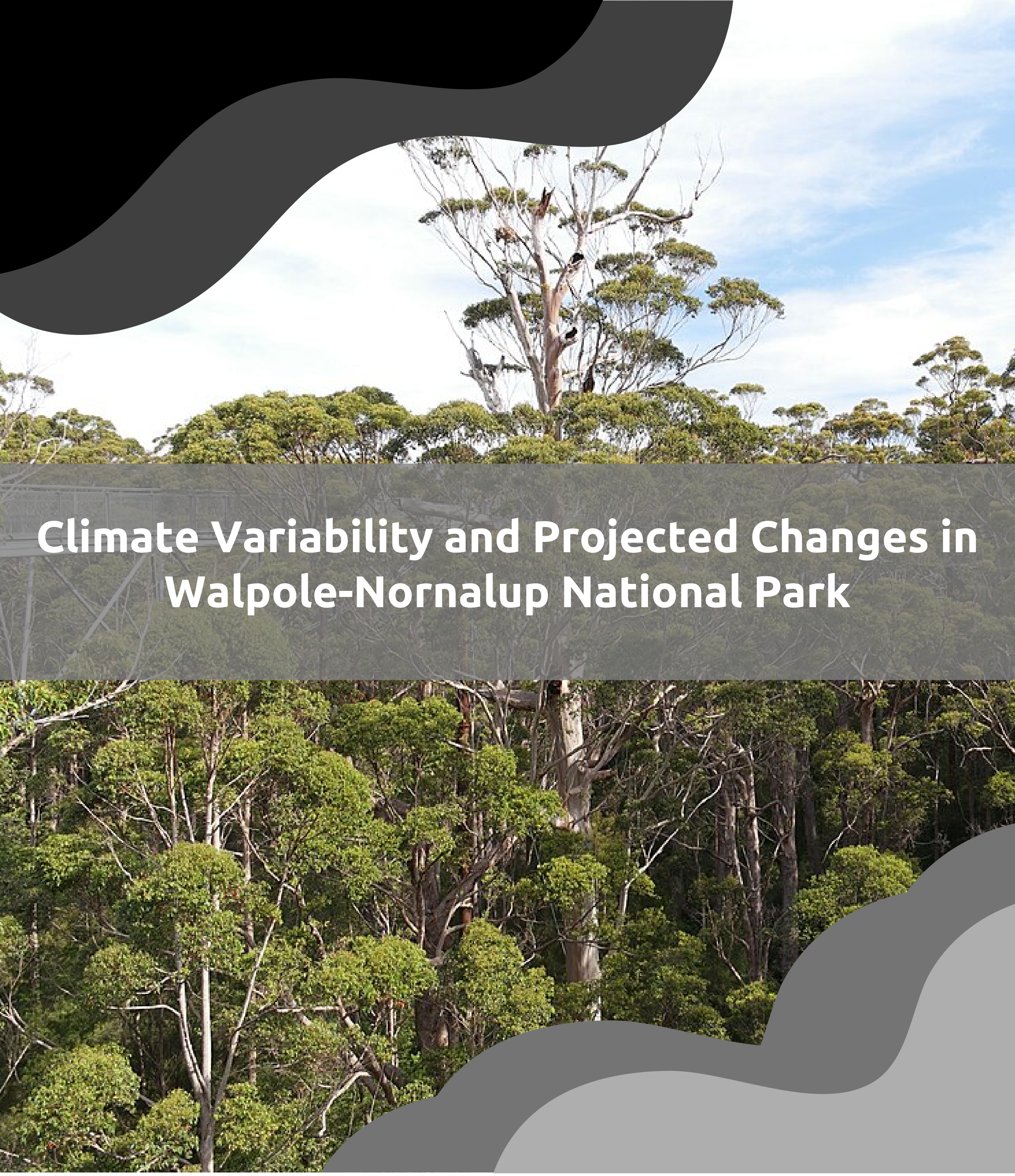

Climate Variability and Projected Changes in Walpole-Nornalup National Park

the climate centre

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Introduction

- Walpole-Nornalup National Park represents a small yet ecologically significant area of Western Australia (WA) that is becoming increasingly vulnerable to climate change. The park is an international biodiversity hotspot, designated as an IUCN category II national park, and the surrounding area has been inhabited for over 30,000 years by the Murrum of the Minang peoples of the Nyoongar group of Indigenous Australians (Shire of Manjimup, 2025).
- The park contains the world's largest-girthed (up to 20 metres in circumference) eucalypt species (Department of Parks and Wildlife, 2016), the red tingle tree (Eucalyptus jacksonii), which is endemic to the area, can live up to 400 years, and relies on stable climate conditions. It has evolved in relatively high humidity and rainfall conditions and also to cope with bush fires.
- The park contains high levels of biodiversity (Department of Biodiversity, Conservation and Attractions, 2023), including various species of tree such as karri (Eucalyptus diversicolor), jarrah (Eucalyptus marginata), marri (Corymbia calophylla), swamp paperbark (Melaleuca rhaphiophylla), red flowering gum (Corymbia ficifolia), bull banksia (Banksia grandis), yellow tingle (Eucalyptus guilfoylei) and Rate’s tingle (Eucalyptus brevistylis).
- The park is also home to quokkas (Setonix brachyurus), western grey kangaroo (Macropus fuliginosus) and western rosella (Platycercus icterotis), as well as a number of wildflowers, orchids, and trigger plants, as well as tree hovea (Hovea elliptica), the Albany pitcher plant (Cephalotus follicularis), tassel flower (Leucopogon verticillatus) and coral vine (Kennedia coccinea), many of which are endemic to the area.
- Although recognised for its outstanding beauty, highly specialised habitat, unique species and incredible biodiversity, this area is poorly studied. Located in the historically highest rainfall zone of WA, it contains a number of specialised habitats that act as refugia for species that are relics from ancient Gondwana times.
- Climate change has caused a substantial decrease in rainfall over the past few decades which has led to the decline or disappearance of some of these important relic species (Western Australian Community Impact Hub, 2021). This study examines historical climate trends and future projections for temperature, rainfall, and drying to understand long-term climate variability and anticipated changes to this sensitive conservation area.

