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El Niño and the human-environment nexus: Drought and vulnerability in Singapore 1877-1911

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CHAPTER 8

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The historiography of the Indian Ocean World (IOW) has long reflected how climatic forces have shaped the region's civilisations and economies. As Philip Gooding rightly notes in the introduction to this volume, these

[1] Sunil Amrith, *Unruly Waters: How Mountain Rivers and Monsoons have Shaped South Asia's History* (London: Penguin, 2018); Edward A. Alpers, *The Indian Ocean in World History* (Oxford: Oxford University Press, 2014); Peter Boomgaard, *A World of Water: Rain, Rivers and Seas in Southeast Asian Histories* (Singapore: NUS Press, 2007); Richard Hall and John Stravinsky, *Empires of the Monsoon: A History of the Indian Ocean and its Invaders* (London: Harper Collins, 1996); K.N. Chaudhuri, *Trade and Civilisation in the Indian Ocean: An Economic History from the Rise of Islam to 1750* (Cambridge: Cambridge University Press, 1985).

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begin with histories of monsoon and trade interaction before moving towards environmental and atmospheric histories of the IOW.[1] However, such readings have not (or are not), necessarily conveying how shorter-term or multi-scale climatic fluctuations may have impacted society, environment, or culture beyond perhaps some scholarship undertaken on extreme events.[2] Yet, recent science has shown that many atmospheric phenomena—such as the monsoon, one of the most complex atmospheric mechanisms to affect the IOW—are not stable.[3] What this modern awareness brings is a greater appreciation of the impacts of atmospheric dynamics on society and culture at different stages of our past, which includes (with direct relevance for our purposes here) the periods of variation and amplitude in the tropical Pacific and El Niño Southern Oscillation (ENSO).[4]

In the late 1990s and early 2000s, climatic and environmental histories of the IOW began to be read through socio-cultural perspectives on impact and change.[5] Championed by geographers as well as historians—Mike Hulme one of the best known of the former—such readings have helped form a deeper appreciation of climatic factors that have influenced past societies.[6] Concurrently, advances in historical climatology and in the recovery of weather narratives and climatic data for the region have

[2] Greg Bankoff and Joseph Christensen (eds.), *Natural Hazards and Peoples in the Indian Ocean World: Bordering on Danger* (New York: Palgrave Macmillan, 2016); James F. Warren, 'Weather, History and Empire: The Typhoon Factor and the Manila Galleon Trade, 1565–1815,' in *Anthony Reid and the Study of the Southeast Asian Past*, eds. Geoff Wade and Li Tana (Singapore: Institute of Southeast Asian Studies, 2012), 183–220.

[3] Yen Li Loo, Lawal Billa, and Ajit Singh, 'Effect of Climate Change on Seasonal Monsoon in Asia and Its Impact on the Variability of Monsoon Rainfall in Southeast Asia,' *Geoscience Frontiers*, 6, 6 (2015), 817–23.

[4] Rosanne D'Arrigo, Edward R. Cook, Rob J. Wilson, Rob Allan, and Michael E. Mann, 'On the Variability of ENSO Over the Past Six Centuries,' *Geophysical Research Letters*, 32, L03711 (2005), 1–4; Michael E. Mann, R.S. Bradley, and M.K. Hughes, 'Long-term Variability in the ENSO and Associated Teleconnections,' in *ENSO: Multiscale Variability and Global and Regional Impacts*, eds. H.E. Diaz and V. Markgraf (Cambridge: Cambridge University Press, 2000), 357–412.

[5] Dipesh Chakrabarty, 'The Climate of History: Four Theses,' *Critical Inquiry*, 35, 2 (2009), 197–222; Richard Grove, *Ecology, Climate and Empire: Colonialism and Global Environmental History, 1400–1940* (Cambridge: White Horse Press, 1997); Richard Grove and J. Chappell, *El Nino: History and Crisis: Studies from the Asia–Pacific Region* (Cambridge: White Horse Press, 2000).

[6] Mike Hulme, *Weathered: Cultures of Climate* (London: Sage, 2017).

enabled historians to better integrate scientific data into their work. This has enabled a deeper understanding of the global teleconnections that created shared experiences across time and space. For example, it is now commonly understood that fluctuations in precipitation are connected to ENSO phases, the Madden–Julian Oscillation (MJO), the Indian Ocean Dipole (IOD) and Pacific Decadal Variability as much as seasonal cycles and monsoon systems.[7] During El Niño events, for instance, tropical warming displaces major rainfall-producing systems and interacts with the Indo-Asian monsoon.[8] As the Asian monsoon system affects more than half the world's population, fluctuation and uncertainty have major potential to affect historical human experiences. Climate can thus be conceptualised as an aspect of *habitus*, assimilated into the totality of learned behaviours and intrinsic to the organising, unconscious structures governing the rhythms of everyday life.

While scientists grapple with the intricacies of understanding ENSO or IOD stability (especially as we further complicate things with Anthropogenic climate change), historians can see how these forcings have shaped our past. The 1860s–1920s, for example, saw particularly strong ENSO fluctuations and teleconnections across vast regions.[9] This brought unusually strong weathers resulting in floods, droughts and famines in places as far afield as India, America, England, Africa, Brazil, Australia and Russia, with population displacement and millions of deaths globally.[10] The fundamentality of climate in affecting lives and transforming environments, especially for those in developing worlds or with predominantly rural economies, should thus not be underestimated. Climate reaches across national borders and political structures, binding disparate cultures in shared experiences that transcend nationhood. As a frame through which to view the past, therefore, a climatic perspective can

[7] Edward R. Cook, Kevin J. Anchukaitis, Brendan M. Buckley, Rosanne D. D'Arrigo, Gordon C. Jacoby, and William E. Wright, 'Asian Monsoon Failure and Megadrought During the Last Millennium,' *Science*, 328, 5977 (2010), 486.

[8] Allan, 'ENSO and Climatic Variability,' 4–5.

[9] Rob Allan, 'ENSO and Climatic Variability in the Past 150 Years,' in *ENSO: Multiscale Variability*, eds. Diaz and Markgraf, 3–55.

