interviews with ages ranging from 8 to 85 years. Breaking through preconceptions about lack of knowledge or concern about climate change, the data collected from the anonymous interviews confirm the important roles played by trees and that creativity and interdisciplinary efforts are crucial to address pressing environmental issues through openness and collaboration.

{39}In conclusion

{40}Beech tree tipping points, aggravated by lack of water and increasing temperatures of climate change, provide compelling scientific data about the tree's resilience, which in turn, produces dimensional data renderings with art. The beech's "positive stress" dimensions are expressed in numbers, in sequencing this data in time and in its effects on collaborative research and publics. The internal and external dynamics of beech tree data are extended in sensory visualizations of its processes through dynamic moving images in an outdoor digital art installation. Opening dialogues about climate change through creativity, the process of writing this text in an interdisciplinary mode is also a move to push through research field boundaries for publics who share concerns about climate change.

{41}

Figure 11: Ælab and MÉDIANE (2023). Devenir-Hêtre [outdoor digital installation]. Fondation Grantham for the Arts and the Environment, Saint-Edmond-de-Grantham, Quebec. Public discussion with a group of elders. Photo credit: Mélodie Claire Jetté.

{42}Photo credits: Cover image Smartforests Canada.

{43}Bibliography

{44}

- {45}Orée des bois: *MEDIANE*. UQAM. Retrieved (June 2022) from https://mediane.uqam.ca/oree-des-bois/.
- {46}N. Bélanger, A. Collin, R. Khlifa and S. Lebel-Desrosiers: Balsam fir and American beech influence soil respiration rates in opposite directions in a sugar maple forest near its northern range limit, *Frontiers in Forests and Global Change*, vol. 4, 664584, https://doi.org/10.3389/ffgc.2021.664584, 2021.
- {47}B. Courcot: Suivi et modélisation du potentiel hydrique du sol dans un contexte de stress climatiques : le cas d'une érablière à bouleau jaune à la marge nordique de sa distribution, Mémoire de maîtrise en technologie de l'information, Université Téluq, 2023.
- {48}B. Courcot, N. Bélanger and D. Lemire: L'expansion du hêtre dans l'érablière à

bouleau jaune peut-elle s'expliquer par l'entremise du potentiel hydrique du sol ? Aperçu d'une variable inexplorée, in: ACFAS 2023, Colloque 632 : Les érablières dans un environnement en mutation, Université de Montréal, 2023. Retrieved from https://www.acfas.ca/evenements/congres/programme/90/600/632/c.

- {49}Devenir-Hêtre: *MEDIANE*. UQAM. Retrieved (August 2023) from https://mediane.uqam.ca/devenir-hetre/.
- {50}DOT-Lab: *Data Science Laboratory*. Université TELUQ. Retrieved (August 2023) from https://dot-lab.teluq.ca/en/.
- {51}Grantham Foundation: Grantham Foundation for the Arts and the Environment. Retrieved (August 2023) from https://www.fondationgrantham.org/en/home.
- {52}Jennifer Gabrys: Program Earth. Environmental Sensing Technology and the Making of a Computational Planet. Minnesota University Press, https://doi.org/10.5749/j.ctt1b7x5gq, 2016.
- {53}D. Herring: What is an "extreme event"? Is there evidence that global warming has caused or contributed to any particular extreme event?, 2020. Retrieved from https://www.climate.gov/news-features/climate-qa/what-extreme-event-there-evidence-global-warming-has-caused-or-contributed.
- {54}Hexagram: *Réseau de recherche-création en arts, cultures et technologies*. UQAM. Retrieved (August 2023) from https://hexagram.ca/en/.
- {55}C. Holling: Engineering resilience versus ecological resilience, 31-43, 1996.
- {56}M. Igini: The Tipping Points of Climate Change: How Will Our World Change?, 2023.
- {57}F. Kögler and D. Söffker: State-based open-loop control of plant growth by means of water stress training, *Agricultural Water Management*, vol. 230, https://doi.org/10.1016/j.agwat.2019.105963, 2020.
- {58}Patrik Lechner: Multimedia Programming Using Max/MSP and TouchDesigner: A Step-by-Step Guide to Designing, Building, and Refining Immersive Audio-Visual Applications and Performance Environments Using Max and TouchDesigner. Packt Publishing, 2014.
- {59}N. Li, I. I. Villanueva, T. Jilk, Matre B. R. Van and D. Brossard: Artistic Representations of Data Can Help Bridge the US Political Divide Over Climate Change, *Communications Earth & Environment*, vol. 4, 195, https://doi.org/10.1038/s43247-023-00856-9, 2023.
- {60}Nate G. McDowell, Gerard Sapes, Alexandria Pivovaroff, Henry D. Adams, Craig D. Allen, William R.L. Anderegg, Matthias Arend, David D. Breshears, Tim Brodribb and co-authors: Mechanisms of woody-plant mortality under rising drought, CO2 and vapour pressure deficit, *Nature Reviews Earth and Environment*, vol. 3, 294-308, https://doi.org/10.1038/s43017-022-00272-1, 2022.
- {61}MEDIANE: *Chaire de recherche du Canada en arts, écotechnologies de pratique et changements climatiques*. UQAM. Retrieved (August 2023) from https://mediane.uqam.ca/.

