NOTES

INTRODUCTION

1. Ivan Nechepurenko, "A Love of Trees or a Display of Power? The Odd Park of an Oligarch," *New York Times*, January 17, 2022, https://www.nytimes.com/2022/01/17/world/europe/bidzina-ivanishvili-georgia-trees.html.
2. The Smithson Floating Island was produced by Minetta Brook in collaboration with the Whitney Museum of American Art, the assistance of the Hudson River Park Trust, and the NYC Department of Parks and Recreation in 2005. *Smithson Floating Island*, Balmori, accessed January 15, 2023, http://www.balmori.com/portfolio/smithson-floating-island.
3. On fertilizing Central Park and beyond, see Jane Hutton's *Reciprocal Landscapes: Stories of Material Movements* (Abingdon: Routledge, 2020), 26–62.
4. Robert Smithson, "Frederick Law Olmsted and the Dialectical Landscape," in *Robert Smithson: The Collected Writings*, ed. Jack Flam (Berkeley: University of California Press, 1996), 160. See also Hutton, *Reciprocal Landscapes*, 1–3.
5. We would like to thank Lisa Le Fleuvre from the Holt/Smithson Foundation for contextualizing Smithson's original idea.
6. *An Allegory with a Dog and an Eagle*, ca. 1508–1510, Royal Collection Trust, accessed January 15, 2023, https://www.rct.uk/collection/912496/an-allegory-with-a-dog-and-an-eagle.
7. Aby Warburg, *Mnemosyne Atlas*, panel 48, https://warburg.library.cornell.edu/panel/48.
8. On media archaeological topoi, see Erkki Huhtamo, "Dismantling the Fairy Engine: Media Archaeology as Topos Study," in *Media Archaeology: Approaches, Applications, and Implications*, ed. Erkki Huhtamo and Jussi Parikka (Berkeley: University of California Press, 2011), 27–47.
9. Keller Easterling, *Medium Design. Knowing How to Work on the World* (London: Verso, 2021), 10 and passim.
10. Hutton, *Reciprocal Landscapes*, 3–7.
11. Brett Milligan, "Accelerated and Decelerated Landscapes. On the Techniques, Knowledges, and Ethics of Bending Time," *Places*, February 2022, https://placesjournal.org/article/accelerated-and-decelerated-landscapes/. See also Easterling, *Medium Design*.
12. On a multiscalar approach to the concept of drift, see Bronislaw Szerszynski, "Drift as a Planetary Phenomenon," *Performance Research* 23, no. 7 (2018): 136–144.

13. See, for example, Olga Goriunova and Matthew Fuller, *Bleak Joys: Aesthetics of Ecology and Impossibility* (Minneapolis: University of Minnesota Press, 2019). The scaffolding of our book and its thematic and methodological choices also are based on foundations of artistic practices. Abelardo Gil-Fournier's art has, for a long period, dealt with questions of mediation of environmental surfaces that become interfaces to grasp a plethora of historical, experiential, and material forces of medium design. The visual technical character of some of the agrarian landscapes described in chapter 4 features in Gil-Fournier's installation *Mawat* (2017), and the time-lapse imagery in his *Bildung* (2019) video installation concerning plant growth prompts some of the themes in chapter 6 concerning computation and blades. Similarly, *The Quivering of the Reed* (2019) probes, in installation form, many of the themes of our book: the work puts a living plant into movement and frames it as an *ur*-form of cinema and animation; a sequence of subtitles is projected on the screen describing the images as if they had been filmed on a river, while bringing to mind a quote by Andrei Tarkovsky on his concept of the organic rhythm of the "time-pressure" of cinematic sequences (see Andrey Tarkovsky, *Sculpting in Time: Reflections on the Cinema*, trans. Kitty Hunter-Blair [New York: Alfred A. Knopf, 1987], 113–124). The moving plant becomes the image, the moving image becomes the plant. This is also the theme of our joint work, *Seed, Image, Ground* (2020), a video that is briefly discussed in chapter 4, a take on aerial agricultural practices which tie twentieth-century military views with more recent forms of smart agriculture and data-visualized growth. Of course, while such artistic practices are central to many of the methodological, stylistic, and theoretical views we propose in the book, Gil-Fournier's and our joint work sits as part of a broader burgeoning field of technical imaging, data, and plants. We can here mention also, among other references: the work on agriculture and the politics of space featured in Agnes Denes's *Wheatfield: A Confrontation* (1982) and Regina José Galindo's *Mazorca* (2014); Joan Fontcuberta's vegetal photography of industrial detritus in *Herbarium* (1983), along with Anna Ridler's GAN-driven AI work on tulips and speculative value, *Mosaic Virus* (2019); the aesthetics of measurement featuring in Hans Haacke's *Grass Grows* (1969) and in Marine Hugonnier's video installation *Apicula Enigma* (2013); the enumerated natures in Zygmunt Rytka's video performance series *Continual Infinity* (1982–1993), as well as in Julian Oliver's *psWorld* (2010); the critical approach to the concept of green mantle in Teresa Murak's *Easter Carpet* (1974) and in Julius von Bismark's *Landscape Painting* series (2015–2021); the work on ecosystem services in Helen Mayer Harrison and Newton Harrison's *Hog Pasture: Survival Piece #1* (1970–1971) and in Disnovation group's *Life Support System* (2020); the speculative proposals of Superstudio's *Supersurface: An Alternative Model for Life on the Earth* (1972) and Superflux's *Mitigation of Shock* (2019). In recent design and architectural (speculative) practice, see also Frédérique Aït-Touati, Alexandra Arènes, and Axelle Grégoire, *Terra Forma. A Book of Speculative Maps* (Cambridge, MA: MIT Press, 2022).

14. Among the many fabulous sources on the topic, see, for example, Daniela Bleichmar, *Visible Empire: Botanical Expeditions and Visual Culture in the Hispanic*

Enlightenment (Chicago: University of Chicago Press, 2012); Lucile H. Brockway, *Science and Colonial Expansion: The Role of the British Royal Botanic Gardens* (New Haven, CT: Yale University Press, 2002). Londa Schiebinger and Claudia Swan, eds., *Colonial Botany: Science, Commerce, and Politics in the Early Modern World* (Philadelphia: University of Pennsylvania Press, 2005).

15. Harold Wager, "The Perception of Light in Plants," *Annals of Botany* 23, no. 91 (1909): 459–489. Howard Caygill, "Harold Wager and the Photography of Plants," *Photographies* 14, no. 3 (2021): 505–519.

16. See, for example, Janet Janzen, *Media, Modernity and Dynamic Plants in Early 20th Century German Culture* (Leiden: Brill, 2016); Inga Pollmann, *Cinematic Vitalism: Film Theory and the Question of Life* (Amsterdam: Amsterdam University Press, 2018); as well as the edited collection on this topic, *Puissance du végétal et cinéma animiste: La vitalité révélée par la technique*, ed. Teresa Castro, Perig Pitrou, and Marie Rebecchi (Paris: Les Presses du Réel, 2020).

17. This could be said to be at least partly a cybernetic notion of the planet: not a particular geological form so much as a sphere of interlocking biogeochemical dynamics; ecosystems thinking since the 1930s is one part of the story, another one is how this escalated into systems modeling, both computational and reliant on the variety of sensors that started to make sense of Earth. See Jennifer Gabrys, *Program Earth: Environmental Sensing Technology and the Making of a Computational Planet* (Minneapolis: University of Minnesota Press, 2016). See also Paul N. Edwards, *A Vast Machine: Computer Models, Climate Data, and the Politics of Global Warming*, ed. Geoffrey C. Bowker (Cambridge, MA: MIT Press, 2013). On critical zones, see Bruno Latour and Peter Weibel, eds., *Critical Zones: The Science and Politics of Landing on Earth* (Cambridge, MA: MIT Press, 2020).

18. Sydney Mangham, *Earth's Green Mantle: Plant Science for the General Reader* (London: English Universities Press, 1939), 32. See also Veronica della Dora, *The Mantle of the Earth: Genealogies of a Geographical Metaphor* (Chicago: University of Chicago Press, 2020).

19. William Rankin, *After the Map: Cartography, Navigation, and the Transformation of Territory in the Twentieth Century* (Chicago: University of Chicago Press, 2016), color gallery page 2.

20. Matt Edgeworth, "The Relationship between Archaeological Stratigraphy and Artificial Ground and Its Significance in the Anthropocene," in *A Stratigraphical Basis for the Anthropocene*, ed. Colin Neil Waters, Jan Zalasiewicz, Mark Williams, Michael A. Ellis, and Andrea M. Snelling (London: Geological Society of London, 2014), 91–108, at 105, quoted in Stephen Graham, *Vertical: The City from Satellites to Bunkers* (London: Verso, 2016).

21. On afforestation and (landscape) design, for example, see Rosetta S. Elkin, *Plant Life: The Entangled Politics of Afforestation* (Minneapolis: University of Minnesota Press, 2022).

22. On medianatures, see Jussi Parikka, *A Geology of Media* (Minneapolis: University of Minnesota Press, 2015). See also Bernard Stiegler's *Bifurcate: There Is No*

Alternative, ed. Bernard Stiegler and the Internation Collective, trans. Daniel Ross (London: Open Humanities Press, 2021).

23. Hutton, *Reciprocal Landscapes*, 11.
24. Rankin, *After the Map*.
25. Here the Landsat satellite system since the 1970s was instrumental in opening up such practices of sensing to broader agricultural and other sectors. See Pamela E. Mack, *Viewing the Earth: The Social Construction of the Landsat Satellite System* (Cambridge, MA: MIT Press, 1990). See also Gökçe Önal, "Media Ecologies of the 'Extractive View' Image Operations of Material Exchange," *Footprint* 14, no. 2 (2020): 31–48.
26. Kathryn Yusoff, "Excess, Catastrophe, and Climate Change," *Environment and Planning D: Society and Space* 27, no. 6 (2009): 1010–1029, at 1010.
27. Geoff Manaugh, "Geomedia, or What Lies Below," *BLDGBLOG*, December 31, 2020. https://bldgblog.com/2020/12/geomedia-or-what-lies-below/. See also Seán Cubitt, "Three Geomedia," *Ctrl-Z* 7 (2017), accessed January 15, 2023, http://www.ctrl-z.net.au/articles/issue-7/cubitt-three-geomedia/. On the "subsurface," see Karen Pinkus, *Subsurface* (Minneapolis: University of Minnesota Press, 2023).
28. Ros Gray and Shela Sheikh, "The Wretched Earth: Botanical Conflicts and Artistic Interventions," *Third Text* 32, no. 2–3 (2018): 163–175, One could even go so far as to read our book as a variation on what Paul Virilio saw as the fundamental perceptual force of military technologies, especially when introduced to "the blinding Hiroshima flash which literally photographed the shadow cast by beings and things, so that every surface immediately became war's recording surface, its film." Paul Virilio, *War and Cinema: The Logistics of Perception*, trans. Patrick Camiller (London: Verso, 1989), 85. See also Akira Mizuta Lippit, *Atomic Light (Shadow Optics)* (Minneapolis: University of Minnesota Press, 2005). On herbicidal warfare, see David Zierler, *The Invention of Ecocide: Agent Orange, Vietnam, and the Scientists Who Changed the Way We Think about the Environment* (Athens: University of Georgia Press, 2011).
29. Siegfried Kracauer, *The Mass Ornament: Weimar Essays*, trans. and ed., with an introduction by Thomas Y. Levin (Cambridge, MA: Harvard University Press, 1995), 75.
30. Clement Greenberg, "On the Role of Nature in Modernist Painting," in *Art and Culture: Critical Essays* (Boston, MA: Beacon, 1961), 172.
31. Greenberg, "On the Role of Nature in Modernist Painting," 173. This was also the military aesthetic of the aerial view pertinent to Cubism: "The impression that the earth has become a planar grid for abstract data plotting is, in turn, visually enhanced by the flatness of the high-altitude vertical view, with its paradoxical erasure of the vertical dimension; and that leveling might further suggest cubist rejections of perspectival convention in favor of a conspicuously two-dimensional image plane whose depthlessness, like the aerial view's, was no longer hospitable to the conventional pictorial distinction between figure and ground." Paul K. Saint-Amour, "Modernist Reconnaissance," *Modernism/Modernity* 10, no. 2 (2003): 352.

32. Giuliana Bruno, *Surface: Matters of Aesthetics, Materiality, and Media* (Chicago: University of Chicago Press, 2014); Esther Leslie, *Synthetic Worlds: Nature, Art and the Chemical Industry* (London: Reaktion, 2005); Celia Lury, Luciana Parisi, and Tiziana Terranova, "Introduction: The Becoming Topological of Culture," in *Theory, Culture & Society* 29, no. 4–5 (2012): 3–35; Janet Ward, *Weimar Surfaces: Urban Visual Culture in 1920s Germany* (Berkeley: University of California Press, 2001); Yeseung Lee, ed., *Surface and Apparition: The Immateriality of Modern Surface* (London: Bloomsbury, 2020); Tim Ingold, "Surface Visions," *Theory, Culture & Society* 34, no. 7–8 (2017): 99–108.

33. Bruno, *Surface*. See also her more recent book in which issues of art and projection are continued: Giuliana Bruno, *Atmospheres of Projection: Environmentality in Art and Screen Media* (Chicago: University of Chicago Press, 2022).

34. Bruno, *Surface*, 112

35. The surface-screen double becomes architectural in media artistic works such as Janet Cardiff and George Bures Miller's sonic environment installation *The Paradise Institute* (2003) and in projects such as Diller Scofidio + Renfro's cloud building (Blur Building, Yverdon-les-Bains, Switzerland) of 2002; Bruno, *Surface*, 134–137. Expanding on the atmospheric, see also the fog sculptures by Nakaya Fujiko for the Pepsi Pavilion at the Expo '70, discussed by Yuriko Furuhata in *Climatic Media: Transpacific Experiments in Atmospheric Control* (Durham, NC: Duke University Press, 2022), 27–31.

36. The focus on atmosphere as fundamental to contemporary politics is a theme that Peter Sloterdijk has developed. See, for example, Peter Sloterdijk, *Terror from the Air*, trans. Amy Patton and Steve Corcoran (Los Angeles, CA: Semiotext(e), 2009).

37. Lukáš Likavčan and Paul Heinicker, "Planetary Diagrams: Towards an Autographic Theory of Climate Emergency," in *Photography Off the Scale: Technologies and Theories of the Mass Image*, ed. Tomáš Dvořák and Jussi Parikka (Edinburgh: Edinburgh University Press, 2021), 211–230. See also Dietmar Offenhuber, "The Planet as a Photographic Plate," *Fotograf Magazine* 20, no. 40 (2021): 66–71. Also, some approaches in geography and architecture, environmental humanities, and the work on the feral ecologies in and out of soil have defined surfaces beyond flatness. See, for instance, John May, "Logic of the Managerial Surface," *PRAXIS* 13 (2012): 116–124; Robert G. Pietrusko, "The Surface of Data," *LA+* 4 (Fall 2016): 79–83; María Puig de la Bellacasa, *Matters of Care: Speculative Ethics in More than Human Worlds* (Minneapolis, MN: University of Minnesota Press, 2017), and Anna L. Tsing, *The Mushroom at the End of the World: On the Possibility of Life in Capitalist Ruins* (Princeton, NJ: Princeton University Press, 2015).

38. On the work of Jananne al-Ani, see Caren Kaplan, *Aerial Aftermaths: Wartime from Above* (Durham, NC: Duke University Press, 2018), 180–206.

39. Eyal Weizman, *Forensic Architecture: Violence at the Threshold of Detectability* (New York: Zone, 2017), 274. See also Susan Schuppli, *Material Witness: Media, Forensics, Evidence* (Cambridge, MA: MIT Press, 2020).

40. Adrian J. Ivakhiv, *Ecologies of the Moving Image: Cinema, Affect, Nature* (Waterloo: Wilfried Laurier University Press, 2013), 6. For a related argument on the zoetic

character of photography see also Joanna Zylinska, *Nonhuman Photography: Theories, Histories, Genres* (Cambridge, MA: MIT Press, 2017).

41. Graig Uhlin, "Plant-Thinking with Film: Reed, Branch, Flower," in *The Green Thread: Dialogues with the Natural World*, ed. Patrícia Vieira, Monica Gagliano, and John Ryan (Lanham, MD: Lexington, 2016), 201–218, at 203.

42. Nadia Bozak, *The Cinematic Footprint: Lights, Camera, Natural Resources* (New Brunswick, NJ: Rutgers University Press, 2012), 13, 18. "Each film frame is a measure of our civilization's control of the sun, in the form of the fossilized sun or carbon that we have captured, refined, and duly exploited. The cinematic image literalizes in incontrovertible terms, how industry, the images of industrial culture, and the earth's natural ecology are, together and on their own terms, categorically derived from the power that emanates from the sun's rays" (29).

43. James Corner, "Terra Fluxus," in *The Landscape Urbanism Reader*, ed. Charles Waldheim (New York: Princeton Architectural Press, 2005), 21–33. See also Brett Milligan, "Landscape Migration. Environmental Design in the Anthropocene," *Places Journal*, June 2015. https://placesjournal.org/article/landscape-migration/#0, and Alfred W. Crosby, *Ecological Imperialism: The Biological Expansion of Europe, 900–1900* (Cambridge: Cambridge University Press, 2004), on the colonial amplification of such drifts.

44. See for instance the case of the moving borders in the Alps between Italy and its neighbor countries in Marco Ferrari, Elisa Pasqual, and Andrea Bagnato, eds., *A Moving Border: Alpine Cartographies of Climate Change* (New York: Columbia University Press, 2018).

45. See Abelardo Gil-Fournier and Jussi Parikka. "'Visual Hallucination of Probable Events' On Environments of Images, Data, and Machine Learning," in *Big Data: A New Medium?*, ed. Natasha Lushetich (Abingdon: Routledge, 2021), 46–60.

46. Walter Benjamin, *The Arcades Project*, trans. Howard Eiland and Kevin McLaughlin (Cambridge, MA: Belknap Press of Harvard University Press, 1996), 390 (Kla, 3).

47. Anusuya Datta, "Machine Learning Creates Living Atlas of the Planet," *Geospatial World* (blog), April 11, 2017. https://www.geospatialworld.net/article/machine-learning-creates-living-atlas-of-the-planet/.

48. See Jussi Parikka, *A Geology of Media* (Minneapolis: University of Minnesota Press, 2015). See also Jussi Parikka, "Medianatures," in *Posthuman Glossary*, ed. Rosi Braidotti and Maria Hlavajova (London: Bloomsbury Academic, 2018), 251–253. Related accounts appear also for example in Ivakhiv, *Ecologies of the Moving Image*, as well as in Adam Wickberg and Johan Gärdebo, eds., *Environing Media* (Abingdon: Routledge, 2023). Also compare Seán Cubitt's words on mediation as a primal flow: "It is the task of media theory to distinguish the philosophical concept of mediation as primal flow connecting all things from the history of mediation as the engine of disconnection and delay, and thus of exploitation and oppression." Seán Cubitt, *The Practice of Light: A Genealogy of Visual Technologies from Prints to Pixels* (Cambridge, MA: MIT Press, 2014), 2–3.

49. "So-called nature" is a riff on Friedrich Kittler's "so-called Man," which is a figure underpinned by the technological conditioning of such notions in the humanities, and which thus also historicizes such figures as part of cultural techniques that produce them. In Kittler's case that technological conditioning would include psychophysics, writing technologies, audio, cinema, and so on. There is more than a hint of Foucault at the back of Kittler's concept. See Friedrich A. Kittler, *Discourse Networks, 1800/1900*, trans. Michael Metteer with Chris Cullens (Stanford, CA: Stanford University Press 1990).

50. See Cubitt, *Three Geomedia*. This merger of the material and epistemic sides of mediation speaks to the new materialist agenda put forward by, for example, Karen Barad. It also links to John Durham Peters' work where elemental media is discussed not only regarding the environmental impact of media technologies and infrastructures but even more by going back to the large-scale mediations from sun to the sky and waters to nonhuman temporalities that determine a broader way of appreciating some "deep times" of media. John Durham Peters, *The Marvelous Clouds: Toward a Philosophy of Elemental Media* (Chicago: University of Chicago Press, 2015); Karen Barad, *Meeting the Universe Halfway: Quantum Physics and the Entanglement of Matter and Meaning* (Durham, NC: Duke University Press, 2007). See also Richard Grusin, "Radical Mediation," *Critical Inquiry* 42, no. 1 (2015): 124–148.

51. On cultural techniques, see, for example, Geoffrey Winthrop-Young, "Cultural Techniques: Preliminary Remarks," *Theory, Culture & Society* 30, no. 6 (2013): 3–19. Thomas Macho, "Second-Order Animals: Cultural Techniques of Identity and Identification," *Theory, Culture & Society* 30, no. 6 (2013): 30–47.

52. Bernhard Siegert, *Cultural Techniques: Grids, Filters, Doors, and Other Articulations of the Real*, trans. Geoffrey Winthrop-Young (New York: Fordham University Press, 2015), 14

53. Cornelia Vismann, "Cultural Techniques and Sovereignty," *Theory, Culture & Society* 30, no. 6 (2013): 83–93, at 84. Every plan, infrastructure, and media operation comes to be defined, even after the fact, by its own execution. Hence the idea voiced by Vismann, that cultural techniques deal with the middle-voice and the verb form of action, is central to this focus, where "all media and things supply their own rules of execution." All contributing agents, participants, and objects, including those of knowledge, emerge from the primacy of productive cultural techniques. "To derive the operational script from the resulting operation, to extract the rules of execution from the executed act itself: that is what characterizes the approach of cultural techniques"; Vismann, "Cultural Techniques and Sovereignty," 87.

54. Siegert, *Cultural Techniques*, 149.

55. On the invisual, see Adrian MacKenzie and Anna Munster, "Platform Seeing: Image Ensembles and Their Invisualities," *Theory, Culture & Society* 36, no. 5 (2019): 3–22. See also Jussi Parikka, *Operational Images: From the Visual to the Invisual* (Minneapolis: University of Minnesota Press, 2023). Due to our focus in this book, we leave aside experiments related to genes, hormones, or electric

signals. During the same period, when some of the experiments discussed in the book took place, other investigations analyzed plants from the point of view of genetics, hormone regulation, and electric signals. On the link between Darwin's research into plant movement as the basis for plant hormones and the later work on the chemistry of plant hormones, see David Zierler, *The Invention of Ecocide: Agent Orange, Vietnam, and the Scientists Who Changed the Way We Think about the Environment* (Athens: University of Georgia Press, 2011). On experimental cultures related to breeding and genetic research, see Christophe Bonneuil, "Mendelism, Plant Breeding and Experimental Cultures: Agriculture and the Development of Genetics in France," *Journal of the History of Biology* 39, no. 2 (2006): 281–308. On interaction with plants through electric signals, see Stefan Rieger, "What's Talking? On the Nostalgic Epistemology of Plant Communication," in Ryan, Vieira, and Gagliano, *Green Thread*, 59–79.

