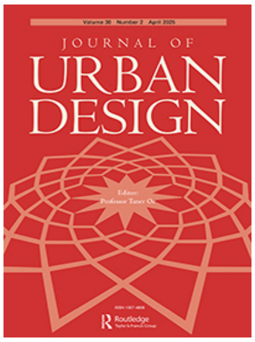


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# Ultraviolet radiation (UVR) exposure in playgrounds: an Australian case study

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**ABSTRACT**

Record cases of skin cancer in Australia emphasizes the urgent need for greater Ultraviolet Radiation (UVR) protection, particularly in public spaces and where children spend time. This study analyses the shade provision of 10 parks in the Sunshine Coast (Australia). Methods used include participant observation, shade analysis and UVR measurements. Results highlighted disparities regarding shade effectiveness. Whilst all parks had some form of built shade, playgrounds with dense trees proved more effective in reducing UVR levels. The size, quality, age and shade cloths' placement also impact its protection capacity. Results indicate the need for greater shade-based regulations to guarantee UVR protection.

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**KEYWORDS**
UVR exposure; playground design; shade; evidence-based design; park design; skin cancer

## Introduction

Ultraviolet Radiation (UVR) causes approximately 57,000 deaths globally each year and poses significant health risks to human skin, immune system and eyes (WHO 2024). UVR exposure causes irreversible skin damage, particularly DNA damage leading to cancer (Narayanan, Saladi, and Fox 2010). This is especially concerning for children and adolescents, whose skin is more vulnerable to sun damage than adults (Garcia et al. 2011). With children spending considerable time outdoors and 50% of Australians developing skin cancer in their lifetime (Collins, Kearns, and Mitchell 2006), effective playground shade infrastructure is crucial, alongside traditional protection methods like sunscreen and protective clothing (Green, Sarah, and McBride 2011). Strategic shade design is therefore essential to enable safe outdoor play while minimizing UVR exposure (Olsen, Kennedy, and Vanos 2019).

Human comfort is another important aspect of the playground environment, encompassing thermal comfort, visual and acoustic comfort (Holman et al. 2018), which are determined by many factors including sun exposure, surface albedo and reflectivity (Requena-Ruiz et al. 2022). Thermal comfort, in particular, is described as an

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individual's contentment with their thermal environment, being influenced by psychological and physiological variables and dependent on environmental parameters (air temperature, radiant temperature, humidity and wind speed and direction) and behavioural (or human) parameters (metabolic rate and clothing) (Vecellio et al. 2022). Overall, people tend to visit parks when the thermal comfort levels are close to neutral (Heng and Chow 2019).

Thermal comfort in urban environment is affected by the property of surfaces surrounding a certain area, particularly their albedo, which represents the percentage of incoming sunlight reflected from a surface. Albedo varies from zero (0) – surfaces absorbing 100% of the radiation – to one (1) – surfaces that reflect 100% of the incoming radiation (Turner and Parisi 2018). Importantly, low-albedo surfaces (closer to zero) transform solar radiation into heat and release this heat into the surroundings, especially during night-time, contributing to urban heating and the formation of urban heat islands (UHI), while high-albedo surfaces (closer to one) result in cooler microclimates by reducing heat absorption (Tsoka et al. 2020).

Combining high-albedo materials such as light coloured pavements and shading infrastructure such as trees create cooler environments (Chen, Zheng, and Hu 2020; Santamouris 2014; Wesener et al. 2017), and a mix of high and low albedo surfaces must be implemented in playgrounds to effectively regulate temperature (Downs et al. 2008; Pfautsch, Wujeska-Klause, and Walters 2022). However, whilst high albedo materials prove effective in reflecting UVR, they can also intensify solar radiation, potentially increasing the risk of sunburn and eyes damage, or even the development of eye cancer (Turner and Parisi 2018). High albedo materials tend to reflect both visible and invisible light, including UVR, and while surfaces are kept cool and may reduce energy demand in buildings, these emerging risks are key factors to consider when introducing light coloured materials in public areas (Birt, Cowling, and Coyne 2004).

The Cancer Council (n.d.), as well as the World Health Organization (WHO 2024) play pivotal roles in creating awareness for skin cancer prevention. However, Australia lacks comprehensive shade-based policies, including for playground areas, resulting in the variance of children's exposure to UVR (Caves 2023). This highlights the need to introduce standards and regulations across Australia to ensure effective UVR protection, and to further align with the WHO guidelines of <3 UVR for skin cancer protection (Safe Work Autralia 2013). There are a few Local Government Areas (LGA) in Australia that have developed strategies to guarantee 50–75% shade coverage in these spaces with a focus on nature-based solutions (for example, City of Monash 2024; Scenic Rim Regional Council 2024), with postimplementation analysis showing 129 playgrounds had significant shade infrastructure improvement (Scenic Rim Regional Council 2024). Whilst the Sunshine Coast Council advocates for shade facilities for increased comfort (Sunshine Coast Council 2023a), there is a need for specific shade guidelines, quantity, standards and effective implementation strategies. To help provide the information and knowledge required to achieve this outcome – both in the Sunshine Coast and elsewhere – this work investigates the UVR exposure of playground users on the Sunshine Coast, and ways in which design and planning help reduce UVR associated risks. More specifically, the study focuses on the following questions: (a) What is the intensity of UVR users in playgrounds are exposed to, on the Sunshine Coast?; (b) How is the design of playgrounds prepared to minimize UVR exposure?; and (c) Does the infrastructure of parks affect the popularity of play spaces?