[10] Ibid., 36–41. For an overview, see: Mike Davis, *Late Victorian Holocausts: El Niño famines and the Making of the Third World* (London: Verso, 2001).

offer a supplementary methodological approach to global or connected history.[11]

This chapter brings a climatic perspective to Singaporean history by exploring the El Niño inspired droughts of 1877, 1902 and 1911. Located within the shifting perimeters of the humid Intertropical Convergence Zone (ITCZ), where trade winds from the northern and southern hemispheres meet, Singapore's normative climate is tropical with high humidity and ample rainfall. When warmer than normal waters develop over the Eastern Tropical Pacific along the coastal regions of South America, however, the trade winds become weaker and the El Niño comes to Southeast Asia. Each of 1877, 1902 and 1911 has been identified by scientists as having experienced strong El Niño events globally[12]; most likely as part of protracted episodes.[13] The significance of protracted events is not simply the duration but the potential for stronger impacts than the 'classical' El Niño event.[14] This was certainly the case in Singapore, when the town experienced some of its worst known droughts since the British had established a settlement in 1819.[15] Scientific studies that have recreated El Niño through evidence from Sea Surface Temperature (SST), Niño-3 and Niño-3.4 indices, the Southern Oscillation Index (SOI) or drought indices have often focussed on the 1877 event as one of the strongest to have occurred in the instrumental record period.[16]

[11] Sanjay Subrahmanyam, 'Connected Histories: Notes Towards a Reconfiguration of Early Modern Eurasia,' *Modern Asian Studies*, 31, 3 (1997), 735–62.

[12] Joëlle L. Gergis and Anthony M. Fowler, 'A History of ENSO Events Since AD 1525: Implications for Future Climate Change,' *Climatic Change*, 92, 3–4 (2009), 368; W.H. Quinn, D.O. Zoff, K.S. Short, and R.T.W. Kuo Yang, 'Historical Trends and Statistics of the Southern Oscillation, El Nino, and Indonesian droughts,' *Fishery Bulletin*, 76, 2 (1978), 672–3.

[13] Gergis and Fowler, 'ENSO Events,' 375.

[14] Robert J. Allan, Joëlle Gergis, and Rosanne D'Arrigo, 'Placing the AD 2014–2016 "Protracted" El Niño into a Long-term Term Context,' *The Holocene*, 30, 1 (2020), 103.

[15] A drought is today defined as more than 15 consecutive days with less than 1 mm of rainfall registered at a climate station.

[16] A small sample of this extensive literature includes: Boyin Huang, Michelle L'Heureux, Zeng-Zhen Hu, Xungang Yin, and Huai-Min Zhang, 'How Significant was the 1877/78 El Nino?,' *Journal of Climate*, 33, 11 (2020), 4855; Deepti Singh, Richard Seager, Benjamin I. Cook, Mark Cane, Mingfang Ting, Edward Cook, and Mike Davis, 'Climate and the Global Famine of 1876–78,' *Journal of Climate*, 31, 23, (2018), 9445–67; J.M. Lough, K.D. Anderson, and T.P. Hughes, 'Increasing Thermal Stress for Tropical Coral Reefs: 1871–2017,' *Scientific Reports*, 8, 6079 (2018), 1–8; Patricio

Yet, this article contends that while the 1877 event was indeed incredibly severe, the *impacts* of the event on Singapore were not necessarily worse than those resulting from the slightly weaker events that took place in 1902 and in 1911 especially. There is a huge literature that explores vulnerability across the social and physical sciences and humanities from which this chapter draws, especially that which uses history as a way into exploring relationships of vulnerability and resilience.[17] These factors are the crux of the argument, which shows how human action created the circumstances that led to disaster, over and above the weather. Thus, this chapter will look to the ground, as well as to the atmosphere, to unpack the nexus of nature-inspired versus human-induced vulnerability to drought within the context of colonial urbanisation in this port town.

While the main narrative focuses on Singapore, the town ought not to be considered in isolation. Malaya, neighbouring Borneo, and Indonesia suffered during each of these events and Singapore was not immune to the fluctuations affecting the regionally interlinked economies, especially in the realm of staple food security.[18] In addition, the droughts inspired new scientific questions at regional and even global scales, as a wealth of evidence became available due to the increasingly connected nature of scientific institutions, scientific literature, and communications systems across the colonial IOW and the globe. By exploring Singapore through these three droughts, this chapter aims to connect with the others in

Aceituno, Maríadel del Rosario Prieto, María Eugenia Solari, Alejandra Martínez, Germán Poveda, and Mark Falvey, 'The 1877–1878 El Niño Episode: Associated Impacts in South America,' *Climatic Change*, 92 (2009), 389–416; C.F. Ropelewski and P.D. Jones, 'An Extension of the Tahiti-Darwin Southern Oscillation Index,' *Monthly Weather Review*, 115 (1987), 2161–65.

17 Paul Erdkamp, Joseph G. Manning, and Koenraad Verboven (eds.), *Climate Change and Ancient Societies in Europe and the Near East: Diversity in Collapse and Resilience* (Cham, CH: Palgrave Macmillan, 2020); Robert Wasson, Arupjyoti Saikia, Priya Bansal, and Chong Joon Chuah, 'Flood Mitigation, Climate Change Adaption, and Technological Lock-in in Assam,' *Ecology, Economy and Society—The INSEE Journal*, 3, 2 (2020), 83–1–4; I. Kelman, J.C. Gaillard, James Lewis, and Jessica Mercer, 'Learning from the History of Disaster: Vulnerability and Resilience Research and Practice for Climate Change,' *Natural Hazards*, 82 (2016), 129–43; Andrea Janku, Gerrit J. Schenk, and Franz Mauelshagen, (eds.), *Historical Disasters in Context: Science, Religion and Politics* (New York: Routledge, 2012); Uwe Lübken and Christof Mauch, 'Uncertain Environments: Natural Hazards, Risk and Insurance in Historical Perspective,' *Environment and History*, 17 (2011), 1–12.

18 'Sarawak,' *The Straits Times* (13 Oct. 1877), 2; 'Java News,' *Singapore Daily Times* (14 Dec. 1877), 3. See also: Chapters by Gooding and Ventura, this volume.

the collection to show how, despite the regional and national differences in governance and in culture of each site of exploration, the experience of climate-induced environmental disaster can provide a shared narrative across the IOW.