56. See, for instance, Sebastian Vehlken, *Zootechnologies: A Media History of Swarm Research* (Amsterdam: Amsterdam University Press, 2019). Furthermore, the question of cultural techniques has an interesting relation to themes of urbanism and the rural, as it underpins the approach as to where "media" or "culture" is found. On related discussions, see Shannon Mattern on the *longue durée* of urbanization in *Code and Clay, Data and Dirt: Five Thousand Years of Urban Media* (Minneapolis: University of Minnesota Press, 2017). See also Manuel DeLanda, *A Thousand Years of Nonlinear History* (New York: Zone, 2000). On ruralism, see Neil Brenner and Nikos Katsikis, "Hinterlands of the Capitalocene," *Architectural Design* 90 (2020): 22–31.

57. Siegert, *Cultural Techniques*, 145.

58. See Jara Rocha and Femke Snelting, "So-called Plants," in *Volumetric Regimes: Material Cultures of Quantified Presence*, ed. Jara Rocha and Femke Snelting (London: Open Humanities Press, 2022), 239–260. In a similar way, cultural techniques research has related more closely to anthropotechnics that have given rise to humans-as-cultural-beings and to domesticated animals. For a discussion on cultural techniques in relation to anthropotechnics and other posthuman anthropological considerations, see Winthrop-Young, "Cultural Techniques." Cultural techniques produce the subjects and objects they operate with. In this regard, it is a media theoretical approach related to Karen Barad's onto-epistemology, where "knowing is a direct material engagement, a practice of intra-acting with the world as part of the world in its dynamic material configuring, its ongoing articulation. The entangled practices of knowing and being are material practices." See Barad, *Meeting the Universe Halfway*, 379. For a more metaphysical approach in plant studies, see Emanuele Coccia, *The Life of Plants: A Metaphysics of Mixture* (Medford, MA: Polity, 2018). Compare also Wietske Maas's proposition that "we can think of photosynthesis itself as a sort of primeval organ of vision spread out across the skin of the vegetable kingdom"; Wietske Maas, "The Corruption of the Eye: On Photogenesis and Self-Growing Images," *e-flux*, 56, Venice Biennale (September 2015), accessed January 15, 2023, http://supercommunity.e-flux.com/texts/the-corruption-of-the-eye-on-photogenesis-and-self-growing-images/.

59. See Michael Marder, *Plant-Thinking: A Philosophy of Vegetal Life* (New York: Columbia University Press, 2013), and Monica Gagliano, John C. Ryan, and Patrícia Vieira, eds., *The Language of Plants: Science, Philosophy, Literature* (Minneapolis: University of Minnesota Press, 2017). For texts coming from the biological sciences, see, for instance, Anthony Trewavas, *Plant Behaviour and Intelligence* (Oxford: Oxford University Press, 2015), and Stefano Mancuso and Alessandra Viola, *Brilliant Green: The Surprising History and Science of Plant Intelligence*, trans. Joan Benham (Washington, DC: Island Press, 2015); and Jeffrey Nealon, *Plant Theory: Biopower and Vegetable Life* (Stanford, CA: Stanford University Press, 2015).

60. See Giovanni Aloi, ed., *Botanical Speculations: Plants in Contemporary Art* (Newcastle upon Tyne: Cambridge Scholars, 2018). On bioart, see George Gessert, *Green Light: Toward an Art of Evolution*, (Cambridge, MA: MIT Press, 2010). For an approach to the topic of plants as queer entities in relation to art and film, see Teresa Castro, "The Mediated Plant," *e-flux* 102 (September 2019), accessed January 15, 2023, https://www.e-flux.com/journal/102/283819/the-mediated-plant/.

61. See Janzen, *Media, Modernity and Dynamic Plants*; Uhlin, "Plant-Thinking with Film"; Matthew Vollgraff, "Vegetal Gestures: Cinema and the Knowledge of Life in Weimar Germany," *Grey Room* 72 (Summer 2018): 68–93; Oliver Gaycken, "The Secret Life of Plants: Visualizing Vegetative Movement, 1880–1903," in *Early Popular Visual Culture* 10, no. 1 (February 1, 2012): 51–69. See also Katharina Steidl, "Leaf Prints. Early Cameraless Photography and Botany," *PhotoResearcher* 17 (2012): 26–35, and Max Long, "The Ciné-Biologists: Natural History Film and the Co-Production of Knowledge in Interwar Britain," *British Journal for the History of Science* 53, no. 4 (2020): 527–551.

62. Pollmann, *Cinematic Vitalism*; Castro, Pitrou, and Rebecchi, *Puissance du végétal et cinéma animiste*; Hannah Landecker, "Microcinematography and the History of Science and Film," *Isis* 97, no. 1 (2006): 121–132. On nonhuman photography, see Zylinska, *Nonhuman Photography*; see also Claire Colebrook, *Deleuze and the Meaning of Life* (London: Continuum, 2010). This is also the key focus of artist and scholar Beny Wagner's work, including his PhD research on metabolism and cinema: Wagner, "Metabolisms of the Moving Image," PhD diss., University of Southampton, September 2023. See also the film by Sasha Litvintseva and Beny Wagner, *My Want of You Partakes of Me* (2023).

63. Susan Schuppli refers here to some of the epistemic uses of the idea of natural sensors, of environmental monitoring through leaves, plants, and vegetal formations. Schuppli, *Material Witness*, 287.

64. Note that such views of plants "conceived of as emitters and receivers of information, following the computational standard of intelligence," are often seen as reductive in the ecocritical articulations of plant studies. See Michael Marder, "To Hear Plants Speak," in Gagliano, Ryan, and Vieira, *Language of Plants*, 103–125, at 115.

65. Consider, for example, the Normalized Difference Vegetation Index (NDVI) as one such operative technique. NDVI is an inconspicuous device for quantification and "coloring," interpreting satellite or other aerial measurements of visible

and invisible light to produce color charts that indicate important information about landcover, such as soil, water, vegetal canopy areas, and importantly, health of vegetation. While the use of infrared film emerged in an earlier period of aerial imaging and had military uses (to detect camouflage), it was early on understood to be useful also for reading the health status of vegetation (Mack, *Viewing the Earth*, 32–33). In subsequent earth observation satellite measurement practices, such as Landsat satellites, the NDVI emerged as one crucial technique of quantification that is often defined simply as quantification of "vegetation by measuring the difference between near-infrared (which vegetation strongly reflects) and red light (which vegetation absorbs)"; GISGeography, 2022, https://gisgeography.com/ndvi-normalized-difference-vegetation-index/. Techniques such as NDVI standardize how color is categorized in the sense data of the earth surface concerning surface biome signatures. For water bodies, different algorithmic devices are used, such as Floating Algae Index (FAI), to help detect algae and to create relevant false-color maps for operational uses. See Melody Jue, "'Pixels May Lose Kelp Canopy': The Photomosaic as Epistemic Figure for the Satellite Mapping and Modeling of Seaweeds," *Media+Environment* 3, no. 2 (2021), https://mediaenviron.org/article/21261-pixels-may-lose-kelp-canopy-the-photomosaic-as-epistemic-figure-for-the-satellite-mapping-and-modeling-of-seaweeds. The quantified coloring of the surface adds a layer of data that is premised on the sensing of and by plants. Such knowledge objects as NDVI emerge as central "administrative" elements in the mediation of light from photosynthesis to quantification of remote sensing data. It also becomes the backbone of scientific observation and environmental services as well as precision agriculture as it is practiced as a data-driven high-tech business. Enumeration and statistical knowledge of surfaces become inextricably linked to fluctuating shades of green; what arose initially as the plant's own primary sensing and absorption of light, the color has become a technical element of the analysis.

66. Stefan Ouma, *Farming as Financial Asset: Global Finance and the Making of Institutional Landscapes* (Newcastle: Agenda, 2020). See also Xiaowei Wang, *Blockchain Chicken Farm: And Other Stories of Tech in China's Countryside* (New York: Macmillan, 2020); Adam Wickberg, "Environing Media and Cultural Techniques: From the History of Agriculture to AI-Driven Smart Farming," *International Journal of Cultural Studies* 26, no. 4 (2023): 392–409, https://doi.org/10.1177/13678779221144762. On plants as dead labor, see Bozak, *Cinematic Footprint*; Luce Lebart, "La photographie d'origine végétale," in Castro, Pitrou, and Rebecchi, *Puissance du végétal et cinéma animiste*, 119–127. On solar energy and bioinfrastructures, see also Puig de la Bellacasa, *Matters of Care*; Nicole Starosielski. "Beyond the Sun: Embedded Solarities and Agricultural Practice," *South Atlantic Quarterly* 120, no. 1 (2021): 13–24.

67. The managerial surface is defined as the technical media control space that governs the new territorial arrangements in electro-statistical media—including digital modes of visualization, tracking, simulation, modelling. See May, "Logic of the Managerial Surface."

68. Already for the twentieth-century imaginary of environmental management, this meant developing systems of sensing that were able to interpret such signs for the development of prediction models, from sensors onboard Landsat satellite in 1970s to more recent precision farming data management plans. See Mack, *Viewing the Earth*.

69. See, for instance, Suzanne Simard, *Finding the Mother Tree: Discovering the Wisdom of the Forest* (New York: Alfred A. Knopf, 2021), and Anna-Sophie Springer, Etienne Turpin, Kirsten Einfeldt, and Daniela Wolf, eds., *The Word for World Is Still Forest* (Berlin: HKW Verlag, 2017). For a biosemiotic take on the environment built by a forest in relation also to its human dwellers, see also Eduardo Kohn, *How Forests Think: Toward an Anthropology beyond the Human* (Berkeley: University of California, 2013).

70. See in this regard Elaine P. Miller, *The Vegetative Soul: From Philosophy of Nature to Subjectivity in the Feminine* (Albany: SUNY Press, 2002), and Michael Pollan, *The Botany of Desire: A Plant's-Eye View of the World* (New York, NY: Random House, 2002). See also Tsing, *Mushroom at the End of the World*.

71. Jennifer Gabrys, "Smart Forests and Data Practices: From the Internet of Trees to Planetary Governance," *Big Data & Society* 7, no. 1 (2020). See also Max Liboiron, *Pollution Is Colonialism* (Durham, NC: Duke University Press, 2021), for a related merger of knowledge practices in relation to the study of plastic pollution in water.

72. See for instance Paulo Tavares, "The Geological Imperative: On the Political Ecology of Amazonia's Deep History," in *Architecture in the Anthropocene: Encounters among Design, Deep Time, Science and Philosophy*, ed. Etienne Turpin (London: Open Humanities Press, 2013), 209–240, and Paulo Tavares, "Nonhuman Rights," in *Forensis: The Architecture of Public Truth*, ed. Forensic Architecture (Berlin: Sternberg, 2014), 553–572.

73. Jennifer Gabrys. "Becoming Planetary," *e-flux*, October 2018, https://www.e-flux.com/architecture/accumulation/217051/becoming-planetary/.

74. Gabrielle Hecht, "Interscalar Vehicles for an African Anthropocene: On Waste, Temporality, and Violence," *Cultural Anthropology* 33, no. 1 (2018): 109–141.

75. Kliment A. Timiriazev, "Croonian Lecture. The Cosmical Function of the Green Plant," *Proceedings of the Royal Society of London* 72, nos. 477–486 (1904): 424–461.

76. On the energy and geopolitics of the Soviet Russia as backdrops to questions of "planetarity," see Daniela Russ, "'Socialism Is Not Just Built for a Hundred Years': Renewable Energy and Planetary Thought in the Early Soviet Union (1917–1945)," *Contemporary European History* 31 (2022): 491–508.

77. See also Matthew Fuller and Eyal Weizman, *Investigative Aesthetics: Conflicts and Commons in the Politics of Truth* (London: Verso, 2021), and Schuppli, *Material Witness*.

CHAPTER 1

1. Giacomo Ciamician, "The Photochemistry of the Future," *Science* 36, no. 926 (1912): 385–394.
2. Ciamician, "Photochemistry of the Future," 394.
3. Ciamician, "Photochemistry of the Future," 394.
4. Achille Mbembe discusses the slavery system as one of energy, of ambulant suns and fossils. "The ecological disturbances brought about by this vast draining of humans and its procession of violence have yet to be systematically studied. But the New World plantations could hardly have operated without the massive use of 'ambulant suns,' that is, African slaves. Even after the Industrial Revolution, these real human fossils continued to serve as coal for producing energy and provided the necessary dynamism for economically transforming the Earth System." Mbembe, *Necropolitics*, trans. Steven Corcoran (Durham, NC: Duke University Press, 2019), 165–166.
5. Marianne Klemun, "Live Plants on the Way: Ship, Island, Botanical Garden, Paradise and Container as Systemic Flexible Connected Spaces in between," *HOST—Journal of History of Science and Technology* 5 (Spring 2012), http://johost.eu/vol5_spring_2012/marianne_klemun_2.htm. Londa Schiebinger, *Plants and Empire: Colonial Bioprospecting in the Atlantic World* (Cambridge, MA: Harvard University Press, 2007).
6. Ciamician, "Photochemistry of the Future," 394.
7. To consider the classic example, namely Paul Scheerbart's *Glasarchitektur* [Glass architecture] (Berlin: Verlag der Sturm, 1914), which painted a picture of transformations of not only the architectural materials from concrete to the iron and glass combinations of urban and garden buildings but also the subsequent speculative terraforming of the surface of the earth itself: "We all know what is meant by colour; it forms only a small part of the spectrum. But we want to have that part. Infra-red and ultra-violet are not perceptible to our eyes—but ultra-violet is perceptible to the sensory organs of ants. If we cannot at the moment accept that our sensory organs will develop appropriately overnight, we are justified in accepting that we should first reach for what is within our grasp—i.e., that part of the spectrum which we are able to in with our own eyes—in fact, the miracles of colour, which we are in a position to appreciate ourselves. In this, only glass architecture, which will inevitably transform our whole lives and the environment in which we live, is going to help us. So we must hope that glass architecture will indeed transform the face of our world." Paul Scheerbart in *Glass Architecture by Paul Scheerbart and Alpine Architecture by Bruno Taut*, trans. Shirley Palmer and James C. Palmes (Westport, CT: Praeger, 1972), 70.
8. Gabrielle Hecht, "Interscalar Vehicles for an African Anthropocene: On Waste, Temporality, and Violence," *Cultural Anthropology* 33, no. 1 (2018): 109–141.
9. Hecht, "Interscalar Vehicles for an African Anthropocene," 115.

10. Seán Cubitt, *The Practice of Light. A Genealogy of Visual Technologies from Prints to Pixels* (Cambridge, MA: MIT Press 2014).
11. On these practices of "environing" and their relation to the concept of environment itself at the planetary scale, see Sabine Höhler, "Ecospheres: Model and Laboratory for Earth's Environment," *Technosphere*, June 20, 2018. https://technosphere-magazine.hkw.de/p/Ecospheres-Model-and-Laboratory-for-Earths-Environment-qfrCXdpGUyenDt224wXyjV.
12. Friedrich A. Kittler, "Computer Graphics: A Semi-Technical Introduction," trans. Sara Ogger, *Grey Room* 2 (Winter 2001): 30–45, at 38.
13. See Jacob Gaboury, *Image Objects: An Archaeology of Computer Graphics* (Cambridge, MA: MIT Press, 2021), 27–54.
14. Light was for Descartes invisible, insubstantial, and static. His faith in the ontological truth of premises such as the axioms of Euclidean geometry, however, made it possible for the philosopher to represent the paths of light through metaphors such as line drawings—"the line is a tool for the representation of light and a description of its behavior", argues Cubitt—making description and representation coalesce. See Cubitt, *Practice of Light*, 56.
15. Cubitt, *Practice of Light*, 58.
16. Cubitt, *Practice of Light*, 77.
17. Edward Grant, *Much Ado about Nothing: Theories of Space and Vacuum from the Middle Ages to the Scientific Revolution* (Cambridge: Cambridge University Press, 2011), 67–100.
18. "The centre of interest in these questions in 1645–1651 was France, where Mersenne reported on the Italian work, and where natural philosophers such as Pascal, Petit, Roberval, and Pecquet all gave their views and experimented with the Torricellian apparatus." Steven Shapin and Simon Schaffer, *Leviathan and the Air-Pump* (Princeton, NJ: Princeton University Press, 1985), 41.
19. As the well-known book by the historians of science Steven Shapin and Simon Schaffer has shown in detail, the inverted glass jar with candles inside or connected to an air-pump succeeded in the seventeenth century in becoming the model of legitimate production of science—based on the value of systematic experimental practices—after a public struggle between experimentalist Robert Boyle and natural philosopher Thomas Hobbes. See Shapin and Schaffer, *Leviathan and the Air-Pump*.
20. See Laura Baudot, "An Air of History: Joseph Wright's and Robert Boyle's Air Pump Narratives," *Eighteenth-Century Studies* 46, no. 1 (2012): 1–28.
21. Joseph Priestley, *Experiments and Observations on Different Kinds of Air* (London: J. Johnson, 1775), 50. "Noxious air" was carbon dioxide, as it was addressed by Priestley. See also 89–90.
22. Priestley, *Experiments and Observations*, 50. See also Joe Jackson, *A World on Fire: A Heretic, an Aristocrat, and the Race to Discover Oxygen* (New York: Viking Penguin, 2005), 106–107.

23. Priestley, *Experiments and Observations*, 86
24. The president of the Royal Society, Sir John Pringle, on the occasion of presentation of the Copley medal to Priestley. Kliment A. Timiriazev, *The Life of the Plant: Ten Popular Lectures* (Moscow: Foreign Languages Publishing House, 1958), 395.
25. Priestley, *Experiments and Observations*, 93.
26. Kijan Malte Espahangizi, "Wissenschaft im Glas: Eine historische Ökologie moderner Laborforschung," PhD diss., ETH Zürich, 2010, 38.
27. This exchange is related to an observation that John D. Peters makes in relation to an experiment by James C. Maxwell, where two lenses in contact are shown to be infinitesimally distanced as they produce a diffraction pattern that only distance would be able to generate. This episode is analyzed by Peters in relation to the modern Western subject that at the end of the nineteenth century faced a wide spectrum of media for communication while at the same time felt deeply the experience of isolation. It highlights the tension between the inevitable presence of vacuum between bodies and objects and the resort to communication to mitigate the anxiety of solipsism. In this regard, in Priestley's case light operates as an elemental form of communication where the communicated message is the continuity of the inhabitable world. See John D. Peters, *Speaking into the Air: A History of the Idea of Communication* (Chicago: University of Chicago Press, 2001). A discussion on Peters observation can be found also in Sybille Krämer, *Medium, Messenger, Transmission: An Approach to Media Philosophy* (Amsterdam: Amsterdam University Press, 2015).
28. Schiebinger, *Plants and Empire*, 89.
29. Luke Keogh, *The Wardian Case: How a Simple Box Moved Plants and Changed the World* (Chicago: University of Chicago Press, 2020), 32
30. This is well reflected in such works as John Woodward's *Brief Instructions for Making Observations in All Parts of the World; as also for Collecting, Preserving and Sending Over Natural Things* from 1696. See also Keogh, *Wardian Case,*, 33.
31. Zeynep Çelik Alexander, "Managing Iteration: The Modularity of the Kew Herbarium," in *Iteration: Episodes in the Mediation of Art and Architecture*, ed. Robin Schuldenfrei (Abingdon: Routledge, 2020), 1–24.
32. Nathaniel B. Ward, *On the Growth of Plants in Closely Glazed Cases*, 2nd ed. (London: John van Voorst, Paternoster Row, 1852), 72. The first edition came out in 1842.
33. The case can be seen as one emblem of the broader inspiration provided by glass materials in the nineteenth century. See Isobel Armstrong, *Victorian Glassworlds: Glass Culture and the Imagination, 1830–1880* (Oxford: Oxford University Press, 2008). As Margaret Flanders Darby notes on her take on the "unnatural history" of the period: "As parlor accessory, Ward's invention is both an extreme and characteristic the Victorians' artificial manipulation of nature: a portable, frugal expression collecting manias, of the development of the private sphere, of a response pollution that depended on the very innovative industrial

technologies that problem." See Margaret Flanders Darby, "Ward's Glass Cases," *Victorian Literature and Culture* 35, no. 2 (2007): 635–647, at 647. The spread of these terraria and aquaria in private spheres continued beyond the Victorian context; on aquaria, in particular, see Christina Wessely and Thomas Brandstetter, eds., "Der Ozean im Glas: Aquaristische Räume um 1900," special issue, *Berichte zur Wissenschaftsgeschichte* 2, no. 36 (2013).

34. Wolfgang Schivelbusch, *The Railway Journey: The Industrialization of Time and Space in the Nineteenth Century* (Berkeley: University of California Press, 2014), 78.

35. Lucae, quoted in Schivelbusch, *Railway Journey*, 79.

36. Ward, *On the Growth of Plants*. On plant indicators, see chapter 6.

37. Ward, *On the Growth of Plants*, 38.

38. Faraday letter to Ward, November 4, 1851, included in the appendix of Ward, *On the Growth of Plants*.

39. See Alexander, "Managing Iteration." On the concept of center of calculation, see Bruno Latour, *Science in Action: How to Follow Scientists and Engineers through Society* (Cambridge, MA: Harvard University Press, 1988).

40. See Michel Foucault, "Of Other Spaces." Trans. Jay Miskowiec, *Diacritics* 16, no. 1 (1986): 22–27. "The heterotopia is capable of juxtaposing in a single real place several spaces, several sites that are in themselves incompatible" (25).

41. Keogh, *Wardian Case*, 181.

42. Michel Serres, *The Parasite*, trans. Lawrence R. Schehr (Baltimore, MD: Johns Hopkins University Press, 1982).

43. Keogh, *Wardian Case*, 208–217.

44. "Air conditioning is destiny. . . . As soon as air supply ceases to be an unproblematic premise of life processes and enters its technological stage, even this oldest pneumatic and atmospheric basic condition of human existence will have reached the threshold of modernity. From that point on, air mixtures and atmospheres will become objects of explicit production. . . . The bright side of the Enlightenment will become atmotechnics." Peter Sloterdijk, *Globes. Spheres II: Macrospherology*, trans. Wieland Hoban (South Pasadena, CA: Semiotext(e), 2014), 964–965.