The following sections outline the methodology adopted to achieve the study objectives and answer the research questions. The results are then presented, with a discussion of their relevance and contribution regarding previous studies and existing policies, leading on to a concluding section with a summary of key study outcomes, a discussion on study limitations and directions for future studies in the field.

## Methodology

A case study was chosen – the Sunshine Coast Urban Corridor (SCUC) – and embedded cases (Yin 2013) are a focus to explore shade provisions through multiple embedded case study sites (the parks and playgrounds). The SCUC 'stretches from Maroochydore in the north to Caloundra in the south and is approximately 24 km in length covering an area of approximately 2,200 ha' (Sunshine Coast Council 2023d, 6). It is the focus of the Sunshine Coast Infrastructure Coordination Plan (ICP) (Sunshine Coast Council 2023d), and a highly desirable and rapidly developing area with projections of significant increase in population. The ICP is 'a collaborative plan aimed at benefiting the region's community, environment, liveability and economic development' (Sunshine Coast Council 2023d, 4). Through the ICP, the local government aims to assess existing conditions and explore ways to enhance infrastructure while establishing guidelines for both improvements and long-term development. Considering that neighbourhoods where children play, and particularly their playgrounds, are a fundamental part of children's lives and development, and where they spend a lot of their time outdoors (Carroll et al. 2015), the increased density around and population using those parks and playgrounds along the SCUC, makes the area a relevant and timely case study for the investigation of shade provisions. For all these reasons, and with the intention of contributing to planning provisions that support healthy urban spaces in regard to UVR protection, 10 case study sites located in the SCUC were selected out of 379 playgrounds located in the Sunshine Coast (Sunshine Coast Council 2023c) (Table 1 and Figure 1).

To address the research objectives, this study focuses on (1) the place use dynamics (based on participant observation), (2) shade auditing (based on Sky View Factor (SVF)

**Table 1.** Park information.

| | Embedded Cases/Case Study Sites | | | |
|---|---|---|---|---|
| Case Study | Park Location (Neighbourhood) | Park name* | Park area ($m^2$) | Distance to the beach (m) |
| Sunshine Coast Urban Corridor Playgrounds | Coolum Beach | Tickle Park | 2879.39 | 35 |
| | Marcoola | Felix Parry Park | 1354.86 | 60 |
| | Mudjimba | Power Memorial Park | 6946.66 | 80 |
| | Maroochydore | Cotton Tree Park | 4458.1 | 40 |
| | Mooloolaba | Mooloolaba Foreshore Park | 3187.93 | 30 |
| | Buddina | Kawana Beach Park | 1791.68 | 120 |
| | Warana | Wyanda Park | 2717.19 | 90 |
| | Wurtulla | Crummunda Park | 2396.81 | 40 |
| | Currimundi | Grahame Stewart Park | 10857.63 | 450 |
| | Caloundra | Happy Valley Park | 2306.20 | 20 |

*Throughout this paper, we refer to the park names. For park location, please refer back to Table 1 and Figure 1.


Figure 1. Case study sites along the SCUC: Tickle Park (Coolum Beach) (a); Felix Parry Park (Marcoola) (b); Power Memorial Park (Mudjimba) (c); Cotton Tree Park (Maroochydore) (d); Mooloolaba Foreshore Park (Mooloolaba) (e); Kawana Beach Park (Buddina) (f); Wyanda Park (Warana) (g); Crummunds Park (Wurtulla) (h); Grahame Stewart Park (Currimundi) (i); Happy Valley Park (Caloundra) (j) (Source: Authors).

analysis and shade effectiveness calculations) and (3) UVR readings (focused on open space and shaded areas).

Analysing space use patterns through participant observation allows urban designers and planners to determine how the spaces are utilized (Gehl and Svarre 2013; Lofland et al. 2006) – e.g., which facilities/areas are most used, average time of stay and occupancy. Participant observation was adopted to explore space dynamics and how the playground areas are used in relation to shade provisions. It also provided information about the general activity in the case study sites which was then related to the UVR measurements. While undertaking participant observation, a Shade Audit Sheet (SAS) was used (Figure 2). The SAS was prepared using several components from various studies (Caves 2023; SunSmart Victoria 2015), and the observations recorded included the number of people utilizing the playground and surrounding area (within a 15 m buffer area) at the beginning of the audit, halfway (30 min into it) and at the conclusion of the audit (1 h). This data was then totalled and divided by three to determine the average occupancy of each of the parks. The need to calculate the 'average' occupancy is due to the fact that the number of total park users was recorded throughout three intervals, making it difficult to accurately record which park users left or arrived at the park within the audit time.

It is also important to note that participant observation data collection was aimed at understanding the intensity of park usage, and reporting on factors directly observable – e.g., activities performed while at the parks, chosen places for sitting (i.e., shade or sun), clothing, sun hats and so forth. The aim of this analysis was to provide insights of UVR levels and intensity of use of those areas, rather than providing specific numbers or an analysis of reasons why users may have made certain decisions.

Sky View Factor (SVF) was used as an analysis tool as it allows for the comparison of exposure in different areas, examples of this include exposed areas with sparse vegetation compared to an area with an abundance of trees and shade infrastructure (Brown, Grimmond, and Ratti 2001). SVF is given on a 0–1 scale with a SVF of one (1) showing unobstructed radiation and zero (0) indicating complete sky obstruction (Dirksen et al.

| **Movement:** | **Park Location:** | **Shade:** |
|---|---|---|
| **What are people doing?** | **Date:** | **What shade features does the area have?** |
| | **Beginning Audit Capacity:** | |
| **What areas do users mostly use?** | **30 min:** | **Are these effective?** |
| | **Ending Audit Capacity:** | |
| **Are people sitting in the shade or sun?** | | **Are there enough trees and plants to make the space shaded and comfortable?** |
| **Do users avoid any shaded areas?** | | **Is there an appropriate mix of built and natural shade structure?** |
| **What are the main activities performed at the park?** | ***Image of Site*** | **Is the location of the shade appropriate, given the usage patterns of the site?** |
| **What protective sun wear are people wearing?** | | **How can the shade be improved or increased?** |

Figure 2. Example of audit tool (Source: Authors).