The sources used in reconstructing the events of 1877, 1902, and 1911 are varied and derive from many years of interdisciplinary archival research on the climatic history of Singapore and the Malaysian peninsula in the libraries and archives of Kuala Lumpur, Singapore, London, and Cambridge. They comprise a multiplicity of documentary evidence, of the history of meteorology and colonial science; weather records; official records on urban development and land-use change; hydraulic engineering and flood and drought mitigation; official medical statistics and narrative accounts of weather extremes, often to be found in the contemporary press. The weather records themselves are derived from what are commonly called the archives of societies, a term now frequently appropriated to explain observational weather records made by human hands, as opposed to the archives of nature (i.e., proxy records, such as tree-rings).[19] In the Straits Settlements, these are piecemeal for much of the nineteenth century and have had to be recovered and re-connected akin to a jigsaw puzzle, albeit one with significant gaps in the chronology and omissions in detail more useful to a climate scientist, such as exact locations or instruments used during their recording. The weather records are problematic in many ways, especially if we look for the precision required for scientific analysis, with question marks over the skill of the observer—often an amateur or a non-scientist in the pre-1880s period—and the quality of the instruments. By the period of this study, observations had been formalised under the Medical Department and the majority of the weather data used here is drawn from the main meteorological observatory at Kandang Kerbau Hospital, today the site of Singapore's Mass Rapid Transit (MRT) station 'Little India' on Tekka Lane. For a historian, the problem of precision is less significant but, of course, little can be understood of the human experience of drought from rainfall records. Hence the need to place the records in context with a range of sources from social, scientific, medical, and planning perspectives.

[19] Sam White, Christian Pfister, and Francis Mauelshagan, 'Archives of Nature and Archives of Societies,' in *The Palgrave Handbook of Climate History*, eds. Sam White, Christian Pfister, and Francis Mauelshagen (London: Palgrave Macmillan, 2018), 27–36.

Making Sense of the Human-Climate-Environment Nexus

Between 1819 and the First World War, three droughts stand out in Singapore's history: in 1877, 1902 and 1911.[20] Each event was inspired by the El Niño phase of the Southern Oscillation and compounded by factors on the ground, including socio-economic dislocation and municipal planning. The socio-economic narratives attending each event are discussed below and they suggest that although the 1877 event was the most severe, climatically speaking, the impacts in 1911 were in fact worse. Looking at the annual rainfall for each drought year for one main urban station at Kandang Kerbau Hospital—one of the few urban meteorological stations to have been in operation during each drought year—gives some insight into this. The annual total rainfall for each year reads at 65.14 ins (1629 mm) for 1877; 77.52 ins (1969 mm) for 1902; and 88.24 ins (2241 mm) for 1911 respectively. To put this into perspective, a modern average annual rainfall (1981–2010)[21] is just over 85 ins (2159 mm), thus only 1877 saw much lower rainfall overall than what might be considered normal. Drought severity maps generated by the Monsoon Asia Drought Atlas (MADA)[22] of reconstructed Palmer Drought Severity Index (PDSI) for 1877 and an instrumental PDSI for 1902 and 1911 also show 1877 to have been a more severe drought (Fig. 8.1).

However, annual rainfall figures can be misleading, the density and spread of rainfall across the year can be more significant. The 1911 drought began in February, with little respite until June when enough rain fell to allow the authorities to resume the normal 12-hour daily water supply.[23] But it reared its head again in July and did not tail off until November. The 1877 drought had seen a similar trajectory with the normal dry season extending across the inter-monsoonal period and, with the exception of a respite in mid-June, failure of the remaining July to

[20] 1819 was the year that East India Company representative Stamford Raffles negotiated a settlement treaty with Temenggong Abdul Rahman to establish a British settlement at Singapore.

[21] http://www.weather.gov.sg/climate-climate-of-singapore/ [Accessed: 15 Apr. 2021].

[22] Cook et al., 'Asian monsoon failure,' 486–9.

[23] Straits Settlements Government Gazette (hereafter: SSGG) Municipal Progress Report for May 1911 (28 July 1911), 1117.

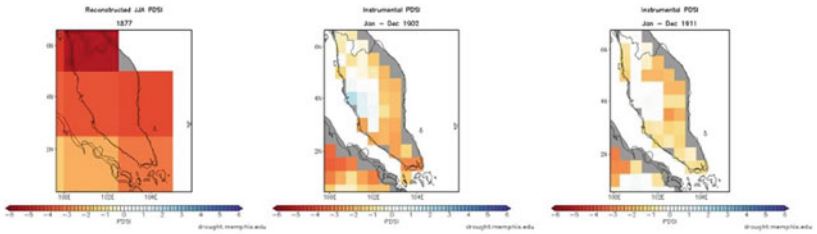

Fig. 8.1 Monsoon Asia Drought Atlas (MADA) reconstructed Palmer Drought Severity Index (PDSI) for 1877 and Instrumental PDSI for 1902 and 1911. http://www.weather.gov.sg/climate-climate-of-singapore/ [Accessed: 15 Apr. 2021]

September southwest monsoon.[24] The 1902 drought, however, only saw its driest periods at the end of the year in October and November, months that do not normally bring the heaviest monsoonal rains.[25] A modern study based on the Standardized Precipitation Evapotranspiration Index (SPEI) dataset is also useful for considering 1902 and 1911 together. This study took into account multi-scale characteristics (including intensity, duration and area) for the evaluation of different types of drought, and is often used for agricultural drought monitoring. While 1877 was not included in the study's scope, it did suggest that 1911 saw more widespread severe drought in Asia than 1902.[26] Building from this, drought is not considered a result of meteorological or atmospheric phenomena alone but a series of complex interactions that also encompass land use, changes to natural water storage and soil moisture, and human water management.[27] Current-day explanations of the causes of urban

[24] Annual Abstract of Meteorological Observations for Kandang Kerbau Hospital, Singapore, 1877.

[25] Annual Abstract of Meteorological Observations for Kandang Kerbau Hospital, Singapore, 1902.

[26] Qianfeng Wang, Jianjun Wu, Tianjie Lei, Bin He, Zhitao Wu, Ming Liu, Xinyu Mo, Guangpo Geng, Xiaohan Li, Hongkui Zhou, and Dachuan Liu, 'Temporal-spatial Characteristics of Severe Drought Events and Their Impact on Agriculture on a Global Scale,' *Quaternary International*, 349 (2014), 15. Data for 1877 are not available.

[27] Rudolf Brázdil, Andrea Kiss, Jürg Luterbacher, David J. Nash, and Ladislava Reznícková, 'Documentary Data and the Study of Past Droughts: A Global State of the Art,' *Climate of the Past*, 14 (2018), 1916.

vulnerability to drought, for example, explain how an amalgam of hydrological and environmental factors combine with demographic sensitivity and socio-economic adaptive capacities to impact the scale of a disaster.[28] Considering this when looking at the available information for each of our three past droughts, we can uncover several reasons why Singapore's 1911 event might have resulted in more extreme social stress than the previous two.