Fig. 1 Habitats, fauna and flora found in the Walpole-Nornalup National Park include: Valley of the Giants (far left), red tingle tree (second from left), swamp paperbark (third from left), tassel flower (third from right), the quokka (second from right), and the Albany pitcher plant (far right).

Methods

- Three complementary datasets were used: SILO, ERA5 and CMIP6. SILO data sourced from the Climate Projections and Services team within the Queensland Treasury, based on Government of Australia Bureau of Meteorology weather data spanning 1889 to present was used for long-term historical analysis of observational data, with geospatial interpolation used where gaps exist. ERA5 reanalysis data from the European Centre for Medium-Range Weather Forecasts was used for 1940 to present, and CMIP6 model data for future projections was used through to 2100.
- Quantities investigated included ambient air temperature, rainfall, evapotranspiration (Morton's wet-environment areal potential evapotranspiration over land and FAO 65 Penman-Monteith evapotranspiration), humidity, and cloud cover. Not all quantities existed in all datasets, limiting comparisons that could be made.
- Daily and subdaily data was converted into annual data capturing annual minimum, mean, and maximum values, as well as the 25th to 75th percentile range of data values. Correlations were calculated using SciPy and differences in values over time were calculated using a linear regression unless otherwise stated.
- ERA5 and SILO datasets overlapped for the period 1940 to present, allowing assessment of the ability of the ERA5 reanalysis dataset at representing local conditions over historical timeframes.
- CMIP6, ERA5 and SILO datasets overlapped for the period 2015 to 2024, allowing assessment of the ability of CMIP6 models at predicting local conditions over short time scales (sub decadal to decadal).
- A variety of CMIP6 models were investigated using data for the SSP5-8.5 scenario, including: ACCESS, AWI, BCC, CAMS, CanESM5, CESM2, CMCC, CNRM, EC-Earth, FGOALS, GFDL, HadGEM3, IITM, INM, IPSL, KACE, KIOST, MIROC6, MPI, MRI, NESM3, NorESM2, TaiESM1 and UKESM.
- River flow data was sourced from the Government of Western Australia Department of Water and Environmental Regulation for the Frankland River Mount Frankland monitoring site, which collected data from 1952 to present on the total volumetric flow in megalitres.