2019), allowing various factors to be determined such as heat release, potential for UHI formation and UVR exposure (Rafieian, Rad, and Sharifi 2014). In this study, the central positions of each of the playgrounds were identified using Nearmap (2024). A DSLR camera (Canon EOS 6D Mark II, full frame sensor) equipped with a fisheye lens was placed on the ground in this identified position facing the sky for image capture. For the purposes of extracting the data and analysing the results, the images sourced were inserted into the software RayMan Pro where a base layer of the sun path creates a ratio ranging from 0 to 1. From these data, the ratio of radiation received by a specific point to what would be received from a complete hemispheric radiant environment in the same area was determined.

UVR data collection was performed using a UVR light meter (Tenmars TM-208 UV light meter) consistently positioned parallel to the ground at waist height (0.9 m) for all readings. These measurements were taken in open areas away from trees, shade cloths and built sheltered areas, approximately with a margin of at least 50 cm from any trees or man-made structure. The visits were conducted during the set testing times of 11 am and 3 pm on sunny, cloudless days on July 2023 (Monday 17 July, and Tuesday 18 July). The protection factor analysis was based on Caves (2023) (Figure 3) facilitating the comparison of the protection factor and shade percentage in a scale system, this analysis is aligned with the AS/NZS 4399:2017 Protection Classification (ARPANSA n.d.-a).

3D models of the parks were generated using SketchUp Pro 2023 to effectively evaluate the shade provision in all 10 parks. Each of the parks was modelled utilizing accurate measurements of the major objects of the playground and surrounding park elements, including trees, equipment, shade cloth, shelter sheds and paths (see Figures 4 and 5). After modelling the case study sites, variation in the sun path was analysed to investigate the shade during different times of the day, specifically at 2 pm between 2nd and 5th of August. These are the time and dates for which the on-site UVR data was also collected, providing a direct comparison, and allowing for recommendations on effective urban design to reduce UV levels.

<table>
<tr><th colspan="2">Shade Quantity</th><th></th><th colspan="2">Shade Quality</th></tr>
<tr><td>Percent cover</td><td>Target</td><td></td><td>Protection factor</td><td>Target</td></tr>
<tr><td>0% - 20%</td><td>Very low</td><td rowspan="2">Inadequate</td><td>0 - <1</td><td>None</td></tr>
<tr><td>21% - 30%</td><td>Some</td><td>1 – 10</td><td>Very Low</td></tr>
<tr><td>31% - 50%</td><td>Sufficient</td><td rowspan="2">Adequate</td><td>>10 - <15</td><td>Some</td></tr>
<tr><td>>50%</td><td>Exemplary</td><td>>15</td><td>Sufficient</td></tr>
</table>

Figure 3. Shade quantity and quality scale (Source: Adapted from Caves 2023).

Figure 4. Model of Felix Parry Park (Marcoola) (Source: Authors).

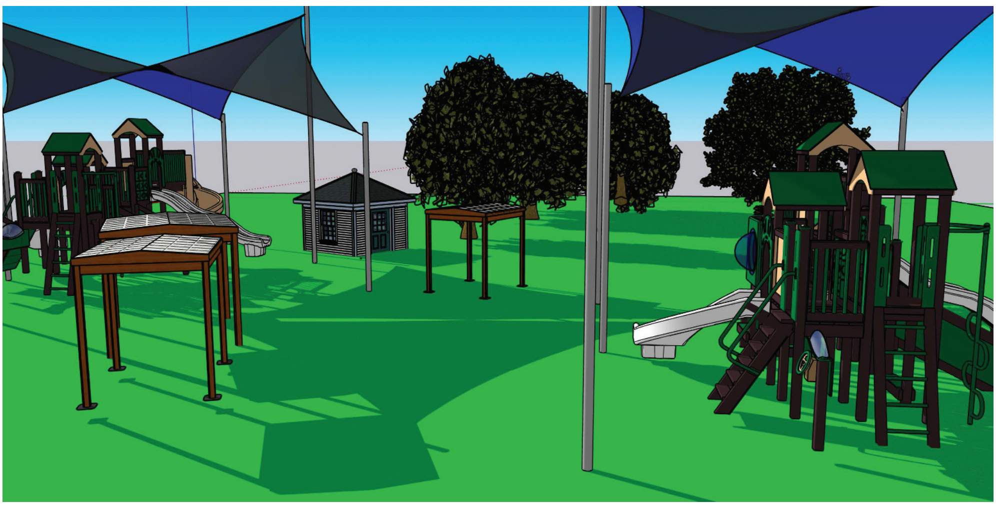

Figure 5. Model of Wyanda Park (Warana) (Source: Authors).

Each of the geographic location coordinates was entered into SketchUp when performing the shade analysis and the measuring tool was then used to measure the areas of shade in comparison to the non-shaded areas, to determine the protection factor. Any changes in tree shade coverage throughout the different seasons, in particular autumn and spring, were compared to the corresponding Nearmap (2024) aerial images. If these changes were evident according to location, they were taken into consideration to account for variations in shade distribution and to provide a comprehensive year-round estimate of UV protection.

