Local-scale urban climate and flood regulation within a Singapore city green-space: A case study of Bishan-Ang Mo Kio Park

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1. INTRODUCTION

Like most tropical, coastal cities, Singapore (1° N 104° E) has **high exposure** to climate extremes e.g. **sea level rise, flooding & droughts affecting water resources, and extreme heat & urban heat islands** (NCCS, 2015). Singapore's exposure is compounded by its rapid urbanisation; much of **its natural rainforest and mangrove environment has been converted to urban, built up area** housing its burgeoning population (1959 = 1.59 million; 2017 = 5.6 million).

The twin stressors of increased exposure to climate hazards and heightened demographic sensitivity, are detrimental to Singapore's vulnerability to climate change. However, **effective and integrated centralised planning** has been a major factor in both increasing its capacity to adapt, and minimising Singapore's overall climate vulnerability e.g. reduction of drought and flooding impacts on Singapore's water security (Tortajada et al., 2013).

This poster describes **a successful case study** of how a major and popular **urban park in Singapore enables effective urban climate and flood regulation to the benefit of adjacent residents and to visitors.**

2. CASE STUDY - BAMK

Located in Central Singapore within a major high-density residential area (258,000 residents over 21.5 km^2), Bishan – Ang Mo Kio Park (BAMK) is one of Singapore's largest urban parks (62 ha). It underwent **extensive redevelopment from 2009–2012** which cost S$76 (US$54) million (Fig 1 & 2); the major change being a canalised 2.7 km stretch of the Kallang River converted to a 3.2 km "natural" river floodplain through water-sensitive urban design techniques (e.g. soil bioengineering, cleansing biotopes, and vegetated swales). The additional **supporting and provisioning ecosystem services** arising from the naturalisation of the river also resulted in a 30% increase in species diversity within BAMK.

Fig. 1: BAMK in 2006 with canalised Kallang River (left); BAMK in 2012 with naturalised river (right)

QR Code above links to time-lapse video of transformation

The makeover was planned under the Public Utility Board's (PUB) **Active, Beautiful and Clean Waters (ABC) Programme** (PUB, 2014); a long-term initiative transforming local water bodies beyond their primary functions of drainage and water supply into vibrant, **new, multi-functional spaces** for **enhanced cultural ecosystem services** e.g. community bonding and recreation.

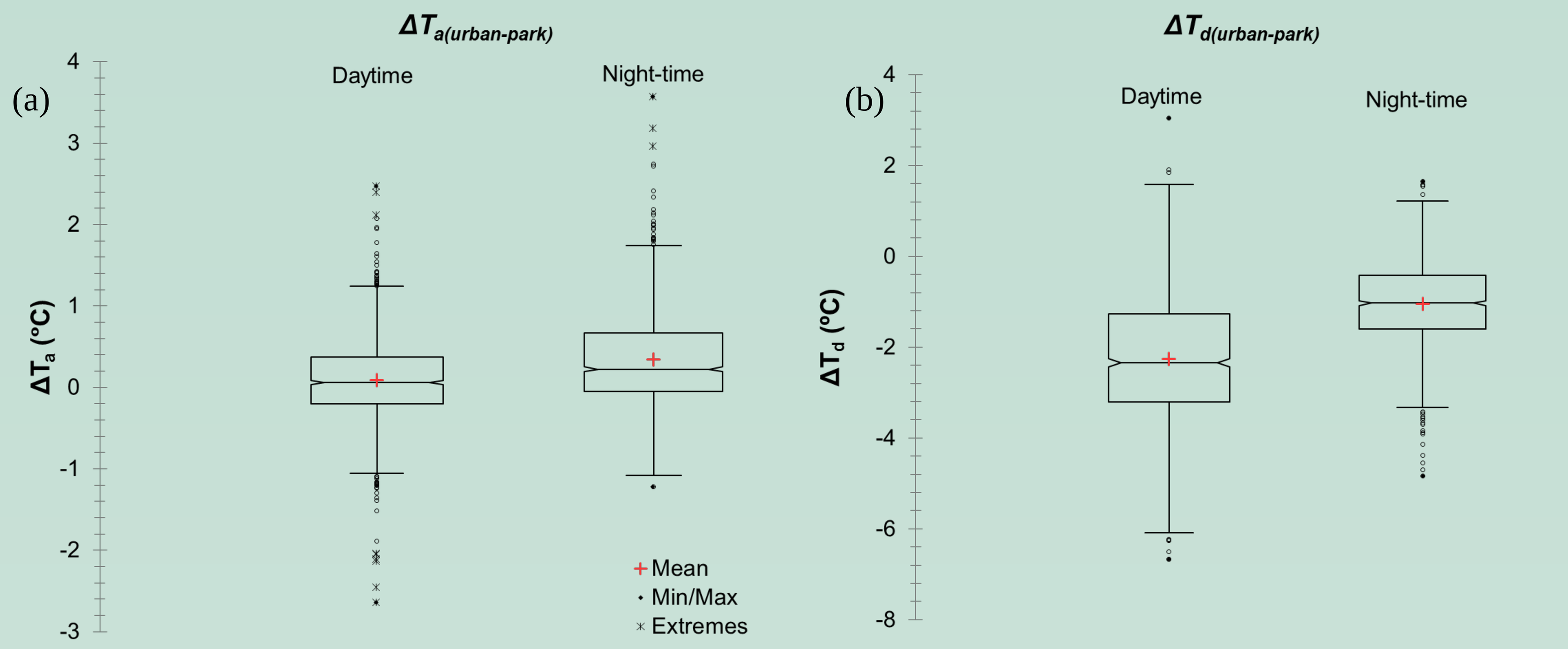
Fig. 2: Additional details of ABC programme applied to BAMK (Straits Times, 2012)