45. The coincidence of plants and enslaved humans traveling through the same routes is a topic that we cannot deal in detail in this book. As Kijan Espahangizi puts it, in the context on his work on glass, "there is a genealogically older layer in which the glass vessel forms a matrix, literally a womb, in which the alchemist / modern man gives birth to a second, i.e. a new artificial nature"; Kijan Espahangizi, "The Twofold Section of Laboratory Glassware," in *Membranes Surfaces Boundaries. Interstices in the History of Science, Technology and Culture*, ed. Mathias Grote and Max Stadler (Berlin: Max Planck Institute for the History of Science, 2011), 27–44, at 28, In addition to the glass case, the slave ship was an ever more important vessel involved in the project of "a new artificial nature." As Christina Sharpe has emphasized in her critique of Sekula and Burch's

take on logistics, *The Forgotten Space*, the cargo ship echoes the "so-called migrant ship," "the prison," the slave ship, and therefore "the womb that produces blackness"; Christina Sharpe, *In the Wake: On Blackness and Being* (Durham, NC: Duke University Press, 2016), 27.

46. See Matthew Fuller, *Media Ecologies: Materialist Energies in Art Technoculture* (Cambridge, MA: MIT Press, 2005). Alexander Klose, *The Container Principle How a Box Changes the Way We Think*, trans. Charles Malcrum II (Cambridge, MA: MIT Press, 2015).

47. Kliment A. Timiriazev, "Croonian Lecture: The Cosmical Function of the Green Plant," *Proceedings of the Royal Society of London* 72, nos. 477–486 (1904): 424–461, at 461.

48. William R. Newman, *Newton the Alchemist: Science, Enigma, and the Quest for Nature's "Secret Fire"* (Princeton, NJ: Princeton University Press, 2018)

49. Timiriazev, "Croonian Lecture," 461.

50. Timiriazev, "Croonian Lecture," 424.

51. This experiment is for instance explained in Charles Bonnet, *Recherches sur l'usage des Feuilles dans les Plantes, et sur Quelques Autres Sujets Relatif à l'Histoire de la Végétation* (Göttingen: Elie Luzac, Fils, 1754).

52. See Jan van Ingenhousz, *Experiments upon Vegetables: Discovering Their Great Power of Purifying the Common Air in the Sun-Shine, and of Injuring It in the Shade and at Night. To Which Is Joined, a New Method of Examining the Accurate Degree of Salubrity of the Atmosphere* (London: P. Elmsly and H. Payne, 1779).

53. See Jean Sénebier, *Mémoires physico-chimiques sur l'influence de la lumière solaire pour modifier les êtres des trois règnes de la nature, et sur-tout ceux du règne végétal* (Geneva: Barthelemi Chirol, 1782), 75.

54. A succinct account of Aristotle's thoughts on the relation between plants, color and sunlight can be read in Elliot Weier, "The Structure of the Chloroplast," *Botanical Review* 4, no. 9 (1938): 497–530, at 497: "Of purely historical interest is the fact that Aristotle attempted to account for the green coloring of plants and apparently appreciated the importance of light in the production of the pigment, although one may be reading present day knowledge into his words. He states that yellow is derived from fire, white from air, water and the earth. Black develops when the elements are transformed from one to another. Green is a compound color and develops from a mixture of yellow (light) and black (the transformation of one element into another; air and water into earth). All plants developed a green color when they grew in the earth. They became white when the fire within them did not mix with the sun's rays."

55. Sénebier, *Mémoires physico-chimiques*, 200–202.

56. For a discussion on volumes and volumetry, see Jara Rocha and Femke Snelting, eds., *Volumetric Regimes: Material Cultures of Quantified Presence* (London: Open Humanities, 2022).

57. The botanist Matthias J. Schleiden explained this recursiveness when describing the mechanism of the microscope to the broad audience of his popular

science book, *The Plant: A Biography*. There he exposes first the features of Anton van Leeuwenhoek's simple microscope. It was a handheld device similar to a loupe, whose optics consisted only of a tiny sphere of glass. The principle of the compound microscope, he continues, "depends on a combination of the camera obscura with the simple microscope." That is, the amplified image after the first sphere would be internally projected and observed in recursion through a second sphere. See his full explanation in Matthias J. Schleiden, *The Plant: A Biography*, trans. Arthur Henfrey (London: Hippolyte Bailliere, 1848), 28.

58. Hugo von Mohl, *Untersuchungen Über Die Anatomischen Verhältnisse des Chlorophylls: Eine Inaugural-Dissertation* (Tübingen: Bähr, 1837), is often credited as the first work to describe the chloroplasts, or *Chlorophyllkörner*. However, botanists since the eighteenth century, such as Andrea Comparetti, Christian K. Sprengel, and Ludolph C. Treviranus, had described them, before von Mohl; see for instance, Conway Zirkle, "The Structure of the Chloroplast in Certain Higher Plants," *American Journal of Botany* 13, no. 5 (1926): 301–320, at 301. Even seventeenth-century microscopist Anton van Leeuwenhoek wrote about them; see Elliot Weier, "The Structure of the Chloroplast," *Botanical Review* 4, no. 9 (1938): 497–530, at 498.

59. Andreas F. W. Schimper, "Uber die Entwicklung der Chlorophyllkörner und Farbkörner," *Botanische Zeitung* 41 (1883): 105–114, at 112, quoted in Jan Sapp, Francisco Carrapiço, and Mikhail Zolotonosov, "Symbiogenesis: The Hidden Face of Constantin Merezhkowsky," *History and Philosophy of the Life Sciences* 24, no. 3/4 (2002): 413–440, at 419. Anecdotally, as it is discussed in the article by Sapp, Carrapiço, and Zolotonosov, these early insights on the possibility of symbiogenesis included the important contribution of the otherwise infamous Constantin Merezhkowsky, often credited wrongly as an earlier proponent of the idea. Years later, in the 1920s, Boris Kozo-Polyansky formulated a Darwinian theory of symbiogenesis. The modern endosymbiosis theory that explains how chloroplasts developed from cyanobacteria was developed by Lynn Margulis in her 1967 text "On the Origin of Mitosing Cells," *Journal of Theoretical Biology* 14, no. 3 (1967): 225–274.

60. See Espahangizi, "Wissenschaft im Glas." In addition to Espahangizi's work, the role of glass and bubbles in the interplay of scales has been highlighted as an important part of the material culture of natural sciences during the nineteenth century. Part of Simon Schaffer's long-time interest in glass (see the already mentioned Shapin and Schaffer, *Leviathan and the Air-Pump*, or Schaffer, "Glass Works: Newton's Prisms and the Uses of Experiment," in *The Uses of Experiment: Studies in the Natural Sciences*, ed. David Gooding, Trevor Pinch, and Simon Schaffer (Cambridge: Cambridge University Press, 1985): 67–104), has also included how bubbles came to be part of the modelling apparatus of natural sciences with scientists such as Michael Faraday and later on William Thompson using bubbles to trace and visualize fluid dynamics. See Simon Schaffer, "A Science Whose Business Is Bursting: Soap Bubbles as Commodities in Classical Physics," in *Things that Talk: Object Lessons from Art and Science*, ed. Lorraine Daston (New York: Zone, 2004), 147–194. On the role of glass as a modeling

material, see Lorraine Daston, "The Glass Flowers," in Daston, *Things that Talk*, 223–256.

61. Espahangizi, "Twofold Section of Laboratory Glassware."

62. Kijan Espahangizi, "Science in Glass: Material Pathologies in Laboratory Research, Glassware Standardization, and the (Un)Natural History of a Modern Material, 1900s–1930s," *Isis* 113, no. 2 (June 2022): 221–244.

63. Espahangizi, "Twofold Section of Laboratory Glassware," 36.

64. The entangled lines of genealogical investigation that come together in this chapter—and the whole book—concern various moments when techniques of light, space, and data unite, which was very much the case in the spheres of plant life and colonialism. This is the other aspect of plants as planetary agents—not only capturing and using the solar energy cast down from the skies but also moving across the surface as part of the established routes within Europe and between Europe and what were called New Worlds, or Neoeuropes, that were refabricated through introduction of imported plants and animals and which led to such disastrous practices as plantations. See Alfred W. Crosby, *Ecological Imperialism: The Biological Expansion of Europe, 900–1900* (Cambridge: Cambridge University Press, 2004).

65. Giuliana Bruno, *Surface: Matters of Aesthetics, Materiality, and Media* (Chicago: University of Chicago Press, 2014), 56.

66. Bruno, *Surface*, 5.

67. See also Anne Friedberg, *Window Shopping. Cinema and the Postmodern* (Berkeley: University of California Press, 1994).

68. "Die Erdoberfläche würde sich sehr verändern, wenn überall die Backsteinarchitektur von der Glasarchitektur verdrängt würde. / Es wäre so, als umkleidete sich die Erde mit einem Brillanten- und Emailschmuck." Scheerbart, *Glasarchitektur*, 21.

69. Janet Janzen, *Media, Modernity and Dynamic Plants in Early 20th Century German Culture* (Leiden: Brill, 2016), 92. This same thesis is also supported by Esther Leslie in *Synthetic Worlds: Nature, Art and the Chemical Industry* (London: Reaktion, 2006), 108. See also the 1957 novel *Gläserne Bienen* by Ernst Jünger; *The Glass Bees*, trans. Louise Bogan and Elizabeth Mayer (New York: New York Review Books, 2000).

70. Richard Drayton, *Nature's Government: Science, Imperial Britain, and the "Improvement" of the World* (New Haven, CT; London: Yale University Press, 2000).

71. See Beatriz Colomina, "Enclosed by Images: The Eameses' Multimedia Architecture," *Grey Room* 2 (Winter 2001): 7–29.

72. This point relates to the fascinating example of artificial light environments for plants in cases such as phytotron research centers of closed chambers and "sun simulators," used to investigate effects of radiation, spectral distribution, and UV-C, UV-B, and UV-A light. Stephan Thiel, Thorsten Döhring, Matthias Köfferlein, Andre Kosak, Peter Martin, and Harald K. Seidlitz, "A Phytotron

for Plant Stress Research: How Far Can Artificial Lighting Compare to Natural Sunlight?," *Journal of Plant Physiology* 148, no. 3–4 (1996): 456–463. The idea of thermocontrol and weather production was a persistent part of the discursive imaginaries these spaces created by operative means with fluorescent lights and air conditioning systems: "Light, temperature, humidity, gas content of the air, wind, rain, and fog—all these factors can be simultaneously and independently controlled," as the first phytotron facility at Caltech's Earhart Plant Research Laboratory was described by its founding member, plant physiologist Frits W. Went in 1949. Frits W. Went, "The Phytotron: Caltech Dedicates Its Fabulous Weather Factory," *Engineering and Science* 12, no. 9 (June 1949): 3. On the history of phytotrons, see David P. D. Munns, *Engineering the Environment: Phytotrons and the Quest for Climate Control in the Cold War* (Pittsburgh: University of Pittsburgh Press, 2017). On thermocontrol and elemental media, see Yuriko Furuhata, *Climactic Media: Transpacific Experiments in Atmospheric Control* (Durham, NC: Duke University Press, 2022).

73. "En effet, vient-on a transporter leur image dans l'appareil de M. Daguerre, ces parties vertes ne s'y trouvent pas reproduites, comme si tous les rayons chimiques, essentiels aux phenomenes daguerriens, avaient disparu dans la feuille, absorbés et retenus par elle." Jean-Baptiste Dumas and Jean-Baptiste Boussingault, *Essai de statique chimique des étres organisés* (Paris: Fortin, Masson, 1842), 24–25.

74. See note 57.

75. Olaf Breidbach, "Representation of the Microcosm: The Claim for Objectivity in 19th Century Scientific Microphotography," *Journal of the History of Biology* 35, no. 2 (2002): 221–250.

76. "To obtain such high magnifications one has to follow a special procedure: A photo of a certain preparation should be produced. This photo should be placed under a microscope and a second photo should be produced. To enhance the magnification of the original, a microphotograph of this second photo could be done. According to the authors, the resulting photos showed magnifications between 8000× and 30,000×. These shots revealed structural peculiarities which were not discernable by direct observation. These authors used the technique in such a way that it was not the microscopic preparations, but the photographs which were thought to provide accurate information about the structure of the microcosm." Breidbach, "Representation of the Microcosm," 232.

77. See Howard Caygill, "Harold Wager and the Photography of Plants," *Photographies* 14, no. 3 (2021): 505–519.

78. Kaja Silverman, *The Miracle of Analogy, or The History of Photography, Part 1* (Stanford, CA: Stanford University Press, 2015), 85.

CHAPTER 2

1. Giacomo Ciamician, "The Photochemistry of the Future," *Science* 36, no. 926 (1912): 385–394.

2. Elizabeth DeLoughrey and George Handley, *Postcolonial Ecologies: Literatures of the Environment* (New York: Oxford University Press, 2011), 11; Luke Keogh, *The Wardian Case: How a Simple Box Moved Plants and Changed the World* (Chicago: University of Chicago Press, 2020).
3. For a discussion about this obscuring of vegetal life in Western philosophy, see Michael Marder, *Plant-Thinking: A Philosophy of Vegetal Life* (New York: Columbia University Press, 2013), 19–36.
4. On the importance of herbaria and botanical illustration among these practices and treatises, see Londa Schiebinger, *Plants and Empire: Colonial Bioprospecting in the Atlantic World* (Cambridge, MA: Harvard University Press, 2007), and Daniella Bleichmar, *Visible Empire: Botanical Expeditions and Visual Culture in the Hispanic Enlightenment* (Chicago: University of Chicago Press, 2012). We do not approach in more detail these practices in the book as we want to focus on nonrepresentational photographic approaches to plants and territories.
5. On roots as pulled down by gravity, see Soraya de Chadarevian, "Laboratory Science versus Country-House Experiments: The Controversy between Julius Sachs and Charles Darwin," *British Journal for the History of Science* 29, no. 1 (1996): 17–41, at 24. On the hypothesis of heat bending plants, see Craig W. Whippo and Roger P. Hangarter, "Phototropism: Bending towards Enlightenment," *Plant Cell* 18, no. 5 (2006): 1110–1119, at 1111. On the irritability of the mimosa in mechanical terms, see Julius Sachs, *Lectures on the Physiology of Plants* (Oxford: Clarendon Press, 1887), 646–648. The *Mimosa pudica*, one of the best-known examples of a plant with retractile leaves, was added to the Linnean taxonomy in 1753.
6. Joseph Reynolds Green, *A History of Botany, 1860–1900: Being a Continuation of Sachs History of Botany, 1530–1860* (Oxford: Clarendon Press, 1909), 458–459. Not by chance, decades later, Charles Darwin and his son Francis carried on a successful series of observations that demonstrated the existence of signal transmission within the plants.
7. On the differences between technoscientific cultures regarding the discussion about plant perception, see de Chadarevian, "Laboratory Science versus Country-House Experiments." On the development of buildings conceived as laboratories and controlled environments, see Christian Reiß "The Biologische Versuchsanstalt as a Techno-Natural Assemblage: Artificial Environments, Animal Husbandry, and the Challenges of Experimental Biology," in *Vivarium: Experimental, Quantitative, and Theoretical Biology at Vienna's Biologische Versuchsanstalt*, ed. Gerd B. Müller (Cambridge, MA: MIT Press, 2017), 115–132. On the transformation of the German biological sciences into quantitative disciplines relying on precision laboratories, and the importance of the development on the cell theory in this process, see Timothy Lenoir, *The Strategy of Life: Teleology and Mechanics in Nineteenth-Century German Biology* (Chicago: University of Chicago Press, 1989), 112–155. On the differences with the Austro-Hungarian context, see Deborah R. Coen, *Vienna in the Age of Uncertainty: Science, Liberalism, and Private Life* (Chicago: University of Chicago Press, 2007), 96–104. For a broader view of the development

of the technological complex of life sciences that preceded this decade, see Olga Elina, Susanne Heim, and Nils Roll-Hansen, "Plant Breeding on the Front: Imperialism, War, and Exploitation," *Osiris* 20 (2005): 161–179.

8. Schmidgen Henning, *The Helmholtz Curves: Tracing Lost Time*, trans. Nils F. Schott (New York: Fordham University Press, 2014).
9. Soraya de Chadarevian, "Graphical Method and Discipline: Self-Recording Instruments in Nineteenth-Century Physiology," *Studies in History and Philosophy of Science* 24 (1993): 267–291. On the importance of Pfeffer's experiments in the observation of the relation between plant stimuli and movements, see Green, *History of Botany*, 111–112.
10. On the importance of autographic devices in the study of plant movements—such as the systematic use by Charles Darwin and his son Francis of smoked glass-plates to register periodic movements—see Oliver Gaycken "The Secret Life of Plants: Visualizing Vegetative Movement, 1880–1903," *Early Popular Visual Culture* 10, no. 1 (2012): 51–69.
11. On the early use in the context of botany of cameraless photography, such as the well-known prints by Anna Atkins, see Katharina Steidl, "Leaf Prints: Early Cameraless Photography and Botany," *PhotoResearcher* 17 (2012): 26–35.
12. On photography and the telescope—an example is John Adams Whipple, *The Moon*, 1857–1860—see Jai McKenzie, *Light and Photomedia: A New History and Future of the Photographic Image* (London: I. B. Tauris, 2014), 25. See the early experiments with microscope daguerrotypes of Alfred Donné and Leon Foucault, published in 1844, discussed in Lorraine J. Daston and Peter Galison, *Objectivity* (New York: Zone, 2007), 134. Already in 1842 John William Draper had made daguerreotypes of solar spectra; see Klaus Hentschel, *Mapping the Spectrum: Techniques of Visual Representation in Research and Teaching* (Oxford: Oxford University Press, 2002), 197.
13. Scott Curtis, "Photography and Medical Observation," in *The Educated Eye: Visual Culture and Pedagogy in the Life Sciences*, ed. Nancy Anderson and Michael R. Dietrich (Hanover, NH: Dartmouth College Press, 2012), 68–93, at 68. See Daston and Galison, *Objectivity*, 120.
14. Curtis, *Photography and Medical Observation*, 76–78. For a cultural and material approach to the use of photographs in nineteenth-century botany, see Caroline Fieschi, *Photographier les plantes au XIXe siècle: La photographie dans les livres de botanique* (Paris: CTHS Sciences, 2008).
15. The experiments discussed in this chapter are contemporary with the projection apparatuses designed to create moving images of living things, which proliferated in the visual instruction of life sciences. As Schmidgen explains, these media devices that the German physiologist and pharmacologist Carl Jacobj named *Anordungs* (arrangements), were "rather complex assemblages of organic and mechanical parts, electrical current and light rays, lenses, carbon rods and mirrors, frogs, wooden boards, and water jars." See Henning Schmidgen, "Cinematography without Film: Architectures and Technologies of Visual

Instruction in Biology around 1900," in Anderson and Dietrich, *Educated Eye*, 94–120, at 99. These instruments include, for instance: the Universal Projection Apparatus by Leitz; the Epidiascope by Zeiss in Jena and the Universal Projectoscope by Stoelting in Chicago; and episcopic projectors of Salomon Stricker (1834–1898) in Vienna and Carl Kaiserling (1869–1942) in Berlin. Johann Nepomuk Czermak's institute (1873) in Leipzig was named Spectatorium. For more details, see Schmidgen, "Cinematography without Film."

16. Raoul H. Francé, *Germs of Mind in Plants* (Chicago: Kerr, 1905), 17. On his later work on the topic of bionics and "functional surfaces," see Jan Mueggenburg, "Clean by Nature: Lively Surfaces and the Holistic-Systemic Heritage of Contemporary Bionik," *Communication+1* 3, no. 1 (2014): 1–28. On Francé's use of photographic sequences to track vegetal movements, see Matthew Vollgraff, "Gestes végétaux," in *Puissance du végétal et cinéma animiste: La vitalité révelée par la technique*, ed. Teresa Castro, Perig Pitrou, and Parie Rebecchi (Paris: Les Presses du Réel, 2020), 195–223.

17. With August Pauly and Adolf Wagner, Francé formed a group of "psychovitalists" which predicated an animist approach to nature. See Vollgraff, "Gestes végétaux," 201–204. Also in Vienna, other forms of "mechanistic vitalisms" were practiced, in the by then well-known and respected Biologische Versuchsanstalt (Institute of Biology), the Vivarium. See Gerd B. Müller, "Biologische Versuchsanstalt: An Experiment in the Experimental Sciences," in Müller, *Vivarium*, 3–18. On Hans Driesch and Henri Bergson, see Jane Bennett, *Vibrant Matter: A Political Ecology of Things* (Durham, NC: Duke University Press, 2010), 62–81. On the disputes against vitalism in the long German nineteenth century, see Lenoir, *Strategy of Life*.

18. Inga Pollmann, *Cinematic Vitalism: Film Theory and the Question of Life* (Amsterdam: Amsterdam University Press, 2018), 27–34.

19. See Janet Janzen, *Media, Modernity and Dynamic Plants in Early 20th Century German Culture* (Leiden: Brill, 2016) as well as the recently edited collection on this topic, Castro, Pitrou, and Rebecchi, *Puissance du végétal et cinéma animiste*. A filmography would include Germaine Dulac, Max Reichmann, Jean Comandon, and Friedrich W. Murnau, among others. A shared argument in the collection edited by Castro, Pitrou, and Rebecchi is that this vegetal animism can also be traced in some experimental practices of the first decades of the twenty-first century. This theme also relates to Beny Wagner's practice-based PhD project on cinema and metabolism at the Winchester School of Art, in which he outlines early cinema as an epistemological staging of questions of metabolism; this also feeds into his work on moving image aesthetics.

20. Howard Caygill, "Harold Wager and the Photography of Plants," *Photographies* 14, no. 3 (2021): 505–519, at 515.

21. Josef Maria Eder, *History of Photography*, trans. Edward Epstean (Toronto: Dover, 1978), 417.

22. Others in the plant science community included Sachs in Berlin, and Pfeffer in Leipzig. See de Chadarevian, "Laboratory Science versus Country-House Experiments."

23. See, for instance, his publication of technical microscopy: Julius Wiesner, *Einleitung in die technische Mikroskopie nebst mikroskopisch-technischen Untersuchungen* (Vienna: W. Braumüller, 1867). He extended his practice to the microscopic analysis of paper—including old manuscripts—while keeping a relation with the paper industry, see Anna-Grethe Rischel, "Julius von Wiesner and His Importance for Scientific Research and Analysis of Paper," *Paper History* 18, no. 1 (2014): 31–38. He dealt also with textiles; see Susanne Heim, Carola Sachse, and Mark Walker, *The Kaiser Wilhelm Society under National Socialism* (Cambridge: Cambridge University Press, 2009). His views about the applications of plant physiology to agriculture and other domains can be read in his inaugural lecture, Julius Wiesner, "Die Beziehungen der Pflanzenphysiologie zu den anderen Wissenschaften," in *Inaugurationsrede im Festsaale der Universität* (Vienna: Universität Wien, 1898).