Shade quality in each playground was analysed based on SketchUp's sun mapping and shadow features. Shade coverage and the protection factor of each park were assessed using aerial photographs sourced from Nearmap to measure tree canopy and shade infrastructure. To accurately calculate the 'protection factor' (PF), a formula (1) developed by Parsons et al. (1998) was used. This formula utilizes measurements collected by the UV light meter, in relation to the shade (trees and shade cloth) measurements to analyse the quality of the shade provided:

$$PF = \frac{Open\ Space\ (UVR)}{Shade\ (UVR)} \tag{1}$$

The SketchUp models were also used to further determine the quantity of shade in each of the study sites, the 'shade percentage' (SP). SP was also calculated using (2) (see also Caves (2023)):

$$SP = \frac{Shaded\ Space\ M_2}{Open\ Space\ M_2} \tag{2}$$

After calculating the effectiveness of shade through its shade percentage and protection factor, the case study sites were evaluated, allowing the overall effectiveness for children's sun safe use to be assessed.

## Results

### *Auditing space use and shade*

The average number of users observed during the audit for this study was 436 (Figure 6), providing insights into the usage of these parks and the importance of sun safety for these individuals, including children.

With the intention of understanding how users utilized and interacted with the public spaces, an investigation was made into the dynamics of places. Individuals who were actively utilizing the area and within approximately 15 metres of the main playground were included in the observation notes. Power Memorial Park had the highest average occupancy with 51 children and 39 adults, followed closely by Grahame Stewart Park which had an average occupancy of 50 children and 34 adults. In contrast, Kawana Beach

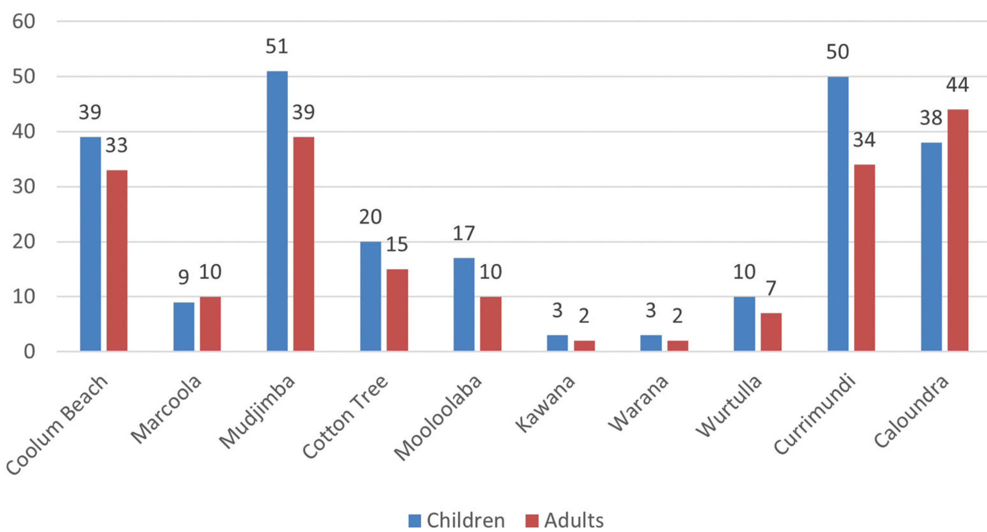


Figure 6. Average number of park users.

Table 2. Park components.

| Park location and name | | Seating areas: Shade cloth | Seating areas: Built | Seating areas: Vegetation | Play areas: Shade cloth | Play areas: Built | Play areas: Vegetation |
|---|---|---|---|---|---|---|---|
| Coolum Beach | Tickle Park | | ✓ | ✓ | ✓ | | |
| Marcoola | Felix Parry Park | | ✓ | | ✓ | | ✓ |
| Mudjimba | Power Memorial Park | | ✓ | ✓ | ✓ | ✓ | ✓ |
| Cotton Tree | Cotton Tree Park | | ✓ | ✓ | ✓ | | ✓ |
| Mooloolaba | Mooloolaba Foreshore Park | ✓ | | ✓ | ✓ | | |
| Buddina | Kawana Beach Park | | ✓ | | | | |
| Warana | Wyanda Park | | ✓ | ✓ | ✓ | | ✓ |
| Wurtulla | Crummunda Park | | ✓ | ✓ | | | ✓ |
| Currimundi | Grahame Stewart Park | | ✓ | | ✓ | | ✓ |
| Caloundra | Happy Valley Park | | | ✓ | ✓ | | ✓ |

Park and Wyanda Park had the lowest occupancy, with an average of three (3) children and two (2) adults.

Participant observation revealed some common aspects in all parks. For instance, most adults wore some form of sun protection (sunglasses and/or hat), whilst very few children were seen wearing any of those. Despite children's lack of sun protection, they utilized both the play equipment underneath shade cloths and surrounding areas that were exposed to UVR. Although adults wore sun protection (hats and sunglasses), they were observed using shaded areas such as shelter sheds and under trees.

While children played on equipment and open space, adults supervised them, socialized, had picnics and social events. Parks with higher occupancy had some form of birthday party or celebration, these being Tickle Park, Power Memorial Park, Grahame Stewart Park and Happy Valley Park.