Each drought realised a burning need to improve the town's water supply. During the 1877 drought, urban inhabitants had largely relied on wells for their water supply; several of which had been built due to the philanthropic donation of Syed Ali Al Junied in the late 1840s and early 1850s.[29] Tanks at Fort Canning and at the port provided additional reserves for dry periods or for combatting fires, but they were still not sufficient for the population during times of stress. However, the town's population was still small, and some people had access to natural water sources. A new reservoir was under development and it was completed in the last month of the year, albeit not early enough to lessen the worst months of drought.[30] Going forward, however, the reservoir, though not without its limitations, did provide a twelve-hour daily piped water to different areas of the town and even some domestic and public buildings.[31] The following year, a further service reservoir was opened at Mount Emily, serving the eastern part of the town and another new facility opened in 1898 at Pearl's Hill (Fig. 8.2).[32]

By 1902, many domestic dwellings had a piped water supply, although many people also relied on standpipes and wells, the latter derived from

[28] C. Joon Chuah, Beatrice H. Ho, and Winston T.L. Chow, 'Trans-boundary Variations of Urban Drought Vulnerability and Its Impact on Water Resource Management in Singapore and Johor, Malaysia,' *Environmental Research Letters*, 13 (2018), 074, 011; Nick Brooks, W. Neil Adger, and P. Mick Kelly, 'The Determinants of Vulnerability and Adaptive Capacity at the National Level and the Implications for Adaptation,' *Global Environmental Change*, 15, 2 (2005), 151–63.

[29] C.B. Buckley, *An Anecdotal History of Old Times in Singapore* (Singapore: Fraser and Neave, 1902), II, 504, 547–8.

[30] Fiona Williamson, 'Responding to Extremes: Managing Urban Water Scarcity in the Late Nineteenth-century Straits Settlements,' *Water History*, 12, 3 (2020), 251–63.

[31] Brenda Yeoh, 'Urban Sanitation, Health and Water Supply in Late Nineteenth and Early Twentieth Century Colonial Singapore' *Southeast Asia Research*, 1, 2 (1993), 147.

[32] Brenda Yeoh, *Contesting Space in Colonial Singapore: Power Relations and the Urban Built Environment* (Singapore: NUS Press, 2003), 207.

Fig. 8.2 (Edited section of) Map of the Island of Singapore and its Dependencies, 1911, War Office (London), 1916. Courtesy of Bibliothèque nationale de France. Original digital map available at: http://catalogue.bnf.fr/ark:/12148/cb407342553 [Accessed: 15 Apr. 2021]

surface water. For example, a contemporary survey of 72 houses in China Street found that 25 per cent of houses still utilised well-water.[33] These were easily contaminated by high tides, floods, and droughts. The authorities recognised this and had closed more than 1904 wells between 1897 and 1901, but the problem was replacing these water sources with efficient and safe supplies. To put this into perspective, when in 1901 the municipality commissioned a survey of remaining wells within town limits, they found that out of 3877 wells, only 609 contained potable water.[34] As well as safety issues, the supply was rapidly falling behind demand.

[33] *The Straits Times* (4 Sep. 1902), 4.

[34] Cited in: James F. Warren, *Rickshaw Coolie: A People's History of Singapore, 1880–1940* (Singapore: Singapore University Press, 2003), 261.

In 1900, the Municipal Engineer had already warned that an increase of 1.5 million gallons per day would be required—up from the current 4 million—over the next decade.[35] In response, a new scheme was created and implemented in phases across the first decade of the new century. Its two main elements were to channel water from the Kallang River watershed and to build a new reservoir, the latter designed by the Municipal Engineer Robert Peirce. This, when completed in 1910, was expected to increase capacity by 3.5 million gallons daily.[36]

In 1911 then, it might be assumed that these schemes would have created a more resilient Singapore. This was not the case. In the nine years between 1902 and 1911—the period during which proposals for the new supply had been enacted—residents had increased by more than 60,000, far more than had been anticipated. This necessitated the creation of new suburbs which demanded in turn new pipelines and water capacity. Newly reclaimed land on the coast had not yet been fully outfitted with an efficient supply.[37] Consumption had also been driven up by commercial expansion, with the newly developed Keppel Docks (then known as New Harbour and fully completed in 1886) piling pressure on the existing water supply. Between 1901 and 1911, water usage had increased from 4.5 million to 5.9 million gallons (slightly over the Municipal Engineer's original estimate), but the worst problem was that the 5.9 million figure was unrepresentative of actual need: the supply was kept deliberately low due to a gap between supply and demand.[38] Hence why, when the rains failed in 1911, the town reserves were not sufficient for the purpose. At the same time, the proposed Kallang River Water works, though partially operational during the 1911 drought, were not fully completed until March 1912. Ironically, work on the scheme actually had to be suspended during the 1902 drought because the water supply failed and the future of the development—which took a further ten years to complete—was in doubt for a period of time due to unexpected costs.[39] This brings

[35] SSGG, Administrative Report of the Singapore Municipality 1901, Appendix M: Minutes by the Municipal Engineer, 28 Nov. 1900.

[36] Yeoh, 'Urban Sanitation,' 149.

[37] Lim Tin Seng, 'Land from Sand: Singapore's Reclamation Story,' *BibioAsia*, 13, 1 (2017), 16–23.

[38] 'Singapore's Water,' *The Straits Times* (27 Mar. 1912), 7.

[39] 'Municipal Commission,' *The Straits Times* (22 Nov. 1902), 5.

us to another key issue: cost. Improvement and extension schemes were immensely expensive, and the structural alterations required to adapt domestic dwellings to piped water were complicated as well as costly. There was also an issue as to from where water should be ascertained in the first place on an island with limited natural fresh water supplies. The clearest possibility—to syphon water from nearby Johore on the mainland peninsula—was a major political, engineering, and financial headache for the Straits Settlements' governors.[40] With deficits in civic improvement and rapid in-migration the norm, municipal authorities had failed to cater even for 'normal' conditions.

Big Picture, Local Impacts: The Socio-Economic Effects of El Niño

This brings us to the second issue, of the level socio-economic adaptive capacity within the town. By the time of the first major drought, in 1877, the port of Singapore was the administrative centre of the Straits Settlements and had developed into a bustling township of around 96,000 inhabitants driven by an influx of (mostly male) migrant labour.[41] Coming out of the customary February dry period with little rain in view, by mid-April 1877 inhabitants were beginning to worry. 'The scarcity of water is now most keenly felt throughout the whole town' claimed one newspaper columnist, and the little that was left was increasingly dirty and undrinkable.[42] This does not come as a surprise when we realise that in 1877, most inhabitants relied on an antiquated system of wells, tanks, and small reservoirs situated in and around the town centre for their water, despite some investment in improving the clean water infrastructure by the municipal government.[43] Piped water to domestic dwellings was a privilege only for the wealthy, and the system of ceramic underground piping for water and for drainage—then commonplace in many

[40] National Archives, Kew, London (TNA, UK) CO273/309, Despatch 266, Straits Settlements, Anderson to Lyttelton, 20 June 1905.