24. On Wiesner as a promoter of a universal knowledge, see Coen, *Vienna in the Age of Uncertainty*, 164–165. His relation with the parliament is mentioned by Kärin Nickelsen, *Explaining Photosynthesis: Models of Biochemical Mechanisms, 1840–1960* (Dordrecht: Springer, 2019), 182. Other colleagues, such as Jose Maria Eder, exhibited regularly their well-known photographic work with experimental techniques, such as x-rays.

25. Julius Wiesner, *Der Lichtgenuss der Pflanzen: Photometrische und physiologische Untersuchungen mit besonderer Rücksichtnahme auf Lebensweise, geographische Verbreitung und Kultur der Pflanzen* (Leipzig: W. Engelmann, 1907), 251.

26. His work on the growth of plants at a microscopic scale is gathered in Julius Wiesner, *Die Elementarstructur und das Wachstum der lebenden Substanz* (Vienna: A. Hölder, 1892) where he proposed his theory of the plasoms as the particles that made up vegetable matter.

27. Wiesner, *Der Lichtgenuss der Pflanzen*, 68.

28. In his work on the history of photography, Eder tracks the development of this invention and explains how the design by Bunsen and Roscoe improved the one by F. J. Malaguti in 1839; see Eder, *History of Photography*, 415. On photometers, see also Michael Pritchard, "Actinometers and Exposure Measurement," in *Encyclopedia of Nineteenth-Century Photography*, ed. John Hannavy (London: Routledge, 2013), 4–5.

29. Wiesner, *Der Lichtgenuss der Pflanzen*, 14.

30. This was achieved through the notion of the relative *Lichtgenuss*: with the aid of assistants, several papers were exposed to light for the same amount of time. One by one, the blackened papers were introduced into the Insolator and pulled out, together with the measuring photographic paper, in order to measure the time the test paper needed to acquire each of the colors. These relative times could then be easily compared and averaged against values of daylight darkening to become absolute figures.

31. Wiesner, *Der Lichtgenuss der Pflanzen*, 2.

32. As Eder puts it, "exposure meters with silver salt papers and normal gray tints with tables were introduced by Stanley (1886), Wynne (1893), Alfred Watkins

('Standard Exposure Meter') 1890, (W. G.) Watkins ('Beemeter'), and others"; Eder, *History of Photography*, 449. For more details, see Pritchard, "Actinometers and Exposure Measurement."

33. Kliment A. Timiriazev, *The Life of the Plant: Ten Popular Lectures* (Moscow: Foreign Languages Publishing House, 1958), 414.
34. Neovitalism's main contributor, Hans Driesch, defined Wiesner as a "static teleologist," in *Hans Driesch, Geschichte des Vitalismus* (Leipzig: Johann Ambrosius Barth, 1922), 163. See also Oskar Ewald, "Die deutsche Philosophie im Jahre 1910," *Kant-Studien* 16, no. 1–3 (1911): 382–430, at 429.
35. Wiesner, *Die Beziehungen der Pflanzenphysiologie*, 67.
36. Wiesner, *Der Lichtgenuss der Pflanzen*, 107s
37. The habitus as the ensemble of adaptations and site-specific regulations of the plants is used throughout his text. Another metaphor used by Wiesner is that of the economy: the interweaving between the shape and the plant's surroundings is understood as an economy of light. See Wiesner, *Der Lichtgenuss der Pflanzen*, 71–74.
38. Lenoir, *Strategy of Life*, 76.
39. Vollgraff, "Gestes végétaux," 204.
40. In a letter sent to biologist George J. Romanes, Charles Darwin's writes: "Wiesner and Tieghem seem to think that this is explained by calling the whole process 'induction,' borrowing a term used by some physico-chemists (of whom I believe Roscoe is one), and implying an agency which does not produce any effect for some time, and continues its effect for some time after the cause has ceased. I believe (?) that photographic paper is an instance. I must ask Leonard [his son] whether an interrupted light acts on it in the same manner as on a plant." In a letter the following day, Darwin expressed his concern about the fact that "most botanists believe that light causes a plant to bend to it in as direct a manner as light affects nitrate of silver." *The Life and Letters of George John Romanes*, edited by Ethel D. Romanes (London: Longmans, 1908), 119. Wiesner's experiment took place in 1878. "The inductive nature of the response was finally confirmed when Julius von Wiesner (1838–1919) showed that plants continue to bend toward a light source even after the light is turned off," Whippo and Hangarter, "Phototropism," 1111. Photochemical induction was introduced as a phenomenon linked to the formation of images in photography: "The laws of photo-chemical induction which we have developed in this Part, explain most completely many of the singular phenomena which lie at the foundation of the photographic processes." Robert Bunsen and Henry Enfield Roscoe, "Photo-Chemical Researches. Part II: Phenomena of Photo-Chemical Induction," *Philosophical Transactions of the Royal Society of London* 147 (1857): 381–402, at 400.
41. Luce Lebart, "La Photographie d'Origine Végétale," in Castro, Pitrou, and Rebecchi, *Puissance du Végétal et Cinéma Animiste*, 119–127.

42. Lebart, "Photographie d'Origine Végétale." On Timiriazev's prints, see Kliment A. Timiriazev, "Croonian Lecture: The Cosmical Function of the Green Plant," *Proceedings of the Royal Society of London* 72, nos. 477–486 (1904): 424–461.
43. The terms refer to whether the growth and orientation of leaves occurred facing the direction of the incident light rays, independent of it, completely perpendicular to it, or facing only the most intense light, respectively. See Wiesner, *Der Lichtgenuss der Pflanzen*, 70–74.
44. Caygill, "Harold Wager and the Photography of Plants," 515.
45. Timiriazev, *Life of the Plant*, 180. The metaphor of forests as factories has evolved into a speculative model of a biosynthetic industrial future, see chapter 7.
46. In relation to exposure tables, see Pritchard, "Actinometers and Exposure Measurement."
47. John Tresch, *The Romantic Machine: Utopian Science and Technology after Napoleon* (Chicago: University of Chicago Press, 2012), 116.
48. Tresch, *Romantic Machine*, 115. See more generally pages 89–122.
49. Such an expanded focus on operational images is described in Jussi Parikka, *Operational Images: From the Visual to the Invisual* (Minneapolis: University of Minnesota Press, 2023). See also Tomáš Dvořák and Jussi Parikka, "Measuring Photographs," *Photographies* 14, no. 3 (2021): 443–457.
50. Vered Maimon, "On the Singularity of Early Photography: William Henry Fox Talbot's Botanical Images," *Art History* 34, no. 5 (2011): 958–977, at 963. See also Michelle Henning, *Photography: The Unfettered Image* (London: Routledge, 2018).
51. Maimon, "On the Singularity of Early Photography," 967.
52. Thomas Macho, "Second-Order Animals: Cultural Techniques of Identity and Identification," *Theory, Culture & Society* 30, no. 6 (2013): 30–47, at 31.
53. Bernhard Siegert, *Cultural Techniques: Grids, Filters, Doors, and Other Articulations of the Real*, trans. Geoffrey Winthrop-Young (New York: Fordham University Press, 2015), 13.
54. Dvořák and Parikka, "Measuring Photographs." See also Parikka, *Operational Images*.
55. Other visually significant organs of plants, such as the flowers, explore a broader spectrum of color-encoded processes of exchange of matter and energy in the planet, that goes "beyond green"; see *Prismatic Ecology: Ecotheory beyond Green*, ed. Jeffrey J. Cohen (Minneapolis: University of Minnesota Press, 2013). See also important elaborations and critiques of the discourses of "greenness" in the project "GREEN Revisited: Encountering Emerging Naturecultures" with various workshops, exhibitions, and publications over the past years. http://green.rixc.org/.
56. Michael Marder, *Plant-Thinking: A Philosophy of Vegetal Life* (New York: Columbia University Press, 2013), 81.
57. Emanuele Coccia, *The Life of Plants: A Metaphysics of Mixture* (Cambridge: Polity, 2018), 5.

58. Wiesner, *Der Lichtgenuss der Pflanzen*, 96.

59. Georges Bataille, *Visions of Excess: Selected Writings, 1927–1939* (Minneapolis: University of Minnesota Press, 1985), 3.

60. The calculation of the LAI is slightly different, however: it is the sum of the one-sided areas of leaves in relation to the area of the ground.

61. Vladimir I. Vernadsky, *The Biosphere* (New York: Copernicus, 1998), 78.

62. Rolf G. Kuehni, *Color Ordered: A Survey of Color Order Systems from Antiquity to the Present* (Oxford: Oxford University Press, 2008), 86.

63. Wiesner, *Der Lichtgenuss der Pflanzen*, 220. The Insolator, the Lichtfläche, and the use of the color charts all involve the presence of devices that belong to what Wolfgang Ernst calls "measuring media": Wolfgang Ernst, *Digital Memory and the Archive*, ed. Jussi Parikka (Minneapolis: University of Minnesota Press, 2013), 178. Such devices enabled the observer to distinguish previously unperceived natural phenomena. Wiesner's image-plants could be seen beyond the threshold of the naked eye's capacity, in a way similar to what was happening in the chronophotographic experiments of Eadweard Muybridge, Ottomar Anschütz, Étienne-Jules Marey and others. See McKenzie, *Light and Photomedia*, 32–33.

64. Wiesner, *Der Lichtgenuss der Pflanzen*, 69

65. "Am 30. März 1893 um 10h45m a.m. beobachtete ich im Wiener Augarten eine Intensität des gesamten Tageslichtes = 0.427. Am Südostrande eines dort befindlichen, dichten, noch gänzlich unbelaubten, aus hochstämmigen Bäumen zusammengesetzten Roßkastanienbestandes herrschte aber im vollen Sonnenlichte gleichzeitig bloß eine Intensität = 0.299. Im Schatten eines Roßkastanienstammes (NE) betrug die Intensität nur 0.023." Wiesner, *Der Lichtgenuss der Pflanzen*, 69.

66. Carl E. Schorske, *Fin-De-Siecle Vienna: Politics and Culture* (Cambridge: Cambridge University Press, 1985), 322.

67. Robert Musil, *The Man without Qualities*, trans. Sophie Wilkins and Burton Pike (London: Picador, 2011).

68. Coen, *Vienna in the Age of Uncertainty*, 101.

69. Here Coen is using Carlo Ginzburg's terms, see Coen, *Vienna in the Age of Uncertainty*, 102. In chapter 5 we address Carlo Ginzburg's historically situated "evidential paradigm" in the analysis of aerial images. See Carlo Ginzburg, *Clues, Myths, and the Historical Method*, trans. John Tedeschi and Anne C. Tedeschi (Baltimore, MD: Johns Hopkins University Press, 2013).

70. It was a complex circuit of mechanical, electrical and chemical components. see Erwin Bunning, *Ahead of His Time: Wilhelm Pfeffer, Early Advances in Plant Biology* (Ottawa: Carleton University Press, 1989), 66.

71. Coen, *Vienna in the Age of Uncertainty*, 101.

72. As film scholar Oliver Gaycken has observed, there was an important tradition of time-lapse media in plant sciences before the photographic ones. Charles

Darwin and his son Francis used systematically smoked glass-plates and drawings to register periodic movements. Gaycken, "Secret Life of Plants," 56.

73. Gaycken, "Secret Life of Plants," 58. Pfeffer's fondness of technical imaging found applications in many domains: "In the winter semester of 1919–20, we saw the microscopic projections which Pfeffer had already described in the year 1900; the protoplasmic streaming, the plasmolysis, and the formation and growth of precipitation membranes. Examples of projections in silhouette were the stimulation of tendrils, the thermonastic opening of tulip buds, and the formation of oxygen bubbles—very impressive—with Elodea. In the latter case, it was demonstrated that the magnitude of the stream of bubbles depended on the light intensity (a diffuse light was obtained by using a wire mesh). Pfeffer also presented time-lapse photos of the following subjects: the geotropic raising to an upright position of a plant of Impatiens glandulifera, the sleep movements of Desmodium gyrans, the movements of Mimosa spegazzinii, and the germination of Vicia faba. He also demonstrated the nutation of the pedicel, and the blossoming and withering of tulips." Bunning, *Ahead of His Time*, 120.
74. See Gaycken, "Secret Life of Plants."
75. The German film pioneer Oskar Messner helped popularize them by showing them at film evenings before main features. Janzen, *Media, Modernity and Dynamic Plants*, 2.
76. Schmidgen, "Cinematography without Film," 114. On visuality and technosciences, see also the classic text by Donna Haraway, *Simians, Cyborgs, and Women: The Reinvention of Nature* (New York: Routledge, 1991), 184–201.
77. Joanna Zylinska, *Nonhuman Photography: Theories, Histories, Genres* (Cambridge, MA: MIT Press, 2017), 17.
78. Sometimes spelled as klinostat.
79. De Chadarevian, "Laboratory Science versus Country-House Experiments," 39. Sachs had additionally been Pfeffer's mentor. Bunning, *Ahead of His Time*, 18.
80. Wilhelm Pfeffer, *Pflanzenphysiologie; Ein Handbuch der Lehre vom Stoffwechsels und Kraftwechsels in der Pflanze* (Leipzig: W. Engelmann, 1897), 569.
81. Coccia, *Life of Plants*, 5.
82. See Keller Easterling, *Medium Design: Knowing How to Work on the World* (London: Verso 2020).
83. Rina Scott, "On the Movements of the Flowers of Sparmannia Africana, and Their Demonstration by Means of the Kinematograph," *Annals of Botany* 17, no. 68 (1903): 761–77, at 773.
84. Scott, "On the Movements of the Flowers," 772.
85. The kammatograph, invented by Leonard Kamm, was one of the early predecessors or the cinema camcorder, see "The Kammatograph," *Image* 1, no. 8 (November 1952): 3.
86. Scott, "On the Movements of the Flowers," 773. Wilhelm Pfeffer, "Die Anwendung des Projectionsapparates zur Demonstration von Lebensvorgängen,"

Jahrbüchen für Wissenschaftliche Botanik 35, no. 4 (1900): 711–745. On the use of the clinostat in the regulation of illumination, see Bunning, *Ahead of His Time*, 66.

87. Timiriazev, *Life of the Plant*, 68.
88. Harold Wager, "The Perception of Light in Plants," *Annals of Botany* 23, no. 91 (1909): 464.
89. This expression comes from Reiß, "Biologische Versuchsanstalt as a Technonatural Assemblage."

CHAPTER 3

1. Giulia Rispoli and Jacques Grinevald, "Vladimir Vernadsky and the Co-Evolution of the Biosphere, the Noosphere, and the Technosphere," *Technosphere Magazine*, June 20, 2018, https://technosphere-magazine.hkw.de/p/Vladimir-Vernadsky-and-the-Co-evolution-of-the-Biosphere-the-Noosphere-and-the-Technosphere-nuJGbW9KPxrREPxXxz95hr. Wladimir I. Vernadsky, "The Biosphere and the Noösphere," *American Scientist* 33, no. 1 (1945): xxii, 1–12.
2. Hannah Holleman, *Dust Bowls of Empire: Imperialism, Environmental Politics* (New Haven, CT: Yale University Press, 2018).
3. Siegfried Giedion, *Mechanization Takes Command: A Contribution to Anonymous History* (New York: Oxford University Press, 1970), 142.
4. Deborah Coen, *Climate in Motion: Science, Empire, and the Problem of Scale* (Chicago: University of Chicago Press, 2018).
5. David Moon, "The Environmental History of the Russian Steppes: Vasilii Dokuchaev and the Harvest Failure of 1891," *Transactions of the Royal Historical Society* 15 (2005): 149–174, at 164.
6. Moon, "Environmental History of the Russian Steppes," 162–163.
7. Vernadsky, "Biosphere and the Noösphere," 5. On chemical modernity and surface aesthetics, see Esther Leslie, *Synthetic Worlds: Nature, Art and the Chemical Industry* (London: Reaktion, 2005).
8. Max Liboiron, *Pollution Is Colonialism* (Durham, NC: Duke University Press, 2021), 110.
9. Anna Lowenhaupt Tsing, "'On Nonscalability: The Living World Is Not Amenable to Precision-Nested Scales," *Common Knowledge* 18, no. 3 (2012): 505–524.
10. Tsing, "'On Nonscalability," 505.
11. Alfred J. Lotka, *Elements of Physical Biology* (Baltimore, MD: Williams and Wilkins, 1925), 360.
12. Liboiron, *Pollution Is Colonialism*, 84.
13. Bruno Latour, *Down to Earth: Politics in the New Climatic Regime*, trans. Catherine Porter (Cambridge: Polity, 2018), 78

14. See Dipesh Chakrabarty, "The Planet: An Emergent Humanist Category," *Critical Inquiry* 46, no. 1 (2019): 1–31.
15. Lynn Margulis and Dorion Sagan, *What Is Life?* (New York: Simon and Schuster, 1995), 47.
16. Vladimir I. Vernadsky, *The Biosphere*, trans. David B. Langmuir, rev. and annotated Mark A. S. McMenamin (New York: Copernicus, 1998), 88.
17. Giulia Rispoli, "Between 'Biosphere' and 'Gaia': Earth as a Living Organism in Soviet Geo-Ecology," *Cosmos and History* 10, no. 2 (2014): 78–91, at 80–82.
18. Examples would be *The Theory of the Earth* (1788) by Scottish geologist James Hutton (1726–1797), the series of works on the estimation of the age of Earth by Lord Kelvin (1824–1907), and *Worlds in the Making* (1908) by Swedish chemist Svante Arrhenius (1859–1927), where the greenhouse effect is proposed; M. D. H. Jones and Ann Henderson-Sellers, "History of the Greenhouse Effect," *Progress in Physical Geography* 14, no. 1 (1990): 1–18. For other related references in the fields of meteorology and geography, see Mike Davis, "The Coming Desert: Kropotkin, Mars and the Pulse of Asia," *New Left Review* 97 (January–February 2016), https://newleftreview.org/II/97/mike-davis-the-coming-desert.
19. Rispoli, "Between 'Biosphere' and 'Gaia,'" 80.
20. John Murray, "1899: The State of Ocean Science," *Scottish Geographical Magazine* 15 (1899): 505–522, https://oceanexplorer.noaa.gov/history/docs/science.html.
21. Jacques Grinevald, "Introduction: The Invisibility of the Vernadskian Revolution," in Vernadsky, *The Biosphere*, 23. See also Rispoli and Grinevald, "Vladimir Vernadsky and the Co-Evolution of the Biosphere."
22. Vernadsky, *The Biosphere*, 39.
23. Grinevald has observed that this wording is a specific reference to the work of French physiologist Claude Bernard, who characterized the living organism as an entity that kept a distinction between the internal and cosmic milieus. Grinevald, "Introduction," 29.
24. Vernadsky, *The Biosphere*, 39
25. Vernadsky was not able to respond to the question concerning the nature of the holistic mechanism: "I will not speculate here about the existence of the mechanism, but rather will observe that it corresponds to all the empirical facts and follows from scientific analysis"; Vernadsky, *The Biosphere*, 40. Such a statement is an example of the empirical generalizations we discuss above.
26. Vernadsky, *The Biosphere*, 51.
27. Vernadsky, *The Biosphere*, 40.
28. On different scales, see Joshua DiCaglio, *Scale Theory: A Nondisciplinary Inquiry* (Minneapolis: University of Minnesota Press, 2021), 9. For a relation between scale and theories of complex systems in the second half of the twentieth century, see Grinevald, "Introduction," 30.
29. Susan L. Brantley, Martin B. Goldhaber, and K. Vala Ragnarsdottir, "Crossing Disciplines and Scales to Understand the Critical Zone," *Elements* 3, no. 5 (2007):

307–314. Daniel DeB. Richter Jr. and Megan L. Mobley, "Monitoring Earth's Critical Zone," *Science* 326, no. 5956 (2009): 1067–1068. See also "The Critical Zone Collaborative Network" (CZNet), https://criticalzone.org/. The Critical Zone was the title and the focus of the exhibition at ZKM (Center for Art and Media Karlsruhe) (2020–2022) curated by Bruno Latour and Peter Weibel. See also the subsequent volume Bruno Latour and Peter Weibel, eds., *Critical Zones: The Science and Politics of Landing on Earth* (Cambridge, MA: MIT Press, 2020).

30. Frank Wigglesworth Clark, *The Data of Geochemistry*, United States Geological Survey Bulletin no. 330 (Washington, DC: Government Printing Office, 1908), 21

31. Vernadsky *The Biosphere*, 51–59.

32. Gabrielle Hecht, "Interscalar Vehicles for an African Anthropocene: On Waste, Temporality, and Violence," *Cultural Anthropology* 33, no. 1 (2018): 109–141.

33. Vernadsky *The Biosphere*, 44.

34. William H. F. Talbot, *The Pencil of Nature* (London: Longman, Brown, Green and Longmans, 1844), 4.

35. Vernadsky *The Biosphere*, 62.

36. Vernadsky, *The Biosphere*, 58.

37. Vernadsky, *The Biosphere*, 44.

38. Katherine N. Hayles, *How We Became Posthuman*. (Chicago: University of Chicago Press, 1999), 8.

39. Etienne Benson, *Surroundings: A History of Environments and Environmentalisms* (Chicago: University of Chicago Press, 2020), 113.

40. Benson, *Surroundings*, 115. Vernadsky writes: "In 1915, a 'Commission for the Study of the Productive Forces' of our country, the so-called KEPS, was formed at the Academy of Sciences. That commission, of which I was elected president, played a noticeable role in the critical period of the First World War. Entirely unexpectedly, in the midst of the war, it became clear to the Academy of Sciences that in Tsarist Russia there were no precise data concerning the now so-called strategic raw materials, and we had to collect and digest dispersed data rapidly to make up for the lacunae in our knowledge m. Unfortunately by the time of the beginning of the Second World War, only the most bureaucratic part of that commission, the so-called Council of the Productive Forces, was preserved, and it became necessary to restore its other parts in a hurry"; Vernadsky, "Biosphere and the Noösphere," 5.

41. Vernadsky, *The Biosphere*, 153.

42. Benson, *Surroundings*, 128.

43. Joan Martínez Alier, "Ecología Industrial y Metabolismo Socioeconómico: Concepto y Evolución Histórica," *Economía Industrial* 351 (2003): 15–26. Grinevald, "Introduction," 26. John Bellamy Foster, *Marx's Ecology: Materialism and Nature* (New York: New York University Press, 2000). To this effect, from a cultural studies of science perspective, Vernadsky's work has been addressed as a marker of a characteristic style of thinking whose ramifications can be traced in later

developments of Russian systems science and cybernetics; see Rispoli, "Between 'Biosphere' and 'Gaia.'"