Observations showed no park areas were avoided, whilst seating areas and playground equipment being most utilized. However, at Kawana Beach Park, most people utilized surrounding walking tracks and open space rather than the playground and were not included in the audit. Most parks featured an appropriate mix of natural and built shade, consequently enhancing the park's comfort and character, with the exception of Kawana Beach Park which lacked shade on the play equipment, making the area appear very unappealing and hot (see Figure 1(f)). Although the shade quality varied, in general study sites had large quantities of trees, and eight parks had some form of shade cloths. While Kawana Beach Park and Crummunda Park lacked shade cloths, Crummunda Park had an abundance of large established trees which provided most of the large playground with shade (Figure 1(h)).

All but Happy Valley Park (Figure 1(j)) had built infrastructure ensuring some areas had a UVR $< 2$ (Table 2). Happy Valley Park lacked sheltered seating areas, which forced parents and adults to seek shade from underneath the trees when supervising their children.

### *Solar exposure and barriers*

The Sky View Factor (SVF) was calculated for each of the parks; parks with a lower SVF exhibit less visible sky and greater obstructions; this is associated with shaded and enclosed environments and a high SVF indicating greater UVR at a ground level (Rafieian, Rad, and Sharifi 2014). SVF was analysed using the software RayMan, and the results show that Wurtulla had the most shade coverage with an SVF of

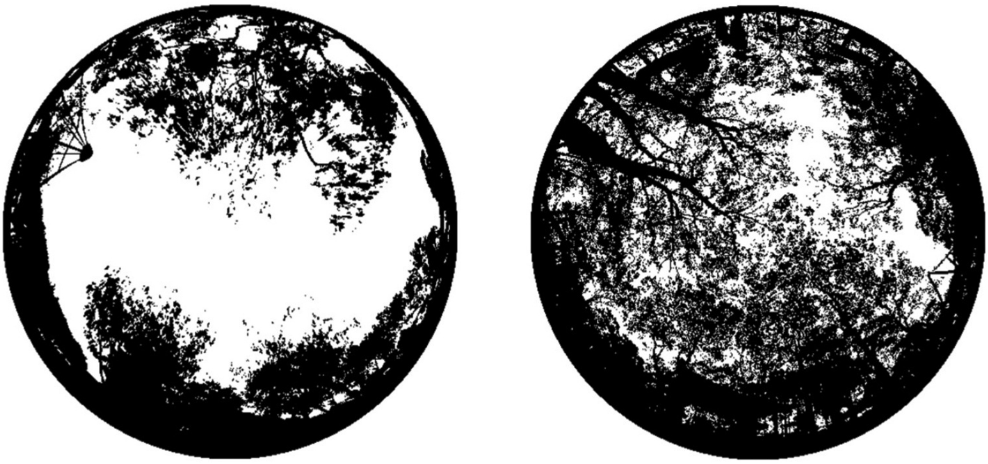

Figure 7. SVF comparison of Kawana Beach Park (Buddina) (a) and Crummunda Park (Wurtulla) (b) (Source: Authors).

0.212 (see Table 2 and Figure 7). This park had an effective combination of built shade (shade cloth) and natural shade (trees), to significantly reduce the UVR levels in the play space as seen in Tables 2 and 3. The low quantity of open sky visible from this perspective indicates that there is an effective combination of hard and soft infrastructure to filter and block UVR levels. As expected, Kawana had the highest SVF of 0.764, as the park had very limited trees to provide shade and also one shelter shed (see Table 3). This means that Kawana Beach Park users are more exposed to the harmful UVR, in comparison to the parks that received a lower SVF. Figure 7 shows the sky dome analysis extracted from RayMan and the shade infrastructure obstructions in Kawana Beach Park in comparison to Crummunda Park.

## *UVR exposure*

UVR measurements were undertaken for all 10 case study sites along the SCUC. The UV light meter was used to obtain measurements in the open space,

Table 3. UVR measurements obtained in each case study site.

| | Open Space | | Shade cloth | | Tree | | Shelter | |
|---|---|---|---|---|---|---|---|---|
| Park | $W/m^2$ | UVR | $W/m^2$ | UVR | $W/m^2$ | UVR | $W/m^2$ | UVR |
| Tickle Park (Coolum Beach) | 640 | 25.6 | 42.9 | 1.716 | 145 | 5.8 | 34.73 | 1.3 |
| Felix Parry Park (Marcoola) | 611 | 24.44 | 87.1 | 3.484 | 234.3 | 9.7 | 37.2 | 1.488 |
| Power Memorial Park (Mudjimba) | 654 | 26.16 | 112.2 | 4.488 | 156 | 6.24 | 43.1 | 1.724 |
| Cotton Tree Park (Maroochydore) | 652 | 26.08 | 126 | 5.04 | 249.2 | 9.968 | 28.91 | 1.156 |
| Mooloolaba Foreshore Park (Mooloolaba) | 572 | 22.88 | 81 | 3.24 | 263.2 | 10.528 | 30.11 | 1.204 |
| Kawana Beach Park (Buddina) | 605 | 24.2 | – | – | 273.6 | 10.944 | 22.65 | 0.90 |
| Wyanda Park (Warana) | 539 | 21.56 | 66 | 2.64 | 211.5 | 8.44 | 50.8 | 2.032 |
| Crummunda Park (Wurtulla) | 607 | 24.28 | – | – | 86 | 3.44 | 22.65 | 0.906 |
| Grahame Stewart Park (Currimundi) | 605 | 24.2 | 45.1 | 1.804 | 113.2 | 4.528 | 24.10 | 0.964 |
| Happy Valley Park (Caloundra) | 614 | 24.56 | 76.2 | 3.048 | 127.8 | 5.112 | – | – |

underneath trees, shade cloth and shelter sheds. Analysis of the shade cloth UVR protection results revealed some parks had an effective level of UVR protection whilst other shade cloths were ineffective. Using the protection factor formula (1), significant disparities between the quality of shade provided by the trees and shade cloth were revealed, compared to open space UVR levels. Results demonstrate that the best quality shade provided by trees was Crummunda Park with a result of 7.058 followed by Grahame Stewart Park with a result of 5.345 (see Table 3).