[41] Swee-Hock Saw, 'Population Trends in Singapore, 1819–1967,' *Journal of Southeast Asian History*, 10, 1 (1969), 41.

[42] *Straits Times Overland Journal* (19 Apr. 1877), 11.

[43] Yeoh, *Contesting Space*, 175–212; Yeoh, 'Urban Sanitation,' 143–72.

British cities—had not been adopted in the Straits Settlements.[44] Indeed, it was not long before cholera was being reported in many of the poorer suburbs and *kampong* (villages) across Singapore and other towns on the peninsula—including Georgetown and Malacca—although reports were confused and contradictory. The press noted several anonymous sources that claimed at least twenty deaths a day amongst indigent Singapore 'natives,'[45] yet they were not being reported officially 'on account of the trouble it would get them into.'[46] Others refuted this news as an exaggeration, quoting government figures of 28 deaths in 24 days and even blaming non-European communities for their own illness, citing their apparent choice of contaminated well-water over and above the government sanctioned water available at the Municipal standpipes.[47]

This blame narrative surfaced again in October when eight cholera afflicted Chinese labourers living in shared quarters on River Valley Road were hospitalised and there was an outbreak at the Chinese Immigration depot.[48] It is difficult to assess the reality of the situation, however, with statistics of cholera cases and deaths hard to come by. The annual medical report—though detailed in many ways—does not list cholera as a separate category, only mentioning it specifically if there had been unusual epidemic outbreaks, and there was a particular lack of detail for 1877.[49] On the other hand, a poor state of public health in general was noted, especially amongst the poorest inhabitants and prison inmates. The 1877 Criminal Prison Report, for instance, stated how the health of incoming prisoners was not as good as normal, citing want and disease induced by the long drought as the chief cause.[50] This is corroborated by complaints

[44] Warren, *Rickshaw Coolie*, 262.

[45] Anon, 'News of the Fortnight,' *Straits Times Overland Journal* (28 Apr. 1877), 7; Nemo, 'Variorum,' *The Straits Times* (28 Apr. 1877), 4.

[46] Anon, 'Tuesday 1 May,' *The Straits Times* (5 May 1877).

[47] Warning Voice, 'Cholera,' *The Straits Times* (14 Apr. 1877), 4; Anon, 'Fortnight's Summary,' *Straits Times Overland Journal* (28 Apr. 1877), 1.

[48] *Straits Times Overland Journal* (18 Oct. 1877), 17.

[49] The limited reports for 1877 might be attributed to the illness and absence of Principle Chief Medical Officer (PCMO) for the Straits Settlements, H. L. Randall, during May and June, his role not filled until Acting PCMO Thomas Irvine Rowell took over on 1 July.

[50] W.R. Gray, 'Criminal Prison Report 1877,' published in: *Singapore Daily Times* (9 July 1878), 3.

by local inhabitants about drought-induced brackish drains, foul smells, dried-up watercourses, and the unbearable 'great heat.'[51] Singapore was not a healthy place to be in 1877.

Disease and poor public health were also serious preoccupations during the droughts of 1902 and 1911, despite the more ready availability of piped water by the early twentieth century. In 1902, Singapore's population had risen significantly to 581,219 and the annual medical report reveals that these inhabitants' health was generally poor. The number of smallpox cases had been high (though not as high as in Penang) and cholera was exceptionally bad with 842 cases, of which 759 had proved fatal.[52] In 1911, smallpox and malaria both saw a spike over June and July, with cholera alone resulting in 479 hospital admissions and 340 deaths.[53] Although lower than 1902, the number of admissions represented a twofold increase in cases from 1901, leading contemporaries to ponder a connection between the drought and waterborne disease.[54]

Impacts also manifested in the costs of piped water and of food. During 1877, the cost of water rose to 5 cents a bucket, causing 'much distress in consequence amongst the poor,' and in 1902, the increased availability of domestic piped water had hastened the introduction of water metres to prevent wastage—the cost of installation and maintenance chargeable to residents.[55] In terms of food, Singapore was not self-sustainable. While vegetables, pork, and chicken were grown or reared locally, plantation farming across the island was mostly for commercial export, dominated by sugar, coconut, and gambier, the latter used in medicines, dyeing, and tanning. These crops were increasingly phased out in the twentieth century as rubber and pineapple took over plantation capacities. The island relied on the mainland peninsula for rice

[51] Anon, 'The Stamford Road Stream,' *Straits Times Overland Journal* (12 May 1877), 9; Anon, 'Victoria Street Drain,' *Straits Times Overland Journal* (21 July 1877), 9.

[52] Wellcome Trust (hereafter WT): WA28.JM2 S89 1902–7, *The Straits Settlements Medical Report for 1902*, 1.

[53] SSGG Hospitals Report 1911; Hospitals Return Annex Z17. Given the propensity for many inhabitants to avoid hospital, one might assume that the actual numbers of cases were higher than reported.

[54] Anon, 'One Less Per Day,' *The Singapore Free Press and Mercantile Advertiser* (3 June 1911), 7.

[55] Buckley, *An Anecdotal History*, II, 737; Yeoh, 'Urban Sanitation,' 158; Anon, 'The Water Famine,' *Singapore Free Press and Mercantile Advertiser* (11 Sep. 1902).

and fruit, and on the region as a whole for rice; importing from China, Indonesia, Cambodia, Vietnam, Thailand, India, and Hong Kong.[56] The 1877 drought brought a temporary but massive shift from Thai suppliers to British Burmese sources in 1878 to manage the shortfall.[57] Likewise, in 1902, the shortfall was managed by shifting supply from Thailand and by now—Vietnam—to Burma.[58] The total value of imports and exports in general also decreased by 3.75 per cent and 1.75 per cent respectively in sterling. For merchandise, this equated to around a 10 per cent change in dollar value, as opposed to an approximate 1% change the previous year—the shift attributed to 'keenness of competition.'[59] Interestingly, one of the causes for this competition was cited as major conflagrations in Pontianak, Kalimantan and Surabaya, Java, which, while not attributed to dry conditions in the report, were areas also hard hit by drought.[60]

In 1911, imports of general merchandise likewise saw an increase in the cost of around 10 per cent from the previous year, with decreases in volume apparent in rice in particular. Homegrown rice harvests were limited, with only one district—at Beruas in Perak—securing a good yield. Exports declined in volume across several staples, with gambier, tapioca, and preserved pineapple all affected.[61] The press reported how, due to rice harvest failures in Thailand, the price of rice available locally had more than doubled, a fact that was expected to hit the 'coolie [labouring] classes' the most due to their reliance on rice as a staple food source.[62] The price increase was especially apparent in July, August, and September as the drought impacts really began to show. In other areas of the Straits Settlements to the north, the correspondent for Bukit Mertajam wrote

[56] SSGG 1877 Rice imports into Singapore 1876, 285.