44. Zachary Horton, *The Cosmic Zoom: Scale, Knowledge, and Mediation* (Chicago: University of Chicago Press, 2021).

45. Vernadsky, *The Biosphere*, 53.

46. Vernadsky quoted in Rispoli and Grinevald, "Vladimir Vernadsky and the Coevolution of the Biosphere." We have not, however, been able to locate the original quote.

47. The notion of a "planetary conveyor belt" features in some more recent discussions in speculative design and urbanism, such as architect Liam Young's work. Liam Young, "New City: Machines of Post Human Production," CCCB (Centre de Cultura Contemporània de Barcelona), December 16, 2015, https://www.cccb.org/en/multimedia/videos/liam-young-talks-about-new-city-machines-of-post-human-production/222592. See also Jussi Parikka, "Folds of Fashion: *Unravelled* and the Planetary Surface," in *Surface and Apparition: The Immateriality of Modern Surface*, ed. Yeseung Lee (London: Bloomsbury, 2020), 19–36.

48. Vernadsky, *The Biosphere*, 59.

49. Vernadsky, *The Biosphere*, 142; see also 16.

50. Vernadsky, *The Biosphere*, 143.

51. Horton, *Cosmic Zoom*, 49. In the cases explored by Horton this tension occurs between "a page or screen" in books or films such as Kees Boeke's *Cosmic View* and the Eames's *The Powers of Ten*, which place themselves in "a referential relationship with some other surface at a different scale" (45).

52. Horton, *Cosmic Zoom*, 48.

53. See Liboiron, *Pollution Is Colonialism*, 84.

54. Grinevald, "Introduction," 26.

55. Julius Wiesner, *Die Elementarstructur und das Wachstum der lebenden Substanz* (Vienna: A. Hölder, 1892).

56. Vernadsky, *The Biosphere*, 62.

57. Vernadsky, *The Biosphere*, 58.

58. Vernadsky, *The Biosphere*, 59.

59. Vernadsky, *The Biosphere*, 59.

60. Many of the parameters were defined in more detail of course, including how respiration was the ultimate determining factor for the minimum and maximum size of living bodies in contrast to physical constraints and the biosphere as limit cases for inert bodies. Vernadsky, "Biosphere and the Noösphere," 4.

61. Soraya de Chadarevian, "Laboratory Science versus Country-House Experiments: The Controversy between Julius Sachs and Charles Darwin," *British Journal for the History of Science* 29, no. 1 (1996): 17–41, at 24.

62. Vernadsky, *The Biosphere*, 59.

63. Vernadsky, *The Biosphere*.

64. See Kliment A. Timiriazev, "Croonian Lecture: The Cosmical Function of the Green Plant," *Proceedings of the Royal Society of London* 72, nos. 477–486 (1904): 424–61, at 439. Optical sensitizers are dyes that make silver halide crystals sensitive to certain light colors. Also, as cultural theorist Michelle Henning has remarked (*Photography: The Unfettered Image* (London: Routledge, 2018), 95–99), in the first decades of the twentieth century photography experienced its own particular revolution thanks, for instance, to the development of new and faster sensitizers. With their aniline dyes, corporations such as Bayer, AGFA, and BASF transferred their industrial mastery of the microtemporal synchronization of chemical cycles to shortened photographic exposure times, and by doing so expanded, in turn, the operational space of photography itself. Measurements and scientific practices relying on chronophotography, such as the ones linked to the experiments reviewed in chapter 2 are an example of this. Another clear case involves aerial photography: during the First World War, these dyes gave rise to specific sensitizers that "reshaped photography in response to the demands of aerial reconnaissance"; Henning, *Photography*, 99. In particular, sensitizers were developed to allow aerial cameras to see through the atmospheric haze.

65. Vernadsky, *The Biosphere*, 59.

66. This has been analyzed as a reason for the relative low impact of his work among his contemporaries; see Kiril M. Khailov, "Vladimir Ivanovich Vernadsky Originator of the Biosphere Concept," *La Mer* 32 (1994): 1–4, at 2. See also Rispoli, "Between 'Biosphere' and 'Gaia.'"

67. Vladimir I. Vernadsky, "The Evolution of Species and Living Matter: Appendix to the French Translation of *The Biosphere*" (1928), trans. Meghan Rouillard, *21st Century* (Spring–Summer 2012), 32–44, at 33; https://21sci-tech.com/Articles_2012/Spring-Summer_2012/05_Species_Matter.pdf. The text is from a speech originally given by Vernadsky to the Society of Naturalists of Leningrad on February 5, 1928, as per the translator's note (32).

68. Rispoli and Grinevald, "Vladimir Vernadsky and the Co-evolution of the Biosphere."

69. Vernadsky, "Evolution of Species and Living Matter," 44.

70. Vernadsky, "Evolution of Species and Living Matter," 38.

71. Vernadsky, "Evolution of Species and Living Matter," 41 On different strands of technics of nature, see Jussi Parikka, *Insect Media: An Archaeology of Animals and Technology* (Minneapolis: University of Minnesota Press, 2010).

72. Vernadsky quoted by Andrei V. Lapo, *Traces of Bygone Biospheres*, trans. V. Purto (Moscow: MIR, 1982)

73. Vernadsky illustrated his ideas about circulations and accumulations of living matter using a variety of data: from the British naturalist G. T. Carruthers, who had observed the annual flight of locusts over the Red Sea; from Nicolaus Steno, the acknowledgement that limestones were formed by skeletal remains of organisms; the formation of Dolomites as a result of the vital activity of

organisms; and the bacterial origin of the iron ores around lakes, described by C. G. Ehrenberg. See Lapo, *Traces of Bygone Biospheres*.

74. Lapo, *Traces of Bygone Biospheres*, 58.

75. Dietmar Offenhuber, *Autographic Design. The Matter of Data in a Self-Inscribing World.* (Cambridge, MA: MIT Press, 2023). Lukáš Likavčan and Paul Heinicker, "Planetary Diagrams: Towards an Autographic Theory of Climate Emergency," in *Photography Off the Scale: Technologies and Theories of the Mass Image*, ed. Tomáš Dvořák and Jussi Parikka (Edinburgh: Edinburgh University Press, 2021), 211–230; Susan Schuppli, *Material Witness: Media, Forensics, Evidence* (Cambridge, MA: MIT Press, 2020).

76. Vernadsky "Evolution of Species and Living Matter," 44. See also Vernadsky, *The Biosphere*, 60.

77. Vernadsky, *The Biosphere*, 51.

78. Vernadsky *The Biosphere*, 60.

79. Vernadsky, *The Biosphere*, 66–67.

80. Vernadsky, *The Biosphere*, 65.

81. Based on this notion, Vernadsky defined the time that it would take for a living form to occupy the whole Earth, if it did not have predators or limited resources (*The Biosphere*, 66). He calculated this time for some species, such as certain bacteria—36 hours—or termites—"a few years" (63).

82. Vernadsky, *The Biosphere*, 61.

83. Leslie, *Synthetic Worlds*.

84. Vernadsky, "Biosphere and the Noösphere," 9.

85. John Bellamy Foster, *Marx's Ecology: Materialism and Nature* (New York: Monthly Review Press, 2000), ix.

86. Leslie, *Synthetic Worlds*, 82.

87. Vaclav Smil, "Population Growth and Nitrogen: En exploration of a Critical Existential Link," *Population and Development Review* 17, no. 4 (1991): 569–601. Leslie, *Synthetic Worlds*, 184–188.

88. John H. Perkins, *Geopolitics and the Green Revolution: Wheat, Genes and the Cold War* (New York: Oxford University Press, 1997)

89. Paul Crutzen, "Geology of Mankind," *Nature* 415 (2002), 23. Anthropogenic nitrogenation of soils is currently so excessive that overfertilization has been considered as one of the main environmental concerns today. See Fred Pearce, "Can the World Find Solutions to the Nitrogen Pollution Crisis?," *Yale Environment E360*, February 6, 2018, https://e360.yale.edu/features/can-the-world-find-solutions-to-the-nitrogen-pollution-crisis.

90. Henning, *Photography*, 95–99.

91. Henning, *Photography*, 99.

92. Vernadsky *The Biosphere*, 61.

93. Paul N. Edwards, "Infrastructure and Modernity: Force, Time, and Social Organization in the History of Sociotechnical Systems," in *Modernity and Technology*, ed. Thomas J. Misa, Philip Brey, and Andrew Feenberg, (Cambridge, MA: MIT Press, 2003), 185–225, at 196.

94. Lapo, *Traces of Bygone Biospheres*, 103.

95. Lapo, *Traces of Bygone Biospheres*, 103.

96. A telling example of this is how life needs to be protected from the otherwise excessive radiation of the sun. Unfiltered light, such as that experienced in outer space, is a lethal agent: no form of life is able to survive the effects of certain ultraviolet components of its spectrum. On the earth, the ozone layer is responsible for this radiation not reaching the surface of the planet. Significantly, it was Vernadsky who proved, with geochemical data, the theory that the totality of the ozone in the atmosphere had a biotic origin; Aleksandr I. Oparin, *The Origin of Life on the Earth*, trans. Ann Synge (New York: Academic Press, 1957), 157. That is, in the biogeochemist's model, it is not only that living matter keeps suitable environmental conditions but it creates its own shielding jar as well, the "ozone screen"; Vernadsky, *The Biosphere*, 120.

97. Vernadsky in 1913, quoted in G. V. Dobrovol'skii, "Vladimir Ivanovich Vernadsky and Soil Science," *Herald of the Russian Academy of Sciences* 83 (2013): 184.

98. Veronica della Dora, *The Mantle of the Earth: Genealogies of a Geographical Metaphor* (Chicago: University of Chicago Press, 2021), 228.

99. The following quotes and references are from the Russian original, Dokuchaev, *К учению о зонах природы. Горизонтальные и вертикальные почвенные зоны* (Theory of natural zones: Horizontal and vertical soil zones) (St. Petersburg: Printing House of St. Petersburg City Administration, 1899), https://ru.wikisource.org/wiki/К_учению_о_зонах_природы. We would like to thank Anastasia Kubrak for the translations. See also Wladimir Dokuchaev, *Tchernozéme (Terre Noire) de la Russie d'Europe* (St. Petersbourg: Imprimerie Trenké & Fusnot, 1879).

100. Dokuchaev, *К учению о зонах природы*.

101. Among the geographical surfaces that Dokuchaev investigated and coded were the horizontal zones of soil, for example, in the Caucasus Mountains.

102. Dokuchaev, *К учению о зонах природы*.

103. See for example Vernadsky, "Biosphere and the Noösphere."

104. John Durham Peters, *The Marvelous Clouds: Toward a Philosophy of Elemental Media* (Chicago: University of Chicago Press, 2015), 47. See also Jussi Parikka, *A Geology of Media* (Minneapolis: University of Minnesota Press, 2015).

105. "Neither living organisms by themselves nor their environment abstracted from them are, Vernadsky argued, the specific objects of biogeochemistry. A biogeochemist is interested, first of all, in studying the cyclic processes of the exchange of chemical elements between living organisms and their environment." Georgy S. Levit, "Looking at Russian Ecology Through the Biosphere Theory," in *Ecology Revisited: Reflecting on Concepts, Advancing Science*, ed. Astrid Schwarz

and Kurt Jax (Dordrecht: Springer, 2011), 333–347, at 339. Vernadsky went so far as to claim that all geological periods include some form of life: "Throughout geological time, no azoic (i.e., devoid of life) geological periods have ever been observed"; Vernadsky, *The Biosphere*, 54.

106. Bruno Latour, *Facing Gaia: Eight Lectures on the New Climatic Regime*, trans. Catherine Porter (Cambridge: Polity, 2017), 111–145.

107. John Ruskin, "The Storm-Cloud of the Nineteenth Century," two lectures delivered at the London Institution, February 4 and 11, 1884; https://www.gutenberg.org/files/20204/20204-h/20204-h.htm.

108. On such a notion of parasitism, see Michel Serres, *The Parasite* (Minneapolis: University of Minnesota Press, 2007), 77–85.

CHAPTER 4

1. Andrey Tarkovsky, *Sculpting in Time: Reflections on the Cinema*, trans. Kitty Hunter-Blair (New York: Alfred A. Knopf, 1987), 132.

2. José Manuel Mouriño, *Andrei Tarkovski y El Espejo: Estudio de Un Sueño* (Madrid: Círculo de Bellas Artes, 2018), 16.

3. Graig Uhlin, "Plant-Thinking with Film: Reed, Branch, Flower," in *The Green Thread: Dialogues with the Vegetal World*, ed. Patrícia Vieira, Monica Gagliano, and John Ryan (Lanham, MD: Lexington, 2015), 215. Moreover, as Matthew Fuller and Olga Goriunova write, the architectural trope of the home is closely aligned with the bordering force of the forest that speaks to an ecological aesthetic found in Tarkovsky and beyond, relating to questions of territory, property, belonging, and migrancy; Matthew Fuller and Olga Goriunova, *Bleak Joys: Aesthetics of Ecology and Impossibility* (Minneapolis: University of Minnesota Press, 2019), 121–153.

4. Tarkovsky, *Sculpting in Time*, 138–150.

5. "The plant's body is all skin," writes Michael Marder in *Plant-Thinking: A Philosophy of Vegetal Life* (New York: Columbia University Press, 2013), 81. "It is for the sake of adhering as much as possible to the world that they develop a body that privileges surface to volume," continues Emanuele Coccia in *The Life of Plants: A Metaphysics of Mixture* (Medford, MA: Polity, 2018), 5.

6. Uhlin, "Plant-Thinking with Film," 211–212.

7. Giuliana Bruno, *Surface: Matters of Aesthetics, Materiality, and Media* (Chicago: University of Chicago Press, 2014), 35–51.

8. Using Bruno's words, see Bruno, *Surface*, 13–22.

9. See, for example, Gilles Deleuze on the cinematics of water: "a perception not tailored to solids, which no longer had the solid as object, as condition, as milieu"; Gilles Deleuze, *Cinema 1: The Movement Image*, trans. Hugh Tomlinson and Barbara Habberjam (London: Continuum, 1992), 80.

10. Nadia Bozak, *The Cinematic Footprint: Lights, Camera, Natural Resources* (New Brunswick, NJ: Rutgers University Press, 2012), 1–11.
11. Bozak, *Cinematic Footprint*, 54.
12. James C. Scott, *Seeing Like a State: How Certain Schemes to Improve the Human Condition Have Failed* (New Haven, CT: Yale University Press, 1999), 53–63.
13. Ross Exo Adams, "Landscapes of Post-History," in *Landscape and Agency: Critical Essays*, ed. Ed Wall and Tim Waterman (Abingdon: Routledge, 2018), 7–17.
14. The Spanish law defined this inner colonization: "an administrative activity, of a technical and legal nature, that transforms the agronomic and economic characteristics of specific extensions of land as well as the social organisations within them, creating rational units of agricultural production whose property is delivered to certain farmers, with the aim to ease the fulfilment of their individual and familiar needs, provide stability to the society as a whole and augment the production"; see Alejo Leal García, "La transformación del medio rural a través de la puesta en regadío y de la colonización," *Revista de Estudios Agrosociales* 66 (1969): 107–137, at 116.
15. See Antonio A. Tordesillas, "Referencias internacionales en los pueblos de colonización españoles," *Ciudades* 13 (2010): 183–200, at 185. Two important exceptions are important to mention, as their influence on Spanish inner colonization has been highlighted several times. The first is the large North American irrigation program the Columbia Basin Project, whose final works took place between 1948 and 1952. It had been designed in the 1920s, but it was only after the war that water started to arrive to the fields. The second is the agrarian reform carried out by the Italian Christian Democrats after the war, as a sister project of the Spanish inner colonization. See also Gina Bloodworth and James White, "The Columbia Basin Project: Seventy-Five Years Later," *Yearbook of the Association of Pacific Coast Geographers* 70, no. 1 (2008): 96–111.
16. This intensification of productivity has been linked by writer and activist Vandana Shiva to the notion of the Bio Nullius, an extension of the colonial Terra Nullius, where "the Earth is defined by her colonizers as dead matter, deemed unable to create, and farmers [are] deemed to have empty heads that cannot innovate"; see Vandana Shiva, *Biopiracy: The Plunder of Nature and Knowledge* (Boston, MA: South End, 1999), 33. The old farmers, together with their old and unimproved nature, become the parasite of a parasitic activity or, as Shiva puts it, a "biopiracy." Shiva describes this process as a colonization of the interior spaces: "The colonies have now been extended to the interior spaces . . . from microbes and plants to animals, including humans" (40).
17. Among these *bonifiche*, the *integrale* (1924–1950) was the most influential for the Spanish program. See Cristóbal Gómez Benito, "Una revisión y una reflexión sobre la política de colonización agraria en la España de Franco," *Historia del presente* 3 (2004): 65–86, at 75.
18. Robert L. Nelson, "From Manitoba to the Memel: Max Sering, Inner Colonization and the German East," *Social History* 35, no. 4 (2010): 445.

19. Nelson, "From Manitoba to the Memel," 444.

20. Nelson, "From Manitoba to the Memel," 447. "Through an inner colonial programme, German settlers were to send wagons east and Germanize the land. With this move, Germany's relationship with its eastern borderlands began to resemble the world of New Imperialism and the link to the specific North American version of that global imperialism was never far away: in a booklet produced in October 1886 to help civil servants better understand their role in the new programme, a helpful list of seven books was provided. concerned the land and history of Posen and West Prussia. The initial six books concerned the land and history of Posen and West Prussia. The seventh was entitled *Manitoba and the Western Territories*" (447).

21. Tiago Saraiva, *Fascist Pigs: Technoscientific Organisms and the History of Fascism* (Cambridge, MA: MIT Press, 2016).

22. Gómez Benito, "Una revisión y una reflexión," 66.

23. Gómez Benito, "Una revisión y una reflexión," 109.

24. As an activity developed over three weekends between April and June of 2017, one of the authors proposed digitizing and uploading with creative commons license the data relative to the INC. The proposal was accepted as part of a collaborative production workshop at Medialab-Prado in Madrid, where a first complete digital inventory of the settler towns, together with other infrastructures, was produced. Andrés Rodríguez Muñoz, Marco Rizzetto, Carmen M. Pellicer Balsalobre, Guillermo Cid, and David Prieto were the other members of the team behind this project. It was an open-data initiative that can be accessed at https://medialab-prado.github.io/poblados-colonizacion-colonias-penitenciarias/index.html.

25. Gómez Benito, "Una revisión y una reflexión," 72.

26. The INC was not in charge of the main water infrastructures, such as dams and reservoirs. This was the task of the Ministerio de Obras Públicas y Urbanismo (ministry of public infrastructure, MOPU).

27. Gómez Benito, "Una revisión y una reflexión," 84.

28. It is necessary to clarify that during the existence of Spanish Inner Colonization, its methodology and scope did not remain constant. Three periods have been distinguished, of approximately ten years each (Eduardo Delgado, *Imagen y memoria: Fondos del archivo fotográfico del Instituto Nacional de Colonización, 1939–1973* [Madrid: Ministerio de Agricultura, Alimentación y Medio Ambiente Centro de Publicaciones, 2013], 79–80). In brief, the first decade was characterized by an autarchy model confident of private initiative: landowners, supported by public resources, would lead the transformation of the land and settle the peasants. The model proved to be a total failure (Tordesillas, "Referencias internacionales," 191) and, beginning in the 1950s, a new law was proposed, in which the state was much more engaged. This second period turned out to be the golden decade of colonization (Delgado, *Imagen y memoria*, 80): big plans, such as the Plan Jaén and Plan Badajoz, were implemented and were coupled

with industrialization programs. In 1962, however, these plans were criticized by a World Bank report as they involved large amounts of national debt. As a consequence, new economic criteria started to be used to evaluate the program, which resulted in the estrangement of the whole project (see Alfredo Villanueva Paredes and Jesús Leal Maldonado, eds., *Historia y evolucion de la colonizacion agraria en España III*, vol. 3, *La planificación del regadio y los pueblos de colonización* (Madrid: Ministerio de Agricultura, Pesca y Alimentación, 1990). Therefore, during the last decade, the INC became a passive technical manager, a mediator, in fact, that gradually facilitated the introduction of big food and agriculture companies in a progressively liberalized economy. See Mario Gaviria, José Manuel Naredo and Juan Serna, *Extremadura saqueada: Recursos naturales y autonomía regional* (Barcelona: Ruedo Ibérico, 1978), 435.

29. Gómez Benito, "Una revisión y una reflexión," 83.

30. Gaviria, Naredo, and Serna, *Extremadura saqueada*, 262.

31. On the evolution of the program, see Carlos Giménez and Luciano Sánchez, eds., *Historia y evolucion de la colonizacion agraria en España IV: Unidad y diversidad en la colonización agraria. Perspectiva comparada del desarrollo de las zonas regables*, vol. 4 (Madrid: Ministerio de Agricultura, Pesca y Alimentación, 1994). On its extractivist and repressive nature, see Gaviria, Naredo, and Serna, *Extremadura saqueada*. On the use of prisoners as slave labor, see José Luis Gutiérrez, Ángel del Río Sánchez, Gonzalo Acosta Bono, and Lola Martínez Macías, eds., *El canal de los presos, 1940–1962. Trabajos forzados: De la represión política a la explotación económica* (Barcelona: Editorial Crítica, 2004). On the relationship with previous colonization programs, see Carlos Barciela López, "La contrarreforma agraria y la política de colonización del primer franquismo, 1936–1959," in *Reformas y políticas agrarias en la historia de España: De la ilustración al primer franquismo*, ed. Ángel García and Jesús Sanz (Madrid: Centro de Publicaciones Agrarias, Pesqueras y Alimentarias, 1996), 351–398. On similar international developments, see Tordesillas, "Referencias internacionales." On its evolution and impact decades later, see Gómez Benito, "Una revisión y una reflexión," 74–84.

32. Delgado, *Imagen y memoria*.

33. Francisco de los Ríos Romero, "Colonización de las bardenas, cinco villas, somontano y Monegros," *Cuadernos de Aragón* 1 (1966): 181–230, at 229–230. The quote from 1966 coincides with the fundamentalist turn concerning land that in Israel—under the Zionist maxim of "making the desert bloom"—and in other countries linked agricultural production to a divine dictate; see Eyal Weizman and Fazal Sheikh, *The Conflict Shoreline: Colonialism as Climate Change in the Negev Desert* (Göttingen: Steidl, 2015), 8.

34. Lino Camprubí, *Engineers and the Making of the Francoist Regime* (Cambridge, MA: MIT Press, 2014).

35. Brenna Bhandar, *Colonial Lives of Property: Law, Land, and Racial Regimes of Ownership* (Durham, NC: Duke University Press, 2018), 77–114. Nelson, "From Manitoba to the Memel," 439–440.