Grahame Stewart Park exhibited relatively new facilities, in particular the recently installed shade cloth which recorded an extremely low UVR level of 1.8044, providing substantial UVR protection for users. Tickle Park shade cloth was replaced during the shade audit process and the new shade cloth recorded very low UVR levels of 1.716. Conversely, Cotton Tree's shade cloth recorded the highest UVR result of 5.04, which equates to a 'moderate risk'. This is quite ineffective in comparison to the other shade cloths, suggesting that the Cotton Tree Park's shade cloth must be replaced, and that a lifetime must be established for these structures. Similarly, Power Memorial Park's shade cloth received 4.488, which is also a moderate risk and confirms that a new shade cloth should be installed. Whilst the exact material composition, location and weather conditions significantly alter the effective lifespan of shade cloths, they have an approximate lifespan of 8–10 years (ARPANSA, n.d.-b; SunSmart Victoria 2015).

Diverse UVR levels were recorded under trees across the 10 parks. Whilst all playgrounds were located along the SCUC, each park contained trees that suited the park's age and the area's character, contributing for the diverse UVR levels. Crummunda Park had the lowest UVR result of 3.44, this is due to the abundance of large trees across the playground. As observed in Table 2, Figures 1(h) and 6(b), this playground did not have any shade cloths and relied on trees for UVR protection, which proved successful. This was followed by Grahame Stewart Park which had a rating of 4.528, which, however, did not contain many of these large trees, and they only shaded the outer portions of the playground. The highest UVR levels recorded were from Kawana Beach Park, this was expected as most of the trees in this area were resilient coastal banksias due to the proximity to the beach. The UVR rating for this area was 10.528 which is very dangerous and provides very little sun protection. High UVR score (9.968) was also observed at the Cotton Tree Park, and although the area did contain some large trees, most of the trees near the playground were sparse and had limited UVR protection.

All audited parks had effectively built shade infrastructures such as sheltered BBQs and seating areas with UVR results ranging from 0.90 to 2.032. However, inequalities between built infrastructure were observed in Kawana Beach Park and Happy Valley Park. On average (not including the open space measurements), Crummunda Park had a UVR average score of 2.173 indicating that this playground has the most effective infrastructure in providing protection from UVR rays. This is closely followed by Grahame Stewart Park with an average of 2.432. However, Kawana Beach Park had the highest average UVR of 5.922.

### *Shade area analysis through 3D modelling*

The shade analysis on Sketchup Pro 2023 revealed the amount of shade area of each of the playgrounds, specific to each location. The shaded areas of these playgrounds in

Table 4. Shade percentage, protection factor and skyview factor for each audited site.

| Park | Shade Percentage | Protection Factor (Trees) | Protection Factor (Shade Cloth) | Skyview Factor |
|---|---|---|---|---|
| Tickle Park (Coolum Beach) | 40.7% | 4.414 | 14.918 | 0.535 |
| Felix Parry Park (Marcoola) | 25.3% | 2.52 | 7.015 | 0.629 |
| Power Memorial Park (Mudjimba) | 61.6% | 4.192 | 5.829 | 0.336 |
| Cotton Tree Park (Maroochydore) | 34.5% | 2.616 | 5.175 | 0.432 |
| Mooloolaba Foreshore Park (Mooloolaba) | 54.5% | 2.173 | 7.062 | 0.655 |
| Kawana Beach Park (Buddina) | 26.0% | 2.211 | N/A | 0.764 |
| Wyanda Park (Warana) | 39.1% | 2.555 | 8.167 | 0.336 |
| Crummunda Park (Wurtulla) | 77.2% | 7.058 | N/A | 0.212 |
| Grahame Stewart Park (Currimundi) | 25.9% | 5.345 | 13.415 | 0.629 |
| Happy Valley Park (Caloundra) | 50.3% | 4.804 | 8.058 | 0.616 |

comparison to the non-shaded areas revealed the shade percentage of each of the sites (Table 4).

Approximately 77.2% of Crummunda Park was shaded, primarily relying on large dense trees and shelter sheds rather than shade cloths, during 2 pm where peak UVR levels are high. Felix Parry Park had the lowest shade percentage of 25.3%; however, this is due to the park design which includes a large open area dedicated to public events. Kawana Beach Park has a 26% shade coverage, which is expected due to the park's severe lack of built infrastructure and shading trees. This park was audited for the smaller area of 2210.94 $m^2$, to disregard the large sparse underutilized open space; however, the results accurately reflected the park's shade deficiency and may be a reason for the low popularity.

The playground at Mooloolaba Foreshore Park is new in contrast to the other parks; however, it contains an insufficient amount of shade infrastructure. Despite the popularity of the area, only the swings and small portion of the playground were covered by shade cloth, leaving a large area exposed to UVR (see Table 3). This gives the impression that playground design and aesthetics may be more valued than shade infrastructure and protection and could be the future priority for new playground design. This is unexpected and unfortunate considering emerging research on UVR danger and the importance of shade protection.