[57] SSGG 1877 Appendix U11, 145; SSGG 1878 Appendix U17, 150.

[58] SSGG 1903 Report on trade 1902, Appendix, 27.

[59] SSGG 1903 Report on the trade of the Straits Settlements for the year 1902, Appendix, 25.

[60] S. Robert Aiken, 'Runaway Fires, Smoke-haze Pollution, and Unnatural Disasters in Indonesia,' *Geographical Review*, 94, 1 (2004), 60; 'Sourabaya revisited,' *The Straits Times* (25 Sep. 1902), 2.

[61] SSGG Oct. 1912, Trade 1911, Appendix, 12, 14, 16. It should be noted however that gambier and tapioca were already on a decline, with many estates brought over to the more profitable para rubber.

[62] 'Price of Rice,' *The Singapore Free Press and Mercantile Advertiser* (11 Sep. 1911), 4.

Table 8.1 Import and Export values of rice in Straits Dollars $ per picul before, during, and after each drought. This table summarises import and export costs and reveals the stark contrast with the years proceeding and after each drought

Year	*Import Prices per picul*	*Export Prices per picul*
1877	2.22	2.229
1878	2.77	3.21
1879	2.23	2.95
1902	4.13	4.44
1903	5.07	5.39
1904	4.03	4.37
1911	4.83	4.95
1912	5.57	6.01
1913	4.71	5.10

how, owing to the drought, many central Province Wellesley rice fields had dried up with an estimated 40% drop in output for the year. On top of this, the coconut crop was 50% less, and even para rubber did not escape the ravages of the drought.[63] Once again, the government turned to Burma to make up the shortfall (Table 8.1).

The droughts also showed up stark differences in social vulnerabilities, as poorer inhabitants struggled to manage this further assault on day-to-day living. Nineteenth and early twentieth-century Singapore presents a classic example of a highly stratified colonial society. Despite British dominance politically, in 1877 and 1911 the British and European population only made up 2% and 5% of the population respectively.[64] In terms of social class, society's most well-to-do (as judged by people of all origins who paid rates of more than 40 rupees) equated to only around 385 people in 1877.[65] While it is hard to tell exactly what the social stratification of the remaining population was, the arrival of around 200,000 immigrants annually by the early 1900s meant that the bulk of the population was comprised of refugees and *coolies*, the latter being skilled and unskilled labourers.[66] Not unsurprisingly, this created a situation where poverty characterised the circumstances for many inhabitants,

[63] *The Straits Times* (27 Jan. 1912), 9.

[64] TNA, UK CO277/11, f.109. Return of the population of Singapore (2 Apr. 1877); Saw, 'Population trends,' 41.

[65] SSGG 2 Nov. 1877, 741–3.

[66] W.J. Simpson, *Report on the Sanitary Condition of Singapore* (London: Waterlow, 1907), 6.

leaving large sections of the population vulnerable to the fluctuating prices of staple foodstuffs and water. With some irony, the less well-off also suffered the added burden of water rates levied for improving municipal water supplies while benefitting little from the better water that this provided.[67] That the municipal government knew of this was well-documented, though efforts to improve the status quo were slow and ineffective.[68]

Water shortages also exacerbated pre-existing social tensions. In 1877, for instance, Europeans criticised non-Europeans for using the heat as an excuse to get drunk rather than work, and tempers frayed as people wasted hours queuing under the burning sun to fill buckets of water at standpipes.[69] Officials reported that minor crimes had increased due to a 'general depression … occasioned by the long drought,' though the more likely explanation was increased poverty.[70] As the hours that the water supply was switched on dwindled, competition increased. In 1902, just as enforcement was being suggested to ensure that everyone had fair access to the supply, a violent fight involving stones, sticks, and buckets broke out between rival Chinese and Malay gangs at a hydrant at Victoria Bridge.[71] The authorities came down hard on the men after one of their number was hospitalised and they were arrested for rioting.[72] As the drought continued into October, police were frequently drafted in to guard the standpipes and the municipal government was put under pressure to re-open old wells that had previously been closed for reasons of health and safety. In most cases, the wells were deemed too insanitary to restore, but some inhabitants chose to take matters into their own hands, tearing down boards and coverings.[73] In 1911, the situation intensified. Violence erupted in dramatic fashion with four-hundred rickshaw coolies

[67] Warren, *Rickshaw Coolie,* 5, 261.

[68] *Straits Times Overland Journal* (19 Apr. 1877), 4.

[69] Nemo, 'Variorum,' *Singapore Daily Times* (2 May 1877), 3; 'The Water Supply,' *The Straits Times* (22 Dec. 1877), 6.

[70] SSGG, 5 July 1878, Medical Report for the Prisons, 1043.

[71] *The Straits Times* (30 Aug. 1902), 4; 'Water Famine,' *The Straits Times* (3 Sep. 1902), 5.

[72] 'The Water Famine,' *The Singapore Free Press and Mercantile Advertiser* (11 Sep. 1902), 164.

[73] *The Straits Times* (4 Sep. 1902), 4; 'Municipal Meeting,' *The Straits Times* (28 Feb. 1903), 5.

fighting over a standpipe in Queen's Street in March, lashing out at one another with sticks and staves.[74] Elsewhere on the peninsula, railway coolies went on strike as the water supply was only switched on for four hours a day, at exactly the same time as they were engaged in loading and unloading cargo at Port Swettenham.[75] Of course, it was not the richer inhabitants who had to queue for hours at the street standpipes. They had the luxury of piped water, or servants to collect water, and they had the resources to purchase the bottled water, which had become so popular in the early twentieth century.[76]

Local Impacts, Big Picture: Did Localised Calamity Help Inspire Scientific Change?