36. The Ley de Colonización de Grandes Zonas (Law for the colonization of large areas) was passed in 1949. Its main aspects are summarized in Jesús González Pérez, "La colonización en zonas regables: La ley de 21 de abril de 1949," *Revista de estudios políticos* 48 (1949): 154–170, at 154–155.

37. On the relation between (landscape) painting and colonial land practices such as plantations, see Jill Casid, *Sowing Empire: Landscape and Colonization*. (Minneapolis: University of Minnesota Press, 2005), 30–93.

38. José Guarc Pérez, "El Instituto Nacional de Colonización y la transformación de Bardenas-Ejea," in *Colonos: Territorio y estado. Los pueblos del Agua de Bardenas*, ed. Alberto Sabio (Zaragoza: Instituto Fernando el Católico, 2010), 81–142, at 104.

39. Miguel Ángel Baldellou, "Prólogo," in Delgado, *Imagen y memoria*, 13–23, at 19.

40. Gaviria, Naredo, and Serna, *Extremadura saqueada*, 356–359.

41. Bernhard Siegert, *Cultural Techniques: Grids, Filters, Doors, and Other Articulations of the Real*, trans. Geoffrey Winthrop-Young (New York: Fordham University Press, 2015); Jussi Parikka, *Operational Images: From the Visual to the Invisual* (Minneapolis: University of Minnesota Press, 2023). See especially chapter 1 for a discussion of grids as operative ontologies.

42. Karsten Jacobsen, Michael Cramer, Richard Ladstädter, Camillo Ressl, and Volker Spreckels, "DGPF-Project: Evaluation of Digital Photogrammetric Camera Systems—Geometric Performance," *Photogrammetrie—Fernerkundung—Geoinformation* 2010, no. 2 (2010): 83–97, at 84.

43. Paul Saint-Amour, "Applied Modernism: Military and Civilian Uses of the Aerial Photomosaic," *Theory, Culture & Society* 28, no. 7–8 (2011): 241–269, at 243.

44. Lorenzo Martín-Retortillo Baquer, "Trayectoria y significación de las confederaciones hidrográficas," *Revista de Administración Pública* 25 (1958): 85–126, at 105.

45. Felipe Fernández García, "Las primeras aplicaciones civiles de la fotografía aérea en España: El catastro y las confederaciones hidrográficas," *Ería* 46 (1998): 117–130. One of the partners and initial president of the company CEFTA was Julio Ruiz de Alda (Fernández, "Las primeras aplicaciones," 222), one of the founders of the fascist movement in Spain, the Falange Española. He was a pioneer of aviation in Spain and a personal friend of the then dictator José Antonio Primo de Rivera and very close to his fascist government; see Barciela, "La contrarreforma agraria y la política de colonización," 355.

46. Francisco Quirós Linares and Felipe Fernández García, "El vuelo fotográfico de la 'Serie A,'" *Ería* 43 (1997): 190–198, at 190.

47. On the uses in Spain of the *Casey Jones* aerial photographs, see Juan Antonio Pérez, Francisco Manuel Bascón, and María Cristina Charro, "Photogrammetric Usage of 1956–57 USAF Aerial Photography of Spain," *Photogrammetric Record* 29, no. 145 (2014): 108–124. On its relation to a potential conflict with the USSR, see Quirós and González, "El vuelo fotográfico de la 'Serie A.'"

48. Pérez, Bascón, and Charro, "Photogrammetric Usage of 1956–57 USAF Aerial Photography of Spain," 22.

49. Fernández, "Las primeras aplicaciones," 118.

50. Guarc Pérez, "El Instituto Nacional de Colonización y la transformación de Bardenas-Ejea," 118. Figure 4.2 illustrates the transformation of the landscape in this particular zone.

51. On the excluded third, see Michel Serres, *The Parasite*, trans. Lawrence R. Schehr (Baltimore, MD: Johns Hopkins University Press, 1982).

52. See for example Alexander Etkind, *Internal Colonization: Russia's Imperial Experience* (Cambridge: Polity, 2011). For more recent discussion in light of the war in Ukraine, see Anna Engelhardt, "War by Any Other Name: Patterns of Russian Colonialism," *The Funambulist* 42 (July–August 2022): 10–13.

53. On the operationalization of the "hinterlands" of urbanism and production of industrial zones of extraction, see Neil Brenner and Nikos Katsikis, "Hinterlands of the Capitalocene," *Architectural Design* 90 (2020): 22–31.

54. In the context of art and design, for example, Benedikt Groß's project *Avena + Test Bed* (2013) employs such methods for large-scale landscape printing as a form of data-driven visual print media; https://benedikt-gross.de/projects/avena-test-bed-agricultural-printing-and-altered-landscapes/.

55. Keller Easterling, *Extrastatecraft: The Power of Infrastructure Space* (London: Verso, 2014), 19.

56. Easterling, *Extrastatecraft*, 22.

57. The new naming system was drawn up in the Plan General de Obras Públicas (1940). It referenced each road with a number that depended on (1) its angular location in relation to the six main radial motorways and (2) its distance to the Puerta del Sol square in Madrid. This nomenclature protocol is still in operation today.

58. Other geographical references were also used, such as the course of rivers or borderlines between provinces.

59. Several towns created during these plans by the Francoist dictatorship received names linked to the colonization of America, as a celebration of an infamous "glorious" national past; see Delgado, *Imagen y memoria*, 21.

60. Penny Harvey and Hannah Knox, *Roads: An Anthropology of Infrastructure and Expertise* (Ithaca, NY: Cornell University Press, 2015).

61. Nigel Thrift, "Movement-Space: The Changing Domain of Thinking Resulting from the Development of New Kinds of Spatial Awareness," *Economy and Society* 33, no. 4 (2004): 582–604, at 597.

62. Celia Lury, Luciana Parisi, and Tiziana Terranova, "Introduction: The Becoming Topological of Culture," *Theory, Culture & Society* 29, nos. 4–5 (2012): 3–35, at 5.

63. The design decision of positioning settlement towns by the existing road system has been discussed by Scott as the control and monitoring disposition of authoritarian states; see Scott, *Seeing Like a State*, 237. In this sense, the INC program has been criticized for its pervasive practices of surveillance on the settlers; see Gaviria, Naredo, and Serna, *Extremadura saqueada*, 356.

64. John Durham Peters, *The Marvelous Clouds: Toward a Philosophy of Elemental Media* (Chicago: University of Chicago Press, 2015), 37.

65. Ned Rossiter, *Software, Infrastructure, Labor: A Media Theory of Logistical Nightmares* (New York: Routledge, 2016), 6.

66. Serres, *The Parasite*, 179.

67. Tordesillas, "Referencias internacionales," 192.

68. José María Alagón Laste, "Los pueblos de colonización del Plan de Riegos del Alto Aragón y su emplazamiento en el territorio," *Scripta Nova* 19 (2015): 500–526, at 507.

69. Alagón Laste, "Los pueblos de colonización del Plan de Riegos del Alto Aragón," 508.

70. Lisa Parks, *Cultures in Orbit: Satellites and the Televisual* (Durham, NC: Duke University Press, 2005); Parks, "Signals and Oil: Satellite Footprints and Post-Communist Territories in Central Asia," *European Journal of Cultural Studies* 12, no. 2 (2009): 137–156.

71. The "cart" in the cart-module was the main transportation means in rural Spain at the time, a cart pulled by a donkey, horse, or farmer. As explained, the plans clearly took this into account. It was so central to the model that, as has been repeatedly argued, it was also its most salient failure, since the design became immediately obsolete with the widespread introduction of mechanized vehicles, following the end of the international blockade of Francoist Spain. See Alagón Laste, "Los pueblos de colonización del Plan de Riegos del Alto Aragón," 508; and Tordesillas, "Referencias internacionales," 199.

72. Cornelia Vismann, "Cultural Techniques and Sovereignty," *Theory, Culture & Society* 30, no. 6 (2013): 83–93, at 92.

73. Gaviria, Naredo and Serna, *Extremadura saqueada*, 356.

74. To keep the big landowners happy, the state assigned the worst lands to the settlers. The rest of the plots—still private property—were connected to the irrigation system. This way, the owners multiplied their benefits, despite the lands having been expropriated. Gaviria, Naredo and Serna, *Extremadura saqueada*, 262.

75. Stefan Ouma, *Farming as Financial Asset: Global Finance and the Making of Institutional Landscapes* (Newcastle: Agenda, 2020). See also Kelly Bronson and Phoebe Sengers, "Big Tech Meets Big Ag: Diversifying Epistemologies of Data and Power," *Science as Culture* 31, no. 1 (2022): 15–28.

76. Tarkovsky, *Sculpting in Time*, 138–150.

77. Tarkovsky, *Sculpting in Time*, 120. This quote is also the starting point of Gil-Fournier's installation *The Quivering of the Reed*, 2019, http://abelardogfournier.org/works/quivering.html.

78. Barbara Novak, *Nature and Culture American Landscape and Painting, 1825–1875*, 3rd ed. (Oxford: Oxford University Press, 2007), 155. On Muybridge, Yosemite, and landscapes, see also Bozak, *Cinematic Footprint*, 93–95.

79. This tension is one of the issues we addressed in our video essay *Seed, Image, Ground* (2020). The video discusses the technique known as seed bombing, the dropping of biodegradable containers filled with seeds and mineral nutrients from aerial vehicles—drones, helicopters, or aircrafts. It is a technique used in forestry and environmental restoration, and its most outstanding characteristic, according to its promoters, is the speed with which it can repopulate when compared to other techniques. Based on communication and advertisement videos of these technologies, and through the image comparison technique conceptualized by Harun Farocki as soft montage, the visual essay outlines a history in which the image has been used not only to catalog and classify plants and species but also to accelerate their growth. In particular, the essay shows how an understanding of the landscape is linked to methods of analysis based on aerial photography. From early twentieth-century laboratory practices to the cameras, sensing practices, and computational analytics involved now, seed bombing has shifted from a "guerrilla" agricultural practice to part of the broader aerial management exemplified in precision farming. The term seed bombing alludes to the military history of the aerial view, yet it also expands into the agricultural practices as a history of accelerating or annihilating growth. Thus, it is also a visual montage version of the argument presented in this chapter: techniques of management of agricultural lands are inherently linked with operational techniques of visual definition, observation, and control.
80. On this question in history of biology, see Robert E. Kohler, *Landscapes and Labscapes: Exploring the Lab-Field Border in Biology* (Chicago: University of Chicago Press, 2002).
81. Commenting on an advertisement in the December 1915 issue of the *Tractor Farming* magazine, the historian of architecture and technology Siegfried Giedion wrote: "to rouse the farmer's imagination, a tractor and an airplane are shown side by side with the comment: 'This butterfly and this ant are sisters under the skin'", Siegfried Giedion, *Mechanization Takes Command: A Contribution to Anonymous History* (New York: Oxford University Press, 1970), 162.
82. For an overview, see for example Abdul Hafeez, Mohammed Aslam Husain, S. P. Singh, Anurag Chauhan, Mohammed Tauseef Khan, Navneet Kumar, Abhishek Chauhan, and S. K. Soni, "Implementation of Drone Technology for Farm Monitoring & Pesticide Spraying: A Review," *Information Processing in Agriculture* 10, no. 2 (2023): 192–203.

CHAPTER 5

1. Joshua DiCaglio, *Scale Theory: A Nondisciplinary Inquiry* (Minneapolis: University of Minnesota Press 2021), 7. See also Zachary Horton, *The Cosmic Zoom: Scale, Knowledge, and Mediation* (Chicago: University of Chicago Press, 2021). For a cautionary take on the concept of scale, see Anna Tsing, "On Nonscalability: The Living World Is Not Amenable to Precision-Nested Scales," *Common Knowledge* 18 (2012): 505–524. See also Dipesh Chakrabarty, "Afterword: On Scale and

Deep History in the Anthropocene," in *Narratives of Scale in the Anthropocene: Imagining Human Responsibility in an Age of Scalar Complexity*, ed. Gabriele Dürbeck and Philip Hüpkes (London: Routledge, 2021), 225–232. Jussi Parikka, *There is Plenty of Room in the Simulation* (Ljubljana: Aksioma, 2023), https://aksioma.org/there-is-plenty-of-room-in-the-simulation.

2. See, for example, Laura Kurgan, *Close up at a Distance: Mapping, Technology, and Politics* (New York: Zone, 2013); Pamela E. Mach, *Viewing the Earth: The Social Construction of the Landsat Satellite System* (Cambridge, MA: MIT Press, 1990); Mariel Borowitz, *Open Space: The Global Effort for Open Access to Environmental Satellite Data* (Cambridge, MA: MIT Press, 2017).
3. John May, "Logic of the Managerial Surface," *PRAXIS* 13 (2012): 116–124; Jennifer Gabrys, *Program Earth: Environmental Sensing Technology and the Making of a Computational Planet* (Minneapolis: University of Minnesota Press, 2016).
4. In relation to this, see Michel Foucault on territory and other terms of relevance: "Territory is no doubt a geographical notion, but it's first of all a juridico-political one: the area controlled by a certain kind of power. Field is an economico-juridical notion. Displacement: what displaces itself is an army, a squadron, a population. Domain [*domaine*] is a juridico-political notion. Soil is a historico-geological notion. Region is a fiscal, administrative, military notion. Horizon is a pictorial, but also a strategic notion"; Michel Foucault, "Questions of Geography," in *Space, Knowledge, and Power: Foucault and Geography*, ed. Jeremy W. Crampton and Stuart Elden, trans. Colin Gordon (Aldershot: Ashgate, 2007), 176.
5. Bo Zhao, Shaozeng Zhang, Chunxue Xu, Yifan Sun, and Chengbin Deng, "Deep Fake Geography? When Geospatial Data Encounter Artificial Intelligence," *Cartography and Geographic Information Science* 48, no. 4 (2021): 338–352.
6. Cindy Lin, "How Forests Became Data: The Remaking of Ground Truth in Indonesia," in *The Nature of Data: Infrastructures, Environments, Politics*, ed. Jenny Goldstein and Eric Host (Lincoln: University of Nebraska Press, 2022), 285–302.
7. See Gillian Rose, *Feminism and Geography: The Limits of Geographical Knowledge* (Minneapolis: University of Minnesota Press, 1993); Irit Rogoff, *Terra Infirma: Geography's Visual Culture* (London: Routledge, 2000); Nigel Thrift, *Non-Representational Theory: Space, Politics, Affect* (London: Routledge, 2008).
8. Bernhard Siegert, "The Map Is the Territory," *Radical Philosophy* 169, no. 5 (2011): 13–16. See also Shannon Mattern, *Code and Clay, Data and Dirt: Five Thousand Years of Urban Media* (Minneapolis: University of Minnesota Press, 2017).
9. Liam Young, "An Atlas of Fiducial Landscapes: Touring the Architectures of Machine Vision" *Log* 36 (Winter 2016): 125–134.
10. See John Pickles, ed., *Ground Truth: The Social Implications of Geographic Information Systems* (New York: Guilford, 1994).
11. Jean-Luc Nancy, *The Ground of the Image*, trans. Jeff Fort (New York: Fordham University Press, 2005). For a related discussion on the troubling of this figure/ground distinction leading to the elaboration of legal infrastructure figures out

of invisible underground formations, see Andrea Ballestero, "Underground as Infrastructure? Figure/Ground Reversals and Dissolution in Sardinal," in *Environment, Infrastructure and Life in the Anthropocene*, ed. Kregg Hetherington (Durham, NC: Duke University Press, 2019), 17–44.

12. Nancy, *Ground of the Image*, 13.
13. Harun Farocki, "Phantom Images," trans. Brian Poole, *Public* 29 (2004): 12–22; Jussi Parikka, *Operational Images: From the Visual to the Invisual* (Minneapolis: University of Minnesota Press, 2023).
14. Machine vision and machine learning do not necessarily lead to images but to all sorts of elevation data, point clouds, models, as well as other higher-dimensional entities; so the technique of flattening takes place not as a cut in the projective space of representation but as a recursive operation, even at the level of hardware, as for instance in the graphical parallel computation performed by graphics processing units. See Jacob Gaboury, *Image Objects: An Archaeology of Computer Graphics* (Cambridge, MA: MIT Press, 2021).
15. Seán Cubitt, "Mass Image, Anthropocene Image, Image Commons," in *Photography Off the Scale: Technologies and Theories of the Mass Image*, ed. Tomáš Dvořák and Jussi Parikka (Edinburgh: University of Edinburgh Press, 2021), 25–40.
16. Caren Kaplan, *Aerial Aftermaths: Wartime from Above* (Durham, NC: Duke University Press, 2018), 34.
17. See, for example, the case of Landsat, 1970s, discussed in Mack, *Viewing the Earth*.
18. Indeed, as is convincingly shown in many studies and contexts, observations are always theory-dependent and part of a more detailed back and forth movement of comparison and synthesis in contexts of the materiality of epistemic practices. See, for instance, Karin Knorr-Cetina and Michael Mulkay, *Science Observed: Perspectives on the Social Study of Science* (London: SAGE, 1983); Ian Hacking, *Representing and Intervening: Introductory Topics in the Philosophy of Natural Science* (Cambridge: Cambridge University Press, 1983); Bruno Latour and Steve Woolgar, *Laboratory Life: The Construction of Scientific Facts* (Princeton, NJ: Princeton University Press, 1986).
19. Thomas M. Lillesand, Ralph W. Kiefer, and Jonathan W. Chipman, *Remote Sensing and Image Interpretation*, 7th ed. (Hoboken, NJ: Wiley, 2015), 39.
20. Roger Hoffer, "The Importance of 'Ground Truth,'" *Data in Remote Sensing* 120371 of LARS Print (1972): 1–13, at 3.
21. Mack, *Viewing the Earth*, 49.
22. Mack, *Viewing the Earth*.
23. EROS CalVal Center of Excellence, "Test Sites Catalog," *U.S. Geological Survey*, accessed June 9, 2022. https://calval.cr.usgs.gov/apps/test_sites_catalog. The following quotations are from the catalog.
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Presser Aiden, Adrian Veres, Matthew K. Gray, Joseph P. Pickett, Dale Hoiberg, et al., "Quantitative Analysis of Culture Using Millions of Digitized Books," *Science* 331, no. 6014 (2011): 176.

25. Parikka, *Operational Images*, 118–126.
26. Denis Cosgrove and William L. Fox, *Photography and Flight* (London: Reaktion, 2010).
27. Paul K. Saint-Amour, "Modernist Reconnaissance," *Modernism/Modernity* 10, no. 2 (2003): 349–380; Saint-Amour, "Applied Modernism: Military and Civilian Uses of the Aerial Photomosaic," *Theory, Culture & Society* 28, no. 7–8 (2012): 241–269; Saint-Amour, "Photomosaics: Mapping the Front, Mapping the City," in *From Above: War, Violence, and Verticality*, ed. Peter Adey, Mark Whitehead, and Alison Williams (Oxford: Oxford University Press, 2014), 119–142.
28. Saint-Amour, "Modernist Reconnaissance," 356
29. Saint-Amour, "Modernist Reconnaissance," 354.
30. Saint-Amour, "Modernist Reconnaissance," 360–361.
31. Saint-Amour, "Modernist Reconnaissance," 357.
32. Saint-Amour, "Modernist Reconnaissance," 358.
33. Saint-Amour, "Modernist Reconnaissance," 358.
34. Saint-Amour, "Photomosaics."
35. Gabrys, *Program Earth*, 71.
36. John Pickles, ed., *Ground Truth: The Social Implications of Geographic Information Systems* (New York: Guilford, 1995).
37. Howard Veregin, "Computer Innovation and Adoption in Geography: A Critique of Conventional Technological Models," in Pickles, *Ground Truth*, 100–101.
38. Paul N. Edwards, *A Vast Machine: Computer Models, Climate Data, and the Politics of Global Warming* (Cambridge, MA: MIT Press, 2010), xiii.
39. Carlo Ginzburg, *Clues, Myths, and the Historical Method*, trans. John Tedeschi and Anne C. Tedeschi (Baltimore, MD: Johns Hopkins University Press, 2013).
40. Eyal Weizman, *Forensic Architecture: Violence at the Threshold of Detectability* (New York: Zone, 2017); Susan Schuppli, *Material Witness: Media, Forensics, Evidence* (Cambridge, MA: MIT Press, 2020).
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44. Schuppli, *Material Witness*, 3.

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48. Adrian Mackenzie, *Machine Learners: Archaeology of a Data Practice* (Cambridge, MA: MIT Press, 2017).

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50. See Ryan Bishop, "Project 'Transparent Earth' and the Autoscopy of Aerial Targeting: The Visual Geopolitics of the Underground," *Theory, Culture & Society* 28, no. 7–8 (2011): 270–286. On the notion of data ensemble, see Ingrid Hoelzl and Rémi Marie, "Google Street View: Navigating the Operative Image," *Visual Studies* 29 (2014): 261–271. On image ensembles, see Mackenzie and Munster, "Platform Seeing."

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52. Stefan Strauß, "From Big Data to Deep Learning: A Leap Towards Strong AI or 'Intelligentia Obscura'?" *Big Data and Cognitive Computing* 2, no. 16 (July 17, 2018): 11.

53. Andrew Lookingbill and Michael Weiss-Malik, "Google I/O 2013—Project Ground Truth: Accurate Maps Via Algorithms and Elbow Grease," Google for Developers, May 16, 2013, YouTube video, 40:20, https://www.youtube.com/watch?v=FsbLEtSouls.

54. Kate Crawford and Vladan Joler, "Anatomy of an AI System: The Amazon Echo as an Anatomical Map of Human Labor, Data and Planetary Resources," *AI Now Institute and Share Lab*, September 7, 2018, https://anatomyof.ai/; Maya Indira Ganesh, "Intelligence Work," *A is for Another: A Dictionary of AI*, accessed 8 April, 2023 https://aisforanother.net/pages/article16.html; Matteo Pasquinelli and Vladan Joler, "The Nooscope Manifested: AI as Instrument of Knowledge Extractivism," KIM HfG Karlsruhe and Share Lab, May 1, 2020, accessed 14 Nov, 2022, https://nooscope.ai/. See also Lin, "How Forests Became Data."

55. Bishop, "Project 'Transparent Earth,'" 276.

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58. Not by accident, these techniques of overlapping images and data in the same frame were published simultaneously with Ian L. McHarg's seminal book, *Design with Nature* (Garden City, NY: American Museum of Natural History, 1969), which proposed the layer-cake model, acknowledged as a forerunner of GIS. The layer-cake model diagrammed representations of different components of a natural environment as different layers. Geology, soils, vegetation, and climate were portrayed as layers superimposed on each other in order to emphasize the viewing of the composite and the relations between the components. See Frederick Steiner and Billy Fleming, "*Design with Nature* at 50: Its Enduring Significance to Socio-Ecological Practice and Research in the Twenty-First Century," *Socio-Ecological Practice Research* 1, no. 3 (October 1, 2019): 173–177.