Results

Air temperature

- SILO and ERA5 air temperature data was well-correlated over the period 1940 to 2024 (SciPy R^2 = 0.7835).
- Mean air temperature values and 25th to 75th percentile ranges were similar in both the ERA5 and SILO datasets, however maximum and minimum ERA5 values (Tmaxav 32.9°C and Tminav 6.5°C) were typically more extreme compared to those observed in the SILO dataset (Tmaxav 27.5°C and Tminav 8.2°C). Maximum values were overestimated by ERA5 more so than minimum values were underestimated when compared to SILO data (ΔTmaxav = 5.4°C compared to ΔTminav = 1.7°C).
- While SILO values from 1889 to 2024 showed a total increase of 0.2°C based on the rate of linear regression over time, more recent increases to the average annual air temperature meant the absolute change was 1.0°C.
- The number of days over 30°C per year increased at a rate of 1 extra day every 11.9 years.
- CMIP6 values from 2015 to 2100 showed an increase of 3.7°C.
- As shown below in Figure 2, mean CMIP6 values predicted between 2015 and 2024 were higher than mean observed values from SILO (17.0°C compared to 15.8°C), but were still within the 25th to 75th percentile range of SILO values (13.1°C to 18.1°C). Both the 25th to 75th percentile range (16.3°C to 17.8°C) and the maximum and minimum range (19.4°C to 14.6°C) of the CMIP6 models were within the observed values seen from SILO (27.4°C to 8.8°C). However, while the minimum, 25th percentile and mean values were higher in CMIP6 than in SILO (14.6°C, 16.3°C and 17.0°C compared to 8.8°C, 13.1°C and 15.8°C), the 75th and maximum values were lower than those observed in SILO (17.8°C and 19.4°C compared to 18.1°C and 27.4°C).

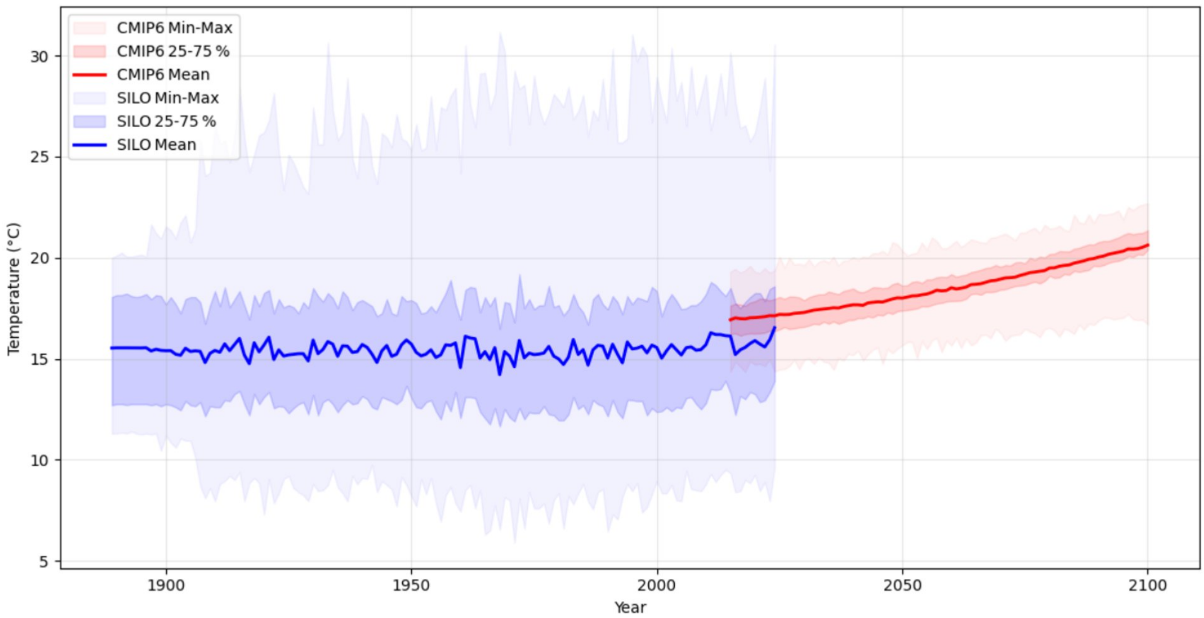

Fig 2. SILO and CMIP6 air temperature values from 1889 to 2100.