## Discussion

### *Intensity of UVR exposure in playgrounds on the Sunshine Coast*

Quantitative analysis of UVR exposure across Sunshine Coast playgrounds revealed a diverse range of UVR levels of 21.56–26.16 (Table 3), demonstrating the urgency of developing safe UVR areas for children. With the severe threat to human health, effective protection is crucial (Green, Sarah, and McBride 2011; Parsons et al. 1998; Narayanan, Saladi, and Fox 2010). Among the 10 playgrounds analysed, three exhibited low UVR levels of 1.716–2.64, these levels are indicated by the WHO (2024) to be acceptable and require no further protection. Tickle Park, Wyanda Park and Grahame Stewart Park displayed lower UVR levels, possibly due to the new condition of the shade cloths. The other remaining five parks had a UVR range of 3.048–5.04, meaning individuals must wear further sun protection (WHO 2024).

It is crucial for playgrounds to have effective shade cloth (Olsen, Kennedy, and Vanos 2019), and tree size and placement as they help maintain a cool climate, increase comfort levels, add character to the playground and reduce sun exposure (Holman et al. 2018). Evaluation of the UVR levels under trees revealed a broad range of results, with five parks categorized as 'moderate' risk and concerning five parks receiving 'very high' UVR level risk. Australian coastal trees such as coastal banksia and horsetail shea oak, prevalent in these areas, contributed to the ineffective shade and UVR filtering, however, possibly were planted to enhance the coastal character of the area or because of their coastal resilience. Whilst all playgrounds had a form of built shade infrastructure exhibiting UVR levels <2. Unfortunately, the majority of the audited areas did not meet the WHO (2024) recommendation of <3, including several shade cloths.

Shade cloths, the predominant playground shade infrastructure, are a cause for concern. Only three of the playgrounds recorded safe UVR levels where protection is not necessary. Shade cloths in Australia are tested against the 'Sun Protective Clothing Standard (AS/NZS 4399)' have an effective UVR filtering lifespan of eight to 10 years (ARPANSA n.d.-b). This lack of UVR effectiveness of many of the shade cloths was further validated in the protection factor shade cloth analysis where Tickle Park received the highest rating of 14.918 (close to sufficient) in comparison to the low quality and weathered shade cloth found in Cotton Tree Park. The shade cloth at Cotton Tree Park was the only shade cloth that was not dark grey/black, instead it was a bright orange colour which may have impacted on its efficacy, as shade cloths of a darker blue and black colour absorb greater UVR rays and make the underneath ground cooler, whilst lighter colours allow more UVR and light to pass through (ARPANSA n.d.-b). This highlights that park users in Cotton Tree Park are much greater exposed to harmful UVR levels compared to users of Tickle Park.

The evaluation of the shaded and non-shaded areas through 3D models revealed the shade percentage of each of the sites. Previous studies also indicated a great need for consistent quality shade cover in parks, and these findings align with this study's results (Anderson et al. 2014; Gage et al. 2018). In summary, several parks analysed contained inadequate shade coverage to protect users from harmful UVR, with these parks having coverage of >40% at 2 pm (highest UVR levels). Protection factor and shade percentage significantly varied between sites, and parks with most effective shade (Crummunda and Grahame Stewart Park) received a 'very low' quality rating, due to the limited UVR filtering of trees in comparison to the built infrastructure which this ranking system often evaluates.

Similarly, the shade percentage results also had a large variation between study sites. Some playgrounds exhibited an 'exemplary' rating of 77.2% shade coverage and another with only a 'some' rating of 26.0% (see Table 4). These findings are aligned with Caves (2023) study, which demonstrated a vast range of PF and SP between each park, and inadequate shade cover to mitigate UVR over-exposure. The SVF results further support these findings, in which there is a range of results, with the average being 0.538 (Table 4) alluding the average shade coverage of parks on the Sunshine Coast is approximately 53%.

Participant observation revealed an unexpected result that have not been a point of discussion in the previous literature. At all parks, adults were observed most frequently using the built shade infrastructure areas and seating compared to children who heavily used the playground equipment and open spaces. While these site usage patterns were predicted; one unexpected result was that adults were commonly seen wearing sunglasses and sometimes hats, although they were in the built shade infrastructure with the lowest UVR levels, whilst very few children (<5) were seen wearing hats as a form of sun protection. This was not anticipated given that young children are reliant on adults for sun protection. Contradicting the assumption that adults would offer children under their care the same level of sun protection that they are using themselves, particularly as these children commonly use the exposed playground equipment and open spaces (Cancer Council n.d.).

### Playgrounds design to minimize UVR exposure

Analysis of all study sites revealed significant disparities between the quantity and design of shade infrastructure. The major differences in design between all the parks that had an extreme effect on the shade provided and UVR protection was the distribution and quantity of trees in each of the parks. Playgrounds such as Crummunda Park relied on large trees as the primary shade source, providing a cooling effect, contributing to pleasant thermal comfort levels in public spaces, a concept explored by Vecellio et al. (2022) as well as adding to the character. This park design proved effective when analysing the shade percentage (77.2% which is very effective). Similarly, Power Memorial Park had a shade percentage of 61.6%, which had an abundance of large trees around the playground, but also had some shade cloth above the play equipment. Both these parks strategically ensured there was shade cover over key utilized areas throughout the day.

All audited sites had at least one built shade infrastructure in the form of a sheltered area or BBQ area. Anderson et al. (2014) Sydney playground study explored the effectiveness of different shade infrastructures and found that built shade infrastructures have great benefits and some positive attributes rather than trees as they can provide immediate protection and materials, size, appearance and location are customizable. These benefits of sheltered areas proved accurate as each of the locations recorded UVR levels of <2 which requires no sun protection (Vecellio et al. 2022).