59. On invisual, see Mackenzie and Munster, "Platform Seeing."

60. Lin, "How Forests Became Data," 291.

61. Paul Virilio, *The Vision Machine*, trans. Julie Rose (Bloomington: Indiana University Press, 1994), 13.

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63. Smyth et al., "Inferring Ground Truth from Subjective Labelling of Venus Images."

64. Bernhard Siegert, *Cultural Techniques: Grids, Filters, Doors, and Other Articulations of the Real*, trans. Geoffrey Winthrop-Young (New York: Fordham University Press, 2015).

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66. Nadia Bozak, *The Cinematic Footprint: Lights, Camera, Natural Resources* (New Brunswick, NJ: Rutgers University Press, 2011), 34.

67. On the question of calibration both as a technical and artistic notion, see Geocinema's work *Framing Territories* (2019), which focuses on remote sensing and science infrastructures of the Digital Belt and Road, and Hito Steyerl's *How Not to Be Seen: A Fucking Didactic Educational .MOV File* (2013), https://www.artforum.com/video/hito-steyerl-how-not-to-be-seen-a-fucking-didactic-educational-mov-file-2013-51651.

68. Lukáš Likavčan, *Introduction to Comparative Planetology* (Moscow: Strelka, 2019).

69. Zhao et al., "Deep Fake Geography?," 338.

70. Zhao et al., "Deep Fake Geography?," 338. The authors explain the typical GAN-created synthetic media process: "The GANs generate two networks—a 'generator' and a 'discriminator'—and enable them to contest with one another through a multiple-epoch training process. In the training process, the generator creates a latent space of candidate datasets, and then the discriminator evaluates whether the candidate datasets are qualified by satisfying an evolving statistical characteristics criterion. The candidate data from the generator, after several training epochs of tuning, can reach an acceptable similarity to the required statistical characteristics. . . . Similarly, if we use a GAN to simulate geospatial data, the GAN's generator will create candidates of geospatial data and ask the discriminator whether the candidates meet the characteristics of a typical geospatial data. Here, the geospatial data can be as simple as a point, polyline or polygon, or relative complex data like satellite images, or even 3D point clouds. After several epochs' training, the candidates could eventually meet the criteria of qualified geospatial data. At this stage, the candidates, recognized as seemingly authentic geospatial data, embody a new mode of fake geography" (341).

71. See "Fake Geography," https://chunxxu.github.io/fakegeo/index.html.

72. Chunxue Xu and Bo Zhao, "Satellite Image Spoofing: Creating Remote Sensing Dataset with Generative Adversarial Networks," *10th International Conference on Geographic Information Science*, *GIScience*, ed. Stephan Winter, Amy Griffin, and Monika Sester (Wadern: Leibniz-Zentrum fur Informatik, 2018), 67:1–67:6.

73. Bo Zhao et al., "Deep Fake Geography?"

74. Weili Shi, "Terra Mars: When Earth Shines on Mars through AI's Imagination," *Leonardo* 52, no. 4 (2019): 357–363.

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76. Bozak, *Cinematic Footprint*, 97.

77. See chapter 4 for the discussion on *Seed, Image, Ground* (2020). On soft montage, see Harun Farocki, "Cross Influence/Soft Montage," in *Harun Farocki: Against What? Against Whom?* Ed. Antje Ehmann and Kodwo Eshun (London: Koenig, 2009), 64–79; Volker Pantenburg, "Working Images: Harun Farocki and the Operational Image," in *Image Operations: Visual Media and Political Conflict*, ed. Jens Eder and Charlotte Klonk (Manchester: Manchester University Press, 2017), 49–62; Nora Alter, "Two or Three Things I Know about Harun Farocki," *October* 151 (Winter 2015): 151–158.

78. Nancy, *Ground of the Image*, 13.

79. Cubitt, "Mass Image."

80. Mackenzie, *Machine Learners*, 53.

81. Mackenzie and Munster, "Platform Seeing." On visual culture and data, see also Parikka, *Operational Images*.

82. John Pickles, *A History of Spaces: Cartographic Reason. Mapping and the Geo-Coded World* (New York: Routledge, 2004), 159.
83. Irmgard Emmelhainz, "Conditions of Visuality under the Anthropocene and Images of the Anthropocene to Come," *e-flux* 63 (March 2015), https://www.e-flux.com/journal/63/60882/conditions-of-visuality-under-the-anthropocene-and-images-of-the-anthropocene-to-come/.

CHAPTER 6

1. Robert E. Kohler, *Landscapes and Labscapes: Exploring the Lab-Field Border in Biology* (Chicago: University of Chicago Press, 2002).
2. Alfred G. Tansley, "The Use and Abuse of Vegetational Concepts and Terms," *Ecology* 16, no. 3 (1935): 284–307, at 285.
3. Robert Gerard Pietrusko, "Ground Cover," *LA+* Geo Issue (Fall 2020): 12–19; John May, "Logic of the Managerial Surface," *PRAXIS* 13 (2012), 116–124.
4. Suzanne Simard, *Finding the Mother Tree: Discovering the Wisdom of the Forest* (New York: Alfred A. Knopf, 2021), 3.
5. After his work on plant succession and plant indicators, Clements did work on the importance of the different densities of root connectors of plants in the prairies. His doctoral student John E. Weaver performed a systematic excavation of the roots of thousands of plants to confirm his ideas on the root networks that sustained the plant's ability to survive the year-long periods of abnormal weather. See Ronald C. Tobey, *Saving the Prairies: The Life Cycle of the Founding School of American Plant Ecology, 1895–1955* (Berkeley: University of California Press, 1981), 191–193.
6. Thomas Kirchoff, "The Myth of Frederic Clements's Mutualistic Organicism, or: On the Necessity to Distinguish Different Concepts of Organicism," *History and Philosophy of the Life Sciences* 42 (2020): 1–27.
7. Pietrusko, "Ground Cover."
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9. Michael Marder, *Plant-Thinking: A Philosophy of Vegetal Life* (New York: Columbia University Press, 2013).
10. Ursula K. LeGuin, "Vaster than Empires and More Slow," in *New Dimensions 1: Fourteen Original Science Fiction Stories*, ed. Robert Silverberg (New York: Avon, 1973), 99–133, at 128.
11. James Lovelock, *Gaia: A New Look at Life on Earth* (Oxford: Oxford University Press, 1995), 10. Quoted in Thomas Pringle, "The Ecosystem Is an Apparatus: From Machinic Ecology to the Politics of Resilience," in *Machine*, ed. Thomas Pringle, Gertrud Koch, and Bernard Stiegler (Minneapolis: University of Minnesota Press and Menson Press, 2019), 49–103, at 77.

12. LeGuin, "Vaster than Empires and More Slow," 118.
13. Grass is considered in relation to the transformation of the prairies of the American Midwest into a place of industrial exhaustion; see Hannah Holleman, *Dust Bowls of Empire: Imperialism, Environmental Politics, and the Injustice of "Green" Capitalism* (New Haven, CT: Yale University Press, 2018); in relation to the European colonial project, see Richard Drayton, *Nature's Government: Science, Imperial Britain, and the "Improvement" of the World* (New Haven, CT: Yale University Press, 2000); and in relation to the longer cultural history of the metaphor of the green mantle, see Veronica della Dora. *The Mantle of the Earth*: *Genealogies of a Geographical Metaphor* (Chicago: University of Chicago Press, 2020).
14. See Chunglin Kwa, "Modeling the Grasslands," *Historical Studies in the Physical and Biological Sciences* 24, no. 1 (1993): 125–155. See also Tega Brain, "The Environment Is Not a System," *APRJA* 7, no. 1 (2018), https://researchvalues2018.wordpress.com/2017/12/20/tega-brain-the-environment-is-not-a-system/.
15. Pringle, "Ecosystem Is an Apparatus," 63.
16. Eugene P. Odum, "Energy Flow in Ecosystems: A Historical Review," *American Zoologist* 8, no. 1 (1968): 11–18. See Mark Glen Madison, "'Potatoes Made of Oil': Eugene and Howard Odum and the Origins and Limits of American Agroecology," *Environment and History* 3, no. 2 (1997): 209–238.
17. Also Lovelock's theorization of Gaia grew out of this period of mapping how surface levels interact with atmospheric chemistry in complex "informational self-regulation." See Pringle, "Ecosystem Is an Apparatus," 76. See also Giulia Rispoli, "Planetary Environing: The Biosphere and the Earth System," in *Environing Media*, ed. Adam Wickberg and Johan Gärdebo (London: Routledge, 2022), 54–74.
18. See Peder Anker, "The Ecological Colonization of Space," *Environmental History* 10, no. 2 (2005): 239–268. In this context it is good to note the science fiction novel by James Lovelock and Michael Allaby, *The Greening of Mars* (New York: Warner, 1985), and the work by Lynn Margulis on the (impossible) terraforming of planets such as Mars, for example in Lynn Margulis and Oona West, "Gaia and the Colonization of Mars," *GSA Today* 3, no. 11 (1993): 277–280, at 291.
19. Isaac Asimov, "Misbegotten Missionary (Green Patches)," *Galaxy Magazine*, November 1950, 34–47.
20. This was not a new concept introduced by Clements. As was fully acknowledged by the botanist in the historical sections in his books, the notion of plant formation had a well-known trajectory before his work. For more details on the history of this idea, see Frederic E. Clements, *Research Methods in Ecology* (Lincoln, NE: University Publishing Company, 1905), 2–4, and Tobey, *Saving the Prairies*, 76–109.
21. Clements, *Research Methods in Ecology*, 199.
22. Clements, *Research Methods in Ecology*, 199.

23. Boris Shoshitaishvili, "Is Our Planet Doubly Alive? Gaia, Globalization, and the Anthropocene's Planetary Superorganisms," *Anthropocene Review* 10, no. 2 (2022): 434–454.
24. Frederic E. Clements, *Plant Succession: An Analysis of the Development of Vegetation* (Washington, DC: Carnegie Institution of Washington, 1916), 3.
25. William Morton Wheeler, "The Ant Colony as an Organism," *Journal of Morphology* 22, no. 2 (2005): 307–325.
26. Jussi Parikka, *Insect Media: An Archaeology of Animals and Technology* (Minneapolis: University of Minnesota Press, 2010), 51–55. Kirchoff, "Myth of Frederic Clements's Mutualistic Organicism," 24.
27. Jan C. Smuts, *Holism and Evolution*, 2nd ed. (London: Macmillan, 1927), https://archive.org/stream/holismandevolutio32439mbp/holismandevolutio32439mbp_djvu.txt.
28. "This refusal is however far from meaning that I do not realise that various 'biomes,' the whole webs of life adjusted to particular complexes of environmental factors, are real 'wholes,' often highly integrated wholes, which are the living nuclei of systems in the sense of the physicist. Only I do not think they are properly described as 'organisms' (except in the 'organicist' sense). I prefer to regard them, together with the whole of the effective physical factors involved, simply as 'systems'"; Tansley, "Use and Abuse of Vegetational Concepts and Terms," 297.
29. On Tansley's critical stance to holism, as well as the context of racialized notions of "imperial ecology," see Peder Anker, *Imperial Ecology: Environmental Order in the British Empire, 1895–1945* (Cambridge, MA: Harvard University Press, 2001), 118–156.
30. Kirchoff, "Myth of Frederic Clements's Mutualistic Organicism," 8.
31. Frederic E. Clements and Victor E. Shelford, *Bio-Ecology* (New York: Wiley, 1939), 238–239; quoted in Kirchoff "Myth of Frederic Clements's Mutualistic Organicism," 9.
32. Clements and Shelford, *Bio-Ecology*, 271; quoted in Kirchoff, "Myth of Frederic Clements's Mutualistic Organicism," 9.
33. Kirchoff, "Myth of Frederic Clements's Mutualistic Organicism," 13–14.
34. Clements, *Research Methods in Ecology*, 270.
35. Clements, *Research Methods in Ecology*, 271.
36. Mary Louise Pratt, *Imperial Eyes: Travel Writing and Transculturation* (London: Routledge, 2008), 169–194.
37. Marie-Noëlle Bourguet, "Landscape with Numbers: Natural History, Travel and Instruments in the Late Eighteenth and Early Nineteenth Centuries," in *Instruments, Travel and Science. Itineraries of Precision from the Seventeenth to the Twentieth Century*, ed. Marie-Noëlle Bourguet, Christian Licoppe, and H. Otto Sibum (London: Routledge, 2002), 96–125, at 106.
38. Tobey, *Saving the Prairies*, 50.

39. Richard Hölzl, "Scientific Forestry in the Eighteenth and Nineteenth Centuries," *Science as Culture* 19, no. 4, (2010): 431–460.
40. Tobey, *Saving the Prairies*, 52.
41. Tobey, *Saving the Prairies*, 70.
42. Tobey, *Saving the Prairies*, 65.
43. Geoffrey Batchen, "Electricity Made Visible," in *New Media, Old Media: A History and Theory Reader*, ed. Wendy Hui Kyong Chun and Thomas Keenan (New York: Routledge, 2002), 27–44, at 28.
44. Batchen, "Electricity Made Visible," 28.
45. Batchen, "Electricity Made Visible," 29.
46. Batchen, "Electricity Made Visible," 29–30.
47. Batchen, "Electricity Made Visible," 30.
48. William Henry Fox Talbot, *The Pencil of Nature* (London: Longman, Brown, Green and Longmans, 1844; repr. 2010), 33.
49. Gilbert Simondon, *Individuation in Light of Notions of Form and Information*, vol. 1, trans. Taylor Adkins (Minneapolis: University of Minnesota Press, 2020), 246.
50. Oliver W. Holmes Sr., "The Stereoscope and the Stereograph," in *Classic Essays on Photography*, ed. Alan Trachtenberg (New Haven, CT: Leete's Island, 1980), 72–82, at 77, 78; quoted by John Durham Peters in "Space, Time, and Communication Theory," *Canadian Journal of Communication* 28, no. 4 (2003): 397–411, at 403.
51. On early photographic images and information abundance, referring to an "overcrowding of detail," see Mary Ann Doane, "Temporality, Storage, Legibility. Freud, Marey, and the Cinema," *Critical Inquiry* 22, no. 2 (1996): 313–343, at 328.
52. Clements, *Research Methods in Ecology*, 271.
53. Lorraine Daston and Peter Galison, *Objectivity* (New York: Zone, 2007).
54. Siegfried Zielinski, *Deep Time of the Media: Toward an Archaeology of Hearing and Seeing by Technical Means*, trans. Gloria Custance (Cambridge, MA: MIT Press, 2006), 215. Anecdotally, this use of statistics also features in W. E. B. Dubois's work; see Maria Farland, "W. E. B. DuBois, Anthropometric Science, and the Limits of Racial Uplift," *American Quarterly* 58, no. 4 (2006): 1017–1045.
55. On the role of statistics at the University of Nebraska, see Tobey, *Saving the Prairies*, 53–57; on their understanding of Darwin's work, see 69.
56. On the importance of counting populations in relation to the development of statistics, see Ian Hacking, *The Taming of Chance* (Cambridge: Cambridge University Press, 1990).
57. Tobey, *Saving the Prairies*, 74.
58. Tobey, *Saving the Prairies*, 55.
59. Kohler, *Landscapes and Labscapes*, 102.

60. Experimental practices were also tested, making the field into a lab: so-called denuded quadrats were "cleared of all vegetation by herbicides or excavation" so as to allow observation of "which plants invade or resettle vacant ground"; Kohler, *Landscapes and Labscapes*, 104. As Kohler notes, this was also an early form of modeling how environments might react after "fire, disease, or human interventions" (105).
61. Clements, *Research Methods in Ecology*, 188
62. Clements, *Research Methods in Ecology*, 188–196.
63. Clements, *Research Methods in Ecology*, 191. On the broader link between addressability, logistical media, and computation, see Ranjodh Singh Dhaliwal, "On Addressability, or What Even Is Computation?," *Critical Inquiry* 49, no. 1 (2022): 1–27.
64. Cindy Lin, "How Forests Became Data: The Remaking of Ground Truth in Indonesia," in *The Nature of Data: Infrastructures, Environments, Politics*, ed. Jenny Goldstein and Eric Host (Lincoln: University of Nebraska Press, 2022), 285–302.
65. Quoted in Shannon Mattern, "Tree Thinking," *Places*, September 2021, https://placesjournal.org/article/tree-thinking/.
66. Jennifer Gabrys, "Smart Forests and Data Practices: From the Internet of Trees to Planetary Governance," *Big Data & Society* 7, no. 1 (2020): 4. Mattern, "Tree Thinking."
67. See Birgit Schneider and Lynda Walsh, "The Politics of Zoom: Problems with Downscaling Climate Visualizations," *Geo: Geography and Environment* 6, no. 1 (2019): 1–11.
68. On these data ensembles in relation to Google Street View, see Ingrid Hoelzl and Rémi Marie, "Google Street View: Navigating the Operative Image," *Visual Studies* 29, no. 3 (2014): 261–271.
69. Steven Brumby, "Teaching the Cloud to See the Earth," TEDx Talks, October 15, 2015, YouTube video, 9:06, https://www.youtube.com/watch?v=VLze6W7SvyY.
70. Della Dora, *Mantle of the Earth*.
71. Current techniques devised to build forest and plantation inventories include automated tree crown detection, delineation, classification, and counting. See, for instance, Aishwarya Chandrasekaran, Guofan Shao, Songlin Fei, Zachary Miller, and Joseph Hupy, "Automated Inventory of Broadleaf Tree Plantations with UAS Imagery," *Remote Sensing* 14, no. 8 (2022): 1931.
72. Dhaliwal, "On Addressability, or What Even Is Computation."
73. May, "Logic of the Managerial Surface," 117.
74. Clements, *Research Methods in Ecology*, 274.
75. Tansley, "Use and Abuse of Vegetational Concepts and Terms."
76. Clements, *Research Methods*, 270.
77. Frederic E. Clements, *Plant Indicators: The Relation of Plant Communities to Process and Practice* (Washington, DC: Carnegie Institution of Washington, 1920), 3.

78. Clements, *Plant Indicators*, 3.

79. Nathaniel B. Ward, *On the Growth of Plants in Closely Glazed Cases*, 2nd ed. (London: John van Voorst, 1852), 14.

80. On a-signifying semiotics and signaletic matter, see Gary Genosko, *Félix Guattari: A Critical Introduction* (London: Pluto, 2009).

81. Kohler, *Landscapes and Labscapes*, 122. "In a general way, plants serve as measures of conditions wherever they grow. This is the principle that underlies the indicator value of native plants. It operates with equal force in the case of cultivated plants and crops of all sorts, though with these it must be recognized that the habitat has been artificially modified to some degree. Whenever a species is planted under new conditions of soil or climate, it serves as a kind of practical phytometer by comparison with its usual growth." Frederic E. Clements and Glenn W. Goldsmith, *The Phytometer Method in Ecology: The Plant and Community as Instruments* (Washington, DC: Carnegie Institution of Washington, 1924), 5.

82. Clements and Goldsmith, *Phytometer Method in Ecology*, 120; italics by the authors.

83. Gernot Böhme, "The Physiognomy of a Landscape" trans. Axel Häusler, in *Thermodynamic Interactions: Architectural Exploration into Material, Physiological and Territorial Atmospheres*, ed. Javier Garcia-German (New York: Actar, 2017), 219–234.

84. Orit Halpern, *Beautiful Data: A History of Vision and Reason since 1945* (Durham, NC: Duke University Press, 2014), 21.

85. Tansley distinguishes autogenic succession of plant formations from allogenic succession "in which the changes are brought about by external factors." Tansley, "Use and Abuse of Vegetational Concepts and Terms," 287.

86. Chris Salter, *Sensing Machines: How Sensors Shape Our Everyday Life* (Cambridge, MA: MIT Press, 2022), 15–40.

87. To refer to ecological, environmental surfaces as affordances that put into circulation all sorts of images, data, and actions is one form of continuing the idea of active surfaces. This aligns with J. J. Gibson's ecological notion of affordances—that material environments afford different capacities of perception, movement, and action—but it also brings into play the point that environmental surfaces are actively involved in their own interpretation, comparison, numbering, counting, and even imaging in ways that expand the repertoire of cultural techniques to ecological aspects of technical systems. Continuing our previous chapter's theme of preparing ground surfaces for machine vision, we can see a similar theme about environment surfaces as dynamic in this fundamental sense of affordance. See James J. Gibson, *The Ecological Approach to Visual Perception* (Hillsdale, NJ: Lawrence Erlbaum, 1986). On Gibson and affordance in media theory, see Parikka, *Insect Media*, passim.

88. Pietrusko, "Ground Cover," 16.

89. Pietrusko, "Ground Cover," 16.

90. Pietrusko, "Ground Cover," 16.
91. Pietrusko, "Ground Cover," 14
92. Pietrusko, "Ground Cover," 18.
93. Pietrusko, "Ground Cover," 16.
94. Pietrusko, "Ground Cover," 17.
95. Cf. Cubitt on Ansel Adams's zoning in Seán Cubitt, *The Practice of Light: A Genealogy of Visual Technologies from Prints to Pixels* (Cambridge, MA: MIT Press, 2014), 91–95.
96. Jacob Darwin Hamblin, *Arming Mother Nature: The Birth of Catastrophic Environmentalism* (Oxford: Oxford University Press, 2013); David Zierler, *The Invention of Ecocide: Agent Orange, Vietnam, and the Scientists Who Changed the Way We Think about the Environment* (Athens: University of Georgia Press, 2011).
97. Kristen Jordan, "Advanced Plant Technologies," *DARPA*, accessed August 8, 2023, https://www.darpa.mil/program/advanced-plant-technologies.
98. Clements, quoted in Kohler, *Labscape and Landscape*, 122.
99. Jordan, "Advanced Plant Technologies."
100. Blake Bextine, the DARPA Program Manager for APT, quoted in "Nature's Silent Sentinels Could Help Detect Security Threats," *DARPA*, November 17, 2017, https://www.darpa.mil/news-events/2017-11-17.
101. Kohler, *Labscape and Landscape*, 118–122.
102. Jennifer Gabrys, *Program Earth: Environmental Sensing Technology and the Making of a Computational Planet* (Minneapolis: University of Minnesota Press, 2016), 15.
103. Gabrys, *Program Earth*, 43.