It is no coincidence that interest in meteorology—especially in rainfall—increased after 1877 in the Straits Settlements under the auspices of the Medical Department. The event had inspired renewed thinking about the causes of drought, linking the lack of rain to man-made environmental changes and deforestation on the peninsula. This fear led the local government to allocate large areas of rural Singapore as forest reserves in 1882.[77] Studies on the subject were undertaken by colonial officers in the medical and survey departments, many contributing to locally based journals of scientific interest, including the *Journal of the Indian Archipelago and Eastern Asia* and the *Journal of the Straits Branch of the Royal Asiatic Society*. Interest in establishing more, and better, weather records continued to grow, especially because of their relevance to agricultural productivity and for countering both surfeit and deficiency of

[74] 'Effects of the Weather,' *The Singapore Free Press and Mercantile Advertiser* (11 Mar. 1911), 7.

[75] *The Straits Times* (11 Sep. 1911), 6. With some irony, the regional impacts of the drought may have led to more coolies arriving in Singapore than normal just when the drought started in earnest, as they fled drought-related hardship (and political conflict) in other countries, especially China. See: *The Straits Times* (24 Mar. 1911), 6.

[76] *The Straits Times* (6 Sep. 1902), 4.

[77] SSGG, J.F.A. McNair, 'Report by the Colonial Engineer on the Timber Forests in the Malayan Peninsula, 21 June 1879' (3 Oct. 1879), 893–903; National Archives of Singapore (hereafter: NAS), Nathanial Cantley, 'Map of the Island of Singapore. Annexure to Report on the Forests of the Straits Settlements' (1882): Media image no. 20050000974-0093_TM000020_000028_TM.

water.[78] The two-pronged question of how frequent and how severe, was tantamount to drafting schemes for future urban water management policy.

Such thinking was also borne out of a regional and global trend towards increasing the number of long-term weather records made across the British empire, and to making simultaneous observational sets available across the colonies to study such phenomena. When the series of droughts occurred across large swathes of the globe from Brazil to Australia during 1876–1878, it was clear to many that the 'coincidence' could not be ignored.[79] Officers responsible for meteorology within the British Empire, such as Henry Blanford, head of the newly established Indian Meteorological Department (IMD), and Government Astronomers in Australia, including Charles Todd, had utilised synchronous time-series weather observations from different regional stations, as well as international news reports, to deduce that the 'condition of excessive pressure prevailed over not only the Indo-Malayan region and Eastern Australia, but also the greater part if not whole of Asia, probably the whole of Australia and the South Indian Ocean.'[80] Todd concluded that 'there can be little or no doubt that severe droughts occur as a rule simultaneously' referring to reports from India, Singapore and Batavia.[81] News of severe droughts from governmental reports and meteorological outposts from elsewhere across the wider region, including Africa, China, and the Philippines, also pointed to similar conclusions.

The sense that droughts—and thus climate—might be linked across wide areas grew over the ensuing decades. Correspondence between the

[78] C.C. James, *Drainage Problems of the East* (Bombay: Times of India Office, 1906), 224. This was also the case in other British colonies. After an especially severe drought in 1890–91, Hong Kong's Surveyor General requested the Hong Kong Observatory furnish a study of almost forty years of rainfall records to establish patterns for predicting potential future droughts.

[79] See also: Chapter by Gooding, this volume.

[80] Henry F. Blanford, 'On the Barometric See-saw between Russia and India in the Sunspot Cycle,' *Nature*, 21 (1880), 477.

[81] Charles Todd (with H.C. Russel and R.L.J. Ellery), 'The Meteorologist: Droughts in Australia,' *The Australasian* (29 Dec. 1888), 40. See also: Ruth Morgan, 'Prophecy and Prediction: Forecasting Drought and Famine in British India and the Australian Colonies,' *Global Environment*, 13, 1 (2020), 95–132; Richard Grove and George Adamson, *El Niño in World History* (Basingstoke: Palgrave, 2018).

British Association for the Advancement of Science (BAAS) and the Secretary of State for the Colonies in the early 1900s for instance, suggests that the scientific world was keen to invest time and resources into deeper analysis of the several decades long time-series observations. In particular, it was noted how such a study would yield dramatic economic benefits for the British lands of the IOW by enabling a better understanding of monsoon rainfall patterns.[82] Thus, in 1905, the BAAS requested that the British government provide a scientific staff specifically to study the:

> General meteorological conditions which affect the weather in the several British Dominions, and in particular to promote the formulation of meteorological laws, and to apply them to explain and ultimately to anticipate the occurrence of abnormal seasons.[83]

The proposed method was to unite and analyse instrumental records made at sea and on land across the whole IOW to investigate the meteorology of large oceanic areas in relation to their adjacent land mass; the underlying premise that the climatic conditions of India, Australia, South Africa, East Africa, and Egypt were closely related to the Indian Ocean. This, it was hoped, would result in better seasonal predictions and a greater understanding of the conditions generating favourable and unfavourable seasons in India, the droughts of Australia and South Africa, and the relation of the weather of the Mediterranean to Indian cold weather anomalies.[84] As Martin Mahony points out, however, many of these grand plans amounted to nought, as an official imperial meteorological office to co-ordinate these activities failed to materialise; the British

[82] Archive of the British Association for the Advancement of Science (hereafter ABAAS): Papers of Committees, 1896–1912, ff.225r-226r, 225r&v. 'Memorandum on a Proposal for Dealing with Meteorological Questions Affecting the British Dominions beyond the Seas,' 2 June 1905.

[83] ABAAS: Papers of Committees, 1896–1912, ff.223r-4v. 'Draft Memorandum, in further explanation of the proposal for dealing with Meteorology of the Colonies and Dependencies, for the Information of the Secretary of State,' 2 June 1905.

[84] Ibid, f.223v.

Meteorological Office and government relying instead on voluntary individual initiatives by enthusiasts, including some of the first unofficial gatherings of imperial meteorologists from 1909.[85]

In the Straits Settlements too, while scientific journals and reports on the matter were widely available in the colony, the emphasis was even less on thinking about regional atmospheric connections, than local concerns.[86] This may be because the colony did not have a dedicated meteorological service until 1929, in contrast to, say, India (1875) or Hong Kong (1884).[87] Neither did the Straits Settlements have a meteorological champion like Blanford or Todd. Government was largely preoccupied with statistical studies correlating local land-use change or public health with rainfall, not the bigger picture. Indeed, the idea that forest loss was a primary cause of drought dominated local scientific thought well into the twentieth century, and it became connected to the associated narrative of deforestation and soil erosion by the 1930s.[88] It was even considered by some that the long-term weather records were not well-made, as the colony lacked a specialist, trained staff.[89] Only a

[85] These gatherings were the forerunner of the Conference of Empire Meteorologists which became a formal entity in 1919 with the first meeting of the Conference of Meteorologists of British Dominions: Martin Mahony, 'For an Empire of 'All Types of Climate': Meteorology as an Imperial Science,' *Journal of Historical Geography*, 51 (2016), 32.