Kawana Beach Park displayed the most ineffective design to minimize UVR exposure, as demonstrated in the UVR results, SVF and protection factor. This park exhibited the absence of large dense trees which have previously been proven in several studies to help filter UVR rays (Cherian and Subasinghe 2023; Holman et al. 2018). Despite having a shelter shed, it appeared disconnected from the playground area and under-utilized. This became evident during fieldwork when a family was using the playground, the parents instead observed their children closer to the playground in the sun, rather than under the shade of the shelter shed.

In summary, playgrounds with a high protection factor exhibited greater design of shade infrastructure to minimize UVR exposure. Similarities of these parks were the inclusion of large dense trees surrounding common areas of the park, good-condition shade cloths that covered the play equipment and sheltered seating areas for parents and celebrations. Green infrastructure, such as plants and trees greatly added to the and perceived thermal comfort of parks. This study highlights the importance of considering the design of play spaces as well as better policies and regulations regarding this, as currently these regulations prioritize users' physical safety over sun protection. These attributes can be taken into consideration in urban policy when creating shade provisions for playgrounds.

### *Shade infrastructure and parks popularity of play spaces*

Numerous studies have observed that the shade infrastructure and facilities of parks have an influence on the popularity of the play space. Pfautsch, Wujeska-Klause, and Walters (2022) explored the concept of shade being a heavily desirable feature of parks, with the evapotranspiration and shade from soft infrastructure such as trees and plants, making public spaces more enjoyable. In this study, parks with greater infrastructure such as shelter sheds and shaded seating areas also appear to have a larger quantity of visitors. These parks were Grahame Stewart Park, Power Memorial Park and Tickle Park, all of which exhibited acceptable shade infrastructures and protection factors. These parks had birthday parties or celebrations, with most users utilizing the shelter sheds. It was also noted that non-shaded areas appeared to be avoided, and while the patterns of usage were similar for all sites, in Kawana Beach Park there were high amounts of pedestrian traffic in the area; however, both adults and children utilized the surrounding walking paths and amenities and appeared to avoid the sunny playground area.

## Conclusion

The objective of this study was to investigate '*How exposed are playground users on the Sunshine Coast to UVR, and how can design and planning help reduce UVR associated risks?*', and this was achieved through the analysis of both quantitative and qualitative data. This study has highlighted the urgent need for effective shade infrastructure in playgrounds, as various studies evaluated the detrimental effects of UVR over-exposure, particularly for children who are most susceptible due to the structure of adolescents' skin (Garcia et al. 2011).

Participant observation yielded some unexpected results. For example, children were observed to play in various areas of the playground regardless of the shade infrastructure, but adults were seen primarily utilizing the shaded or sheltered seating areas. However, in most parks, the adults were the only users who were wearing a form of shade protection instead of the children, although they were under shaded areas.

The UVR results were effective in evaluating the exposure and risk levels of each of the audited sites. These results and associated calculations showed the effectiveness of different shade infrastructures compared to the open space UVR exposure, showing large disparities. Findings depict that shade infrastructure such as shade cloths and shelter sheds are most effective in obstructing UVR levels, with trees also proving to be very beneficial. An unexpected result was the variance in the effectiveness of shade cloth across the sites, with the protection factor confirming that the quality, age and colour of the shade cloth significantly affect UVR blocking capabilities.

Both the SketchUp modelling and SVF further evaluated the exposure of park users in the Sunshine Coast by evaluating the shade composition of parks. It was also observed that the quantity of shade coverage and infrastructure present between the audited parks significantly varied.

Each of these methods of analysis proved successful and helped provide valuable data to answer the research questions. Although the Sunshine Coast Environment and Liveability Strategy (2023b) mentions the requirements of designing public spaces with efficient shade infrastructure, there are further steps that need to be taken to mandate acceptable shade in all playgrounds for the safety of users. It appears that skin cancer prevention is of less importance in urban planning, with shade infrastructure being a low priority when designing new safe public playgrounds.

Whilst this study is focused solely on playgrounds along the Sunshine Coast Urban Corridor, these findings are applicable for a broader range of locations and the methodology adopted in this study applies to any place in any climate context, and can be taken into consideration when creating future planning provisions. To conclude, the integration of UVR mitigating and filtering infrastructure is essential when creating safe and thermally comfortable public spaces for everyone.

### *Limitations of study and future studies*

While the results of this study are valuable for understanding playground UVR exposure in the Sunshine Coast's Urban Corridor, the work also encountered some challenges. First, the UV light meter only specifically measured the direct UVR levels. This reading did not account for indirect UVR levels which may have influenced results depending on the materials and surfaces present in each park. The indirect UVR can also be harmful, and therefore worth being measured. Time constraints were also another limitation of this study. The study was undertaken over numerous days and at specific times on these days and therefore has not accounted for times where different shades may be present due to the path of the sun – i.e., shade area varies during the day. Moreover, other factors related to space use that would ideally be included in the analysis are the average time and length of UVR exposure in playgrounds in relation to the most popular times of playground usage. Future studies focusing on these questions would help further knowledge in the field and support UVR protection in public spaces, particularly focusing on children and vulnerable populations.

## Disclosure statement

No potential conflict of interest was reported by the author(s).

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## Ethics

Human Research Ethics approval for this project has been granted by the University of the Sunshine Coast's Human Research Ethics Committee (HREC). The ethics approval number for the project is [S231859]. Ethics approval indicates that this project meets the requirements of Australia's National Health and Medical Research Council's (NHMRC) National Statement on Ethical Conduct in Human Research (2007).

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