CHAPTER 7

1. Another realm of light where images are literally diving deeper are oceans and other hydric formations. Algae and other marine vegetation and phenomena such as uncontrolled blooms, species invasions of different kinds and the resulting eutrophication of waters parallel the spread of monitoring infrastructure such as specific satellites and machine learning computation. On this topic see Melody Jue, "'Pixels May Lose Kelp Canopy': The Photomosaic as Epistemic Figure for the Satellite Mapping and Modeling of Seaweeds," *Media+Environment* 3, no. 2 (2021), https://mediaenviron.org/article/21261-pixels-may-lose-kelp-canopy-the-photomosaic-as-epistemic-figure-for-the-satellite-mapping-and-modeling-of-seaweeds. We also want to point to Alejandro Limpo's ongoing PhD project (University of Southampton) on visual culture and cultural techniques of oceans and thank him for his research assistance in locating relevant sources.
2. See Robert P. Harrison, *Forests: The Shadow of Civilization* (Chicago: University of Chicago Press, 1993), 197–243.

3. Jennifer Gabrys, "Smart Forests and Data Practices: From the Internet of Trees to Planetary Governance," *Big Data & Society* 7, no. 1 (2020); Rosetta S. Elkin, *Plant Life: The Entangled Politics of Afforestation* (Minneapolis: University of Minnesota Press, 2022). See also Shannon Mattern, "Tree-Thinking," *Places*, September 2021, https://placesjournal.org/article/tree-thinking/.
4. For a wide account of cases of "environcides," including receding forests all around the world ranging from the sixteenth to the early twentieth centuries, see Emmanuel Kreike, *Scorched Earth: Environmental Warfare as a Crime against Humanity and Nature* (Princeton, NJ: Princeton University Press, 2021). On the political and aesthetical dimension of the forest, away from the usual romanticization of its shadowlands, see Matthew Fuller and Olga Goriunova, *Bleak Joys: Aesthetics of Ecology and Impossibility* (Minneapolis: University of Minnesota Press, 2019), 121–153.
5. Gabrys. "Smart Forests and Data Practices."
6. The limiting zones between ecosystems of different kinds display characteristics similar to the transitions of plant formations that we discuss in chapter 6. They are thus fertile regions in relation to the data-gathering processes they give rise to. On the cultures of data in between the Amazon rainforest and the savanna, for example, see Bruno Latour, "Circulating Reference: Sampling the Soil in the Amazon Forest," in *Pandora's Hope: Essays on the Reality of Science Studies*, ed. Bruno Latour (Cambridge, MA: Harvard University Press, 1999), 24–79.
7. The green cascade in the original phrase refers to vegetal matter, not light: "V. Panfilov says that tropical forests resemble a gigantic green cascade frozen in its downfall." The quote is found in Andrei V. Lapo, *Traces of Bygone Biospheres* (Moscow: MIR, 1982), 134.
8. Ute Holl, *Cinema, Trance and Cybernetics* (Amsterdam: Amsterdam University Press, 2017), 19.
9. Fuller and Goriunova, *Bleak Joys*, 123.
10. For an analysis of the capacity of immersive environments—such as Anouk de Clercq's LiDAR imaging of urbanscapes as similar to forest point clouds—to create effective simulations of altered states of consciousness, centered on the use of darkness, see Martine Beugnet and Lily Hibberd, "Cinematic Darkness: Dreaming across Film and Immersive Digital Media," *AN-ICON. Studies in Environmental Images* 1, no. 1 (2022): 129–152.
11. Giuliana Bruno, *Atmospheres of Projection: Environmentality in Art and Screen Media* (Chicago: University of Chicago Press, 2022), 38.
12. Giuliana Bruno, *Surface: Matters of Aesthetics, Materiality, and Media* (Chicago: University of Chicago Press, 2014), 67.
13. Bruno, *Surface*. The quotation is from Georges Didi-Huberman, "The Fable of the Place," in *James Turrell: The Other Horizon*, ed. Peter Noever (Vienna: MAK and Hatje Cantz, 2001), 45–56.
14. Bruno, *Surface*, 67.

15. Bruno, *Surface*, 67.
16. Eduardo Kohn, *How Forests Think: Toward an Anthropology beyond the Human* (Berkeley: University of California Press, 2013), 78, 9.
17. Marcel Minnaert, *The Nature of Light and Colour in the Open Air* (Mineola, NY: Dover, 1954), 1.
18. Mabel L. Todd, *Total Eclipses of the Sun* (Boston, MA: Roberts Brothers, 1894), 20. For a natural (media) history of light from technical apparatuses to such natural cinema, see Amédée Guillemin, *Le Monde physique*, vol. 2, *La lumière* (Paris: Hachette, 1882).
19. Matthew Fuller and Eyal Weizman, *Investigative Aesthetics: Conflicts and Commons in the Politics of Truth* (London: Verso, 2021), 50.
20. Fuller and Weizman, *Investigative Aesthetics*, 50.
21. Margaret C. Anderson and Edward E. Miller, "Forest Cover as a Solar Camera: Penumbral Effects in Plant Canopies," *Journal of Applied Ecology* 11, no. 2 (1974): 691–697.
22. See Nancy Anderson and Michael R. Dietrich, eds., *The Educated Eye: Visual Culture and Pedagogy in the Life Sciences* (Hanover, NH: Dartmouth College Press, 2012).
23. John A. Endler, "The Color of Light in Forests and Its Implications," *Ecological Monographs* 63, no. 1 (1993): 1–27, at 1.
24. Margaret C. Anderson, "Studies of the Woodland Light Climate: I. The Photographic Computation of Light Conditions," *Journal of Ecology* 52, no. 1 (1964): 27–41.
25. Eva Horn, "Air as Medium," *Grey Room*, December 1, 2018, 6–25, at 10–13, 12.
26. Nancy L. Peluso and Peter Vandergeest, "Political Ecologies of War and Forests: Counterinsurgencies and the Making of National Natures," *Annals of the Association of American Geographers* 101, no. 3 (2011): 587–608.
27. For a classic reference on state-driven scientific forestry, see James C. Scott, *Seeing Like a State: How Certain Schemes to Improve the Human Condition Have Failed* (New Haven, CT: Yale University Press, 1999), 11–22. For a more extended approach, see also Richard Hölzl, "Historicizing Sustainability: German Scientific Forestry in the Eighteenth and Nineteenth Centuries," *Science as Culture* 19, no. 4 (2010): 431–460.
28. Anderson, "Studies of the Woodland Light Climate," 27. Anderson emphasizes the importance that Wiesner gave to absolute values of Lichtgenuss when comparing different sites: "Wiesner was clear that comparative measurements of relative 'Lichtgenuss' (instantaneous diffuse site factor) of plant communities from different climates and latitudes could not be used as a basis for comparison of light conditions. Comparison could only be made between absolute, not relative measurements, since the light conditions in the open vary widely with climate and latitude. This point seems subsequently to have been generally overlooked" (39).

29. A summary of this experimentation through different photographic techniques can be followed in G. C. Evans and D. E. Coombe, "Hemisperical and Woodland Canopy Photography and the Light Climate," *Journal of Ecology* 47, no. 1 (1959): 103–113, at 103–104; and in Anderson, "Studies of the Woodland Light Climate," 31–32.

30. For a wider discussion on the relation between addressability and computation, see Ranjodh Singh Dhaliwal. "On Addressability, or What Even Is Computation?," *Critical Inquiry* 49, no. 1 (2022): 1–27. On grids and the "subordination of physical space to computational control," see Jeffrey Moro, "Grid Techniques for a Planet in Crisis: The Infrastructures of Weather Prediction," *Amodern* 9 (April 2020), https://amodern.net/article/grid-techniques/. See also Jussi Parikka, *Operational Images: From the Visual to the Invisual* (Minneapolis: University of Minnesota Press, 2023), 51–56.

31. Anderson, "Studies of the Woodland Light Climate," 33. The method consisted of counting the cells in the grid after classifying them into five classes, depending of leaves-to-sky ratio: "The second complication is that the scale of details of canopy structure is much finer than the scale of the grid. It is necessary to classify the segments of the grid into five classes: entirely unobstructed, less than 33% obstructed, 33–66% obstructed, 66–90% obstructed, and more than 90% obstructed. These classes are then taken as contributing 100%, 75%, 50%, 25% and 0% of the possible illuminance to the total" (34). The similarities of this method with the ones on plant geography discussed in the last chapter are evident.

32. Anderson, "Studies of the Woodland Light Climate," 39.

33. The HemiView system is supplied by Delta-T. On smartphone hemispherical photography, see Simone Bianchi, Christine Cahalan, Sophie Hale, and James Michael Gibbons, "Rapid Assessment of Forest Canopy and Light Regime Using Smartphone Hemispherical Photography," *Ecology and Evolution* 7, no. 24 (2017): 10556–10566.

34. The use of lidar features in many forms of contemporary art practice. Works would include Anouk De Clearcq's *Thing*, and ScanLAB's *Equirectangular Landscapes 05: Nevada Falls (After Muybridge)*. See, respectively, Beugnet and Hibbert, "Cinematic Darkness," and Jussi Parikka, "On Seeing Where There's Nothing to See: Practices of Light beyond Photography," in *Photography Off the Scale: Technologies and Theories of the Mass Image*, ed. Tomáš Dvořák and Jussi Parikka (Edinburgh: Edinburgh University Press, 2021), 185–210.

35. On operational images and "operations other than war" as they feature in different epistemic and operational imaging practices, see Parikka, *Operational Images*.

36. On the details of his invention, see Robin Hill, "A Lens for Whole Sky Photographs," *Quarterly Journal of the Royal Meteorological Society* 50, no. 211 (1924): 227–235.

37. See Goddard's account of this research in George W. Goddard, "I Looked Back, and He Was Smiling," *University of Rochester Library Bulletin* 26, no. 3 (1971), https://rbscp.lib.rochester.edu/3595.

38. This was the average intensity of such photoflash bombs once their production had been industrialized. The Rochester cartridge contained 90 pounds of flashlight power, approximately the same amount as the later ones. For more detailed information on these bombs of lights, see *Department of the Army Technical Manual TM 9-1385-51: Identification of Ammunition (Conventional) for Explosive Ordnance Disposal* (Washington, DC: Headquarters, Department of the US Army: 1967), 72.11–72.16.
39. Goddard, "I Looked Back."
40. On lidar as a version of flash and active sensing, see Parikka, "On Seeing Where There's Nothing to See."
41. Peter Sloterdijk, *Terror from the Air*, trans. Amy Patton and Steve Corcoran (Los Angeles, CA: Semiotext(e), 2009), 9–46.
42. Richard A. Ruth. "The Secret of Seeing Charlie in the Dark: The Starlight Scope, Techno-Anxiety, and the Spectral Mediation of the Enemy in the Vietnam War," *Vulcan* 5, no. 1 (2017): 64–88, at 70.
43. Ruth. "Secret of Seeing Charlie in the Dark," 68.
44. Ian G. R. Shaw. "Scorched Atmospheres: The Violent Geographies of the Vietnam War and the Rise of Drone Warfare," *Annals of the American Association of Geographers* 106, no. 3 (2016): 688–704, at 689, 694.
45. Yuriko Furuhata, *Climatic Media: Transpacific Experiments in Atmospheric Control* (Durham, NC: Duke University Press, 2022), 35.
46. Deborah Shapley, "Weather Warfare: Pentagon Concedes 7-Year Vietnam Effort," *Science* 184, no. 4141 (1974): 1059–1061, at 1060. See also Ryan Bishop, "Military Meteorology," in *Words of Weather*, ed. Daphne Dragona and Jussi Parikka (Athens: Onassis Stegi), 129–134.
47. Shapley, "Weather Warfare," 1061.
48. Shaw, "Scorched Atmospheres," 694.
49. Shaw, "Scorched Atmospheres," 694.
50. Shaw, "Scorched Atmospheres," 693.
51. Furuhata, *Climatic Media*, 2; see also 31–38.
52. Charles Vernon Boys, *Soap-Bubbles: Their Colours and the Forces which Mould Them* (New York: E. S. Gorham, 1912), 128. On soap bubbles and their use as models for different scientific phenomena from the late decades of the nineteenth to the early twentieth century, see Simon Schaffer, "A Science Whose Business Is Bursting: Soap Bubbles as Commodities in Classical Physics," in *Things that Talk: Object Lessons from Art and Science*, ed. Lorraine Daston (New York: Zone, 2004), 147–194.
53. Paul N. Edwards, *A Vast Machine: Computer Models, Climate Data, and the Politics of Global Warming*, ed. Geoffrey C. Bowker (Cambridge, MA: MIT Press, 2013), 418–419.
54. Edwards, *Vast Machine*.

55. Jane Hutton, *Reciprocal Landscapes: Stories of Material Movements* (Abingdon: Routledge, 2020), 11.

56. See Kreike, *Scorched Earth*.

57. On the discussions inside the US Army about the counterinsurgency actions to deal with this undetectable enemy, see David Zierler, *The Invention of Ecocide: Agent Orange, Vietnam, and the Scientists Who Changed the Way We Think about the Environment* (Athens: University of Georgia Press, 2011), 56–58.

58. Hannah Meszaros Martin. "'Defoliating the World': Ecocide, Visual Evidence and 'Earthly Memory,'" *Third Text* 32, no. 2–3 (2018): 230–253. On ecocide and forensic methods, see also Nabil Ahmed, "Proof of Ecocide: Towards a Forensic Practice for the Proposed International Crime against the Environment," *Forensic Archaeology, Anthropology and Ecology* 1, no. 2, (2019): 139–147.

59. The image complex, or the architectural image complex, is a term borrowed from forensic architecture. "What we refer to as the architectural image complex is a method of assembling image evidence in a spatial environment. The architectural image complex can function as an optical device that allows the viewer to see the scene of the crime as a set of relations between images in time and space. It can also be used as a navigational device to help move between images, exploring a space that is at once virtual and photographic. Essentially, it makes manifest the necessity for composing evidence that is simultaneously material, media-based, and testimonial. The architectural image complex thus replaces both the thematic classification system of archives and the linear transition between images in before-and after montages." Eyal Weizman, *Forensic Architecture: Violence at the Threshold of Detectability* (New York: Zone, 2017), 100.

60. Pujita Guha, "Seeding the Forest," *Cultural Politics* 19, no. 2 (2023). On herbicidal warfare in Vietnam, see Zierler, *Invention of Ecocide*. On a critical approach to the US Air Force's "electronic barrier," focusing on its reliance on the persistence of manual operation work, see David Young, "Sensors, Interpreters, Analysts: Operating the 'Electronic Barrier' during the Vietnam War," *Digital War* 2 (2021): 51–63.

61. Ryan Bishop, "Smart Dust and Remote Sensing: The Political Subject in Autonomous Systems," *Cultural Politics* 11, no. 1 (2015): 100–109.

62. Gabrys. "Smart Forests and Data Practices."

63. Gabrys, "Smart Forests and Data Practices," 7.

64. See Jennifer Gabrys, "Becoming Planetary," *e-flux*, October 2018, https://www.e-flux.com/architecture/accumulation/217051/becoming-planetary/. On the concept of planetarity, see Gayatri Chakravorty Spivak, *Death of a Discipline* (New York: Columbia University Press, 2003), 71–102. On its relation with the Cold War's ecologies of remote sensing, see Elizabeth DeLoughrey, "Satellite Planetarity and the Ends of the Earth," *Public Culture* 26, no. 2 (2014): 257–280. See also John Beck and Ryan Bishop, eds., *Cold War Legacies: Systems, Theory, Aesthetics* (Edinburgh: Edinburgh University Press, 2016).

65. Fuller and Goriunova, *Bleak Joys*, 152. See also Mattern, "Tree-Thinking."

66. See Spivak, *Death of a Discipline*, 71–102.

67. Spivak, *Death of a Discipline*, 151.

68. Paulo Tavares, "The Geological Imperative: On the Political Ecology of Amazonia's Deep History," in *Architecture in the Anthropocene: Encounters Among Design, Deep Time, Science and Philosophy*, ed. Etienne Turpin (London: Open Humanities Press, 2013), 209–240. See also Ryan Bishop, "Project 'Transparent Earth' and the Autoscopy of Aerial Targeting: The Visual Geopolitics of the Underground," *Theory, Culture & Society* 28, no. 7–8 (2011): 270–286.

69. Geoff Manaugh, "Geomedia, or What Lies Below," *BLDGBLOG* (blog), December 31, 2020, https://bldgblog.com/2020/12/geomedia-or-what-lies-below/.

70. Paulo Tavares, "In the Forest Ruins," *e-flux*, December 2016, http://www.e-flux.com/architecture/superhumanity/68688/in-the-forest-ruins/.

71. Tavares, "In the Forest Ruins."

72. On other indigenous practices of mapping in relation to current design and technological culture, see Shannon Mattern, "Mapping's Intelligent Agents," *Places Journal*, September 2017, https://placesjournal.org/article/mappings-intelligent-agents/.

73. Keller Easterling, *Medium Design* (London: Verso, 2021), viii–ix. There is also an interesting link between such recent notions as environmental media and medium design with Serres's natural contract. See Michel Serres, *The Natural Contract*, trans. Elizabeth MacArthur and William Paulson (Ann Arbor: University of Michigan Press, 1995).

74. Here we are paraphrasing Lapo, *Traces of Bygone Biospheres*, a similar recursive and archaeological take on the scale of the planet, which is discussed also in chapter 3.

75. Rob Nixon, "The Less Selfish Gene," *Environmental Humanities* 13, no. 2 (2021): 348–371, at 353.

76. For an argument about forests as accomplishers of the industrial fantasy of locally produced biotech products and services, see, for example, Elliot Hershberg, "Atoms Are Local," *Century of Biology* (blog), November 7, 2022, https://centuryofbio.substack.com/p/atoms-are-local.

77. See also Lukáš Likavčan, *Introduction to Comparative Planetology* (Moscow: Strelka, 2019).

78. Gabrielle Hecht, "Interscalar Vehicles for an African Anthropocene: On Waste, Temporality, and Violence," *Cultural Anthropology* 33, no. 1 (2018): 109–141.

79. Eliza Rose, "Cold-War Cabin Ecologies: Soviet-American Biospheric Thinking," *Science Fiction Studies* 49, no. 2 (2022), 267–287; Peder Anker, *From Bauhaus to Ecohouse: A History of Ecological Design* (Baton Rouge: Louisiana State University Press, 2010).

80. This was the case also when we discussed how the scale of empires at the end of the nineteenth century brought in models of planetary phenomena that reshaped the planet itself.

81. Roger Stahl, "Becoming Bombs: 3D Animated Satellite Imagery and the Weaponization of the Civic Eye," *Mediatropes* 2, no. 2 (2010): 65–93, at 86.

82. For a different perspective of this metaphor in relation to the infrastructure of fashion, following the work of the studio Unknown Fields Division, see Jussi Parikka, "Folds of Fashion: *Unravelled* and the Planetary Surface," in *Surface and Apparition: The Immateriality of Modern Surface*, ed. Yeseung Lee (London: Bloomsbury, 2020), 19–36. See also Veronica della Dora, *The Mantle of the Earth: Genealogies of a Geographical Metaphor* (Chicago: University of Chicago Press, 2020).

83. Simryn Gill and Michael Taussig, *Becoming Palm*, ed. Ute Meta Bauer (Amsterdam: Sternberg, 2017), 11.

84. Jussi Parikka and Abelardo Gil-Fournier, "An Ecoaesthetic of Vegetal Surfaces: On Seed, Image, Ground as Soft Montage," *Journal of Visual Art Practice* 20, no. 1–2 (2021): 16–30.

85. The work of forensic anthropologist Margaret Cox on living surfaces, tracing mass graves, and its elaboration by artist Jananne al-Ani are examples of this. See Caren Kaplan, *Aerial Aftermaths: Wartime from Above* (Durham, NC: Duke University Press, 2018), 180–206; Margaret Cox, Ambika Flavel, Ian Hanson, Joanna Laver, and Roland Wessling, eds., *The Scientific Investigation of Mass Graves: Towards Protocols and Standard Operating Procedures* (Cambridge: Cambridge University Press, 2008).

86. Susan Schuppli, *Material Witness: Media, Forensics, Evidence* (Cambridge, MA: MIT Press, 2020), 257.

87. Wietske Maas, "The Corruption of the Eye: On Photogenesis and Self-Growing Images," *e-flux*, September 1, 2015, http://supercommunity.e-flux.com/texts/the-corruption-of-the-eye-on-photogenesis-and-self-growing-images/. Emanuele Coccia explores in depth such an approach in his essay on the "metaphysics of mixture": Emanuele Coccia, *The Life of Plants: A Metaphysics of Mixture*, trans. Dylan J. Montanari (Medford, MA: Polity, 2019).

88. In this, we are following the footsteps of the eco-aesthetic take by Seán Cubitt. See Cubitt, *Finite Media: Environmental Implications of Digital Technologies* (Durham, NC: Duke University Press, 2016).

89. Irmgard Emmelhainz, "Conditions of Visuality under the Anthropocene and Images of the Anthropocene to Come," *e-flux* 63 (March 2015), http://www.e-flux.com/journal/63/60882/conditions-of-visuality-under-the-anthropocene-and-images-of-the-anthropocene-to-come/. From the perspective of our book, the experimental film practices discussed in her essay—such as North American structural film in the 1960s and 1970s, dealing with forms of vision beyond a humanist-centered view—can be expanded to embrace larger circuits and scales of time and duration, which can even be taken as bioinfrastructure, even social, architectural, and media formations beyond solarity. From this expanded perspective, Emmelhainz's suggestion of reading anew Jean-Luc Goddard's prompt to understanding images as entities aiming not to show, know, or possess, but

as embodying a desire to see, emerges as an environmentally sound statement. On media formations beyond solarity, see Puig de la Bellacasa, *Matters of Care: Speculative Ethics in More than Human Worlds* (Minneapolis, MN: University of Minnesota Press, 2017); Nicole Starosielski, "Beyond the Sun: Embedded Solarities and Agricultural Practice," *South Atlantic Quarterly* 120, no. 1 (2021): 13–24. On plants as dead labor, see Nadia Bozak, *The Cinematic Footprint: Lights, Camera, Natural Resources* (New Brunswick, NJ: Rutgers University Press, 2012); Luce Lebart, "La photographie d'origine végétale," in *Puissance du végétal et cinéma animiste: La vitalité révélée par la technique*, ed. Teresa Castro, Perig Pitrou, and Marie Rebecchi (Paris: Les Presses du Réel, 2020), 119–127.

90. Walter Benjamin, *The Arcades Project*, trans. Howard Eiland and Kevin McLaughlin (Cambridge, MA: Belknap Press of Harvard University Press, 1996), 390 (Kla, 3).

91. The original quote is "the world and its potential for becoming are recursively remade in each meeting"; Karen Barad, *Meeting the Universe Halfway: Quantum Physics and the Entanglement of Matter and Meaning* (Durham, NC: Duke University Press, 2007), x.

92. Barad, *Meeting the Universe Halfway*, 153.

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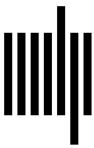

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