[86] An interesting article was published in Singapore in 1878, drawing connections between oceanic currents, weather, and global teleconnections. See: 'Extract from an American Paper,' *Singapore Daily Times* (16 Jan. 1878), 3. The colony also received copies of scientific journals and books. In 1911 alone, the Raffles Museums and Library received 100 new texts on subjects of scientific interest, some donated from worldwide museums and institutions including the Smithsonian Institution, Bureau of Science, Manila and the Geological Institute, Mexico: Supplement to the SSGG 23 February 1912, No. 4., 'Annual Report on the Raffles Museum and Library for the Year 1911,' 3.

[87] NAK CO 273/541 ff.9r-13r 'Memorandum on a pamphlet entitled "A Meteorological Department for Malaya" by Sir George Maxwell and Herbert C. Robinson,' (1927), 3.

[88] 'Influence of Forests on Drought,' *The Singapore Free Press and Mercantile Advertiser* (13 Oct. 1911), 9. On soil erosion, see: Fiona Williamson, 'Malaya's "Greatest Menace"? Slow Onset Disasters and the Politics of the environment c. 1920–1950,' *International Review of Environmental History*, 4, 2 (2018), 45–68; ABAAS Sectional Transactions—E.E.P. Stebbing, 'The Encroaching Sahara: Increasing Aridity in West Africa,' Printed Material for the Annual Meetings held in Leicester, Aberdeen and Norwich, eds. O.J.R. Howarth, P.W. Jewson et al. (1935–36), 54.

[89] 'The Agricultural Bulletin,' *The Straits Times* (28 Sep. 1911), 6.

few lone voices bucked the trend, arguing for natural cycles that were bound to repeat and renew, or that sunspot activity might be the reason behind climatic variation.[90]

Conclusion

The Straits Settlements were something of an outlier in the British Empire's journey towards improving meteorological knowledge. Under-provisioned in comparison to Australia, India and Hong Kong, and relying on piecemeal services co-ordinated by the Medical Department, they lacked a dedicated research agenda or facility into the 1920s.[91] In some ways this reflects the British government's lackadaisical attitude towards the science prior to the First World War, which changed rapidly as the strategic and military applications of meteorology for aviation became clear. The situation in the Straits Settlements also reflected the British government's positioning on funding the colony for much of the nineteenth century, preferring the local municipal council to raise its own funds for grand schemes, or to rely on philanthropy, rather than granting loans for major works. The two strands connected in the lack of provision for science, as well as for water works. Arguably though, the lack of scientific knowledge about tropical climates within the ITCZ played a role in shaping these attitudes. It was generally considered that Singapore and the Malayan peninsula did not suffer extreme weathers and, while it was known that the peninsula had two monsoon seasons, they were considered mild in comparison to the rest of the IOW. Thus, the events of 1877 and beyond took the colony by surprise. Drought, and mitigation for drought, were little considered until the last decades of the nineteenth century, and likewise there was little pull to invest in weather science in a country that appeared to have generally abundant rainfall. Nonetheless, while the Straits Settlements lagged behind, arguably, the narrative and practical shift to understanding climate as a teleconnected system was slow elsewhere in British colonial Asia too. While pioneering research was

[90] 'Malacca,' *The Singapore Free Press and Mercantile Advertiser* (26 Mar. 1895), 10; A.M. Skinner, 'Straits Meteorology,' *Journal of the Straits Branch of the Royal Asiatic Society*, 12 (1883), 245–55.

[91] See also: Fiona Williamson, 'Weathering the British Empire: Meteorological Research in the Early Nineteenth-century Straits Settlements,' *The British Journal for the History of Science*, 48, 3 (2015), 475–92.

being undertaken—Henry Blanford and the slightly later IMD scientists, Rai Bahadur Hem Raj and Gilbert Walker, for example, developed ideas on natural variations in the climate system, sunspots, and relationships with Indian monsoon rainfall, and Edwin Quayle undertook work on climatic oscillation—but the nascent field of ENSO research was not fully developed until after the 1960s.[92]

While the study of climate science history provides many answers as to how contemporaries understood weather systems and their associated failures in properly predicting or adapting to local or regional atmospheric phenomena, a broad-brush historical study also provides a considerable methodological opportunity to illuminate and unpick the complex reasons underlying why a drought was so impactful. Indeed, here we see that weather was not the direct cause of the worst impacts, but certain failings of government to sufficiently prepare mitigation strategies and reserves, against a backdrop of severe social inequality. While it is certainly not new to study the climate in history, or the history of nature-induced disaster, this chapter has argued that a close reading of specific events through the lens of human-climatic-environmental interconnections and an understanding of the meteorology of each event, does enable a new avenue into the history of the IOW. First, the study of drought (or indeed flood or other disaster) allows for a different lens into the discussion of colonial science and the ways in which people conceptualised, understood, and responded to the world around them. As the discussion of Singapore suggests, such ideas fed directly into practical projects, such as new hydraulic schemes rather than scientific research, which allows insight into what the colonial government felt ought to be prioritised and why. Second, understanding the meteorology allows greater insight into the human role in creating disasters and, third, the study of a particular event enables insight into a far wider range of historical themes and how these respond directly or indirectly to climatic fluctuation. This includes urban planning, development and government responsiveness, socio-economic stress, resilience and social stratification, and intersections between climate

[92] George Adamson, 'Imperial Oscillations: Gilbert Walker and the Construction of the Southern Oscillation,' in *Weather, Climate and the Geographical Imagination: Placing Atmospheric Knowledges*, eds. Martin Mahony and Sam Randalls (Pittsburgh: University of Pittsburgh Press, 2020), 43–66; Ruth Morgan, 'Southern Skies: Australian Atmospheric Research and Global Climate Change,' *Disaster Prevention and Management,* 30, 1 (2021), 47–63.

and health, amongst others. Such studies are especially important in the IOW, given the macro-region's susceptibility to disaster and its intimate relationship with the vagaries of the monsoon. Arguably, useful lessons might be learned about social resilience and cascading disaster which go beyond climatic modelling or indeed social or political histories. Such an approach to the study of the IOW has the potential for shedding new light on the rich and multifaceted history of the region.

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