3. BAMK REGULATORY SERVICES

A measurement campaign over five months (Jul–Nov 2017) examined the **climate regulation** of BAMK vegetation relative to its "urban" surroundings. Six Onset Hobo U23 Pro T/RH sensor-loggers measuring air temperature and humidity were deployed throughout the park. "Urban" reference temperature and humidity were obtained at the Ang Mo Kio Automated Weather Station sited within a compact, high-rise residential area 4 km from BAMK, which is maintained by Singapore's Meteorological Services.

Generally, **increased vegetation in BAMK contributed to significantly lower nocturnal park temperatures** vs. daytime (Fig. 3a), with **mean (maximum) cooling of ~0.4 (~3.5) °C**. There was also a significant "**humidity island**" in BAMK, with a **urban moisture deficit (significantly larger during the day vs. night)** measured at the reference station with the park sensors (Fig. 3b).

Fig. 3: Box-plots of "urban" vs. park differences in hourly (a.) air and (b.) dew-point temperatures during BAMK measurement campaign. Notches in plots indicate 95% confidence intervals around median.



The naturalised river also **regulates local flood impacts arising from extreme rainfall** events, which have recently been more frequent and intense in Singapore (Chow et al., 2016). These **flash floods cause considerable economic damage when severe**; a 2010 event in Singapore resulted in insurance claims totalling S$23 million. The floodplain efficiently conveys run-off within its watershed, **minimising flooding risk along adjacent residential areas when heavy rain occurs** (Fig. 4). Despite the significant increase of documented flash floods in Singapore since 2000 (Fig. 5), **no reported floods or surface inundation were reported in the BAMK area since 2012** from either governmental or archived media sources.