Rainfall

- SILO and ERA5 rainfall data was poorly correlated over the period 1940 to 2024 (SciPy $R^2 = 0.2816$).
- ERA5 mean values were lower than SILO mean values (1.8 mm compared to 3.2 mm), and ERA5 maximum values were also lower than SILO maximum values (30.3 mm compared to 49.2 mm), i.e. ERA5 typically underestimated the amount of rainfall compared to that observed in the SILO dataset.
- SILO values from 1889 to 2024 showed a total annual rainfall decrease of 2.1mm per year, representing an approximate total decrease in total annual rainfall of 285mm.
- The number of rainy days per year has decreased at a rate of 1 less rainy day every 2.8 years, based on SILO data.
- CMIP6 values from 2015 to 2100 showed a total annual rainfall decrease of 7.4mm per year, representing an approximate total decrease in total annual rainfall of 628mm.
- Mean CMIP6 values predicted between 2015 and 2024 (6.0 mm) were higher than mean and 75th percentile observed values from SILO (2.7 mm and 2.8 mm), but were still within the maximum values observed in the SILO dataset (44.9 mm).

Evaporation

- SILO and ERA5 evaporation data was poorly correlated over the period 1940 to 2024 (Morton's wet-environment areal potential evapotranspiration over land SciPy $R^2 = 0.1413$; FAO 65 Penman-Monteith evapotranspiration SciPy $R^2 = 0.2329$).
- Both Morton's wet-environment areal potential evapotranspiration over land and FAO 65 Penman-Monteith evapotranspiration mean values (3.2 mm and 2.8 mm, respectively) from the SILO dataset were lower compared to the potential evaporation in the ERA5 dataset (3.5 mm). The 25th to 75th percentile range was also higher in ERA5 (1.8 mm to 4.9 mm) compared to SILO (1.5 mm to 4.5 mm for Mwet and 1.5 mm to 3.8 mm for FAO). Maximum values were also higher in ERA5 than in SILO (10.1 mm compared to 7.9 mm for Mwet and 7.6 mm for FAO), while the minimum values were broadly comparable (0.4 mm, 0.5 mm, and 0.6 mm for ERA5, Mwet, and FAO, respectively).

Relative humidity

- SILO values from 1889 to 2024 showed a total decrease of 3.95%. CMIP6 values from 2015 to 2100 showed a total decrease of 1.65%. Mean CMIP6 values predicted between 2015 and 2024 were lower than mean observed values from SILO, but were still within the maximum values observed in the SILO dataset.

Cloud cover

- ERA5 data from 1940 to 2024 showed a total increase of 3.4%.
- CMIP6 values from 2015 to 2100 showed a total decrease of 9.0%.

- Mean CMIP6 values predicted between 2015 and 2024 were lower than mean observed values from ERA5, but were still within the maximum values observed in the ERA5 dataset.

River flow

- River flow data showed an annual average decrease of 1147 megalitres per year. Considering the average annual flow between 1952 to 2024 was 1.54*105 megalitres per year, this represents a 0.7% decrease per year. Over the entire observational record this would represent a 53.5% decrease in river flow.
- When considering the total flow per decade, the 1960s saw 2.36*106 megalitres, which has decreased over time through to the 2010s which saw 0.86*106 megalitres, representing a 63.5% decrease.

Discussion

- These trends pose severe threats to the park's unique biodiversity and have implications for conservation.
- Red tingle trees, which evolved under high humidity and rainfall conditions, face increasingly unsuitable habitat conditions with declining rainfall and humidity.
- Specialised habitats that serve as refugia for Gondwanan relic species are particularly vulnerable to the combined stresses of warming, drying, and reduced water availability.
- Endemic species adapted to the historically wet conditions may face local extinction as their specialised niches disappear.
- Bushfires may intensify with higher temperatures, lower humidity, and drier conditions, potentially overwhelming the fire-adapted but moisture-dependent ecosystems.
- Data validation shows that while CMIP6 models generally align with observed trends for 2015-2024, they tend to predict somewhat higher mean temperatures and rainfall than currently observed, though still within historical variability ranges. This suggests the projections may be reasonable, though uncertainty remains in capturing local-scale climate dynamics in this topographically complex region.
- The combination of warming, drying, and declining river flows presents a substantial threat to this internationally significant biodiversity hotspot, indicating the need for adaptive conservation strategies.
- However, given a lack of funding and support for conservation in this location, it is unlikely to remain resilient in the face of climate change given these projections.

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