- {62}Agnes Meyer-Brandis: Have a Tea with a Tree, Artwork (2013)
- {63}bois eau métal: *MEDIANE*. UQAM. Retrieved (July 2021) from https://mediane.uqam.ca/installation/.
- {64}J. A. Otkin, M. Svoboda, E. D. Hunt, T. W. Ford, M. C. Anderson, C. Hain and J. B. Basara: Flash droughts: A review and assessment of the challenges imposed by rapid-onset droughts in the United States, *Bulletin of the American Meteorological Society*, vol. 99, 911-919, https://doi.org/10.1175/BAMS-D-17-0149.1, 2018.
- {65}C. Pappas, N. Bélanger, Y. Bergeron, O. Blarquez, H. Y. H. Chen, P. G. Comeau, Grandpré L. De, S. Delagrange, A. DesRochers and co-authors: Smartforests Canada : A Network of Monitoring Plots for Forest Management Under Environmental Change, 521-543, https://doi.org/10.1007/978-3-030-80767-2_16, 2022.
- {66}SBL: *Station de biologie des Laurentides*. Université de Montréal in Saint-Hippolyte. Retrieved (August 2023) from https://sbl.umontreal.ca/accueil/.
- {67}Smartforests: *Smartforests Canada*. UQAM. Retrieved (August 2023) from https://smartforest.uqam.ca/.
- {68}R. Smite and R. Smits: Atmospheric Forest, Artwork (2020)
- {69}David Spiegelhalter: The Art of Statistics: Learning from Data. Basic Books, 2019.
- {70}S. Stevenson, S. Coats, D. Touma, J. Cole, F. Lehner, J. Fasullo and B. Otto-Bliesner: Twenty-first century hydroclimate: A continually changing baseline, with more frequent extremes, *Proceedings of the National Academy of Sciences*, vol. 119, 1-9, https://doi.org/10.1073/pnas.2108124119, 2022.
- {71}Per Espen Stoknes: What We Think About When We Try Not to Think About Global Warming. Chelsea Green Publishing, 2015.
- {72}J. Tingley: The Foresta-Inclusive, Artwork (2020-23)
- {73}M. G. Tosca, A. Galvin, I. Gilbert, K. L. Walls, G. E. Tyler and A. M. Nastan: Reimagining Futures: Collaborations Between Artists, Designers, and Scientists as a Roadmap, *Elementa: Science of the Anthropocene*, vol. 9(1), 00016, 2021.

Manuscript information

Cite as: Blandine Courcot, Gisèle Trudel and Marc-André Cossette, The dimensional data of American beech trees in changing climates: environmental data science meets digital art installations in public space, *Climanosco Research Manuscripts (Subm.)* **5**, 28 Apr 2025, https://doi.org/10.37207/CRM.5.1s

ISSN 3043-0062
DOI https://doi.org/10.37207/CRM.5.1s

Retrieved 5 Apr 2026

Version 1, Submitted manuscript
In collection 5, Entangled forests

Authors

Blandine Courcot, DotLab, Université Téluq, Quebec, Canada
Gisèle Trudel, École des arts visuels et médiatiques, Université du Québec à Montréal, Canada
Marc-André Cossette, Université Concordia, Montreal, Canada

Categories

Activism, Climate of the future, Climate of the present, Extremes, Human activities, Life, Soil, Vegetation, Canada, North America

Metadata

Submitted 28 April 2025
Type of article: Focus article; Multiple source article
Change of editor on 28 August 2025 from Dr Cassandra Bolduc to Dr Kate Johnson due to unexpected reduced availability of editor

Permanent url address:
https://www.climanosco.org/manuscript/the-dimensional-data-of-beech-trees-in-changing-climates-environmental-data-science-meets-digital-art-installations-in-public-space/