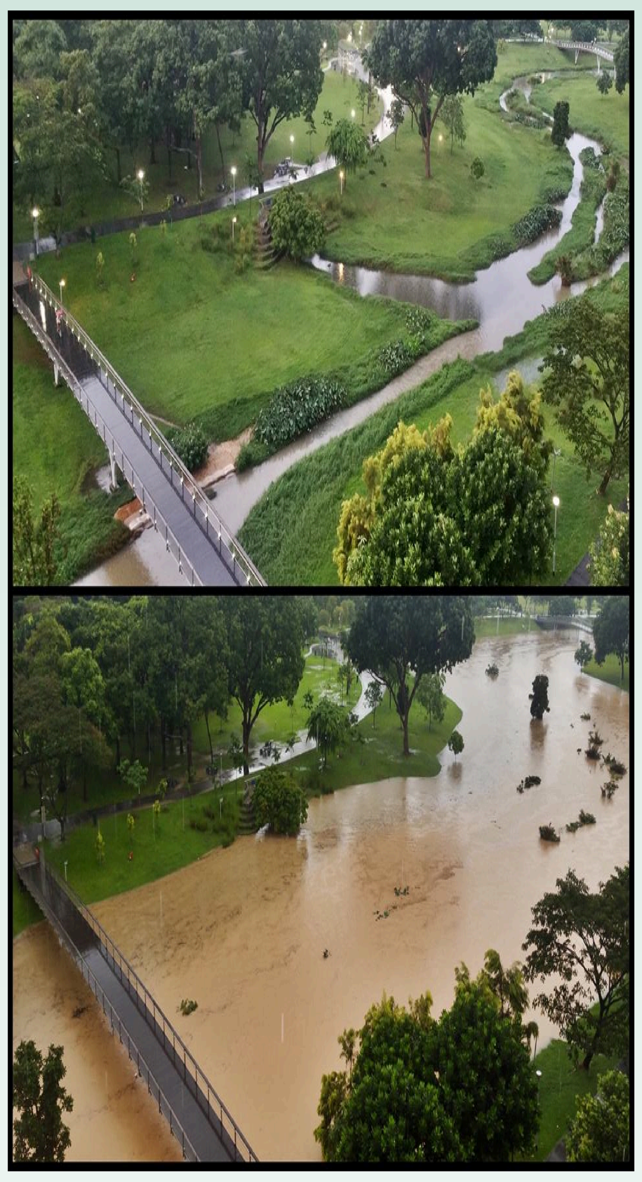
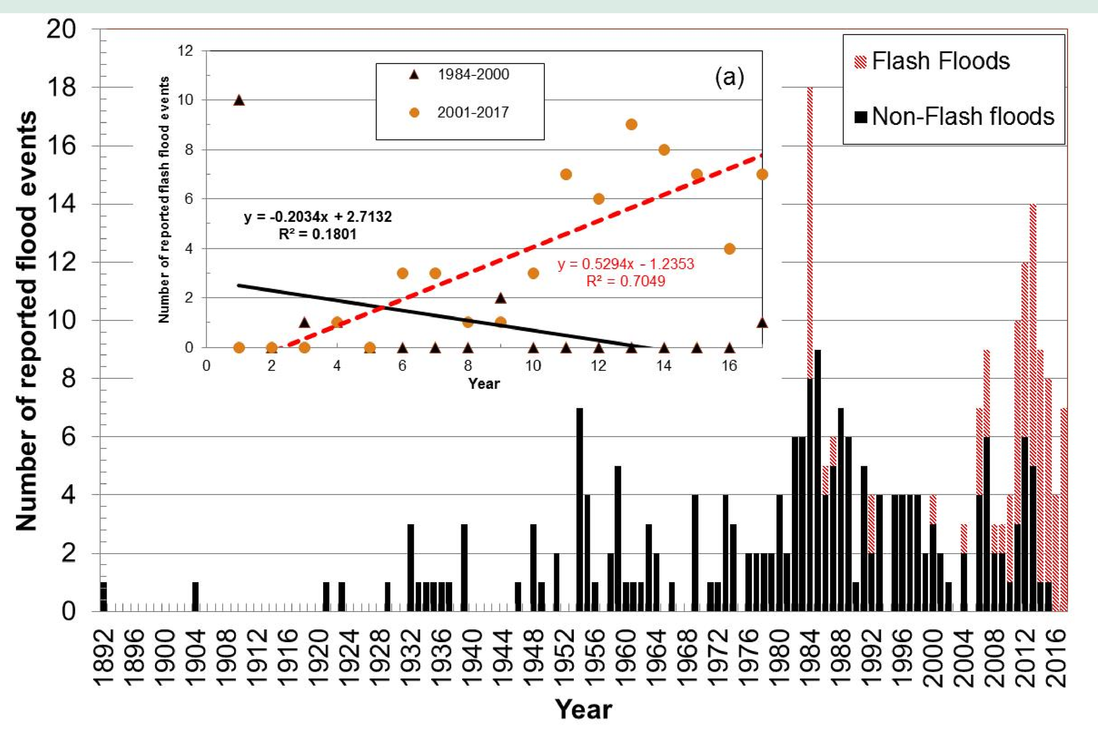


Fig. 4 (left) : "Normal" channel flow conditions in the Kallang River within BAMK (top) and flood conditions (bottom) during a heavy rain event. QR code on the left links to video of flood event on 13 Jul 2017

Fig. 5 (below) : Reported Singapore flood events via archival media reports from 1892–2016; insert (a) shows OLS linear trend of reported flash floods from 1984–2000 (black) and 2001–2016 (red dashed) (updated from Chow et al. 2016).



4. TAKE-HOME POINTS

Ahren (2011) notes several integrated strategies that urban planners and stakeholders in any city should consider applying when **maximising urban resilience to (climate) hazards**. BAMK's successful redevelopment exhibits aspects of these strategies that would be transferable across most (if not all) urban contexts:

- **Expanding the multi-functionality of spaces** (e.g. the combined climate and flood regulation of BAMK vegetation) and **maximizing the biodiversity and social diversity of adaptation development measures** (e.g. the variety of recreational spaces and increase in species diversity within BAMK);
- **Enhancing multi-scale networks and increasing system connectivity** (e.g. BAMK is an important component of a island-wide network of green corridors**), that spreads hazard risk through redundancy and modularisation** (e.g. effective flood control within BAMK reduces the 'levee' effect downstream)**;**
- **Anticipatory adaptive design and planning to account for imperfect knowledge** (BAMK was part of the ABC Programme that manages rainwater drainage along sources, pathways, and receptors to (a.) reduce flood risk and (b.) maximise water resources in the advent of adverse climate change).

5. REFERENCES

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