Supporting the strategic planning of City of Unley (SA) towards a water sensitive city by quantifying the urban microclimate benefits using the Water Sensitive Cities Modelling Toolkit

A Collaboration between City of Unley, South Australia and the Cooperative Research Centre for Water Sensitive Cities

A draft report

Context

To create a more liveable, resilient and sustainable city for future generations, the City of Unley is committed to a journey towards becoming a water sensitive city by introducing green infrastructure/WSUD strategies. The strategies focus on delivering urban greening, enhanced streetscapes and mitigated urban heat load. The concept of liveability within the urban environment in the context of these strategies seeks to improve microclimate benefits, which will result from enhancing tree health and creating shade across the city.

The CRC for Water Sensitive Cities is collaborating with the City of Unley to support the strategic planning by quantifying potential microclimatic benefits associated green infrastructure and WSUD implementation. The Water Sensitive Cities (WSC) Toolkit is a numerical model developed by the CRC for Water Sensitive Cities consisting of a number of separate but connected modules that quantify the bio-physical performance of green infrastructure scenarios for stormwater management and urban greening.

Figure 1 Location and map of City of Unley

Assessing the benefit of green infrastructure/WSUD on urban microclimate

Theoretical background. The impact of different green infrastructure / stormwater management initiatives on land surface temperatures (LST) during extreme heat conditions were quantified using the WSC Toolkit's *Microclimate - Extreme Heat Module*. The data underpinning the model was obtained by the work done by Monash University for the Victorian Centre for Climate Change Adaptation Research (VCCCAR) (Coutts and Harris, 2013). Land Surface Temperature (LST) monitored between 12 pm and 2 pm within the City of Port of Phillip, Victoria on 26th February 2012 forms the database for the module, therefore allowing for an assessment of the various heating effects of the urban form of during a heatwave. The land surface temperature was found to be directly linked to different land covers, i.e. tree, water, road, roof, irrigated/non-irrigated grass and concrete. As such, changing the land cover proportions by introducing green infrastructure / WSUD is like to lead to a change in land surface temperature.

Input data generation. Two input files are needed for the Toolkit for assessing the microclimate benefits: (1) Land cover map (a geo-referenced raster file) and (2) study area image. Firstly, aerial imagery (provided by City of Unley) was used to generate a base land cover map using interactive supervised classification in

ESRI's ArcGIS Software (Figure 2). This was however identified as inaccurate in terms of roads/concrete surface as they share similar colours. Cars on roads were also problematic as they were frequently identified as roofs. To solve this problem, a road map generated from a land use map (source: www.sa.gov.au) was used to correct these auto-classification problems for the land cover map, i.e. the road map was burned into the base land cover map without replacing the tree coverage on the roads. Finally, the corrected land cover map was converted into a geo-referenced raster file (in ASCII .txt format) as input. The aerial image was also exported into study area image (in *.png* format) as the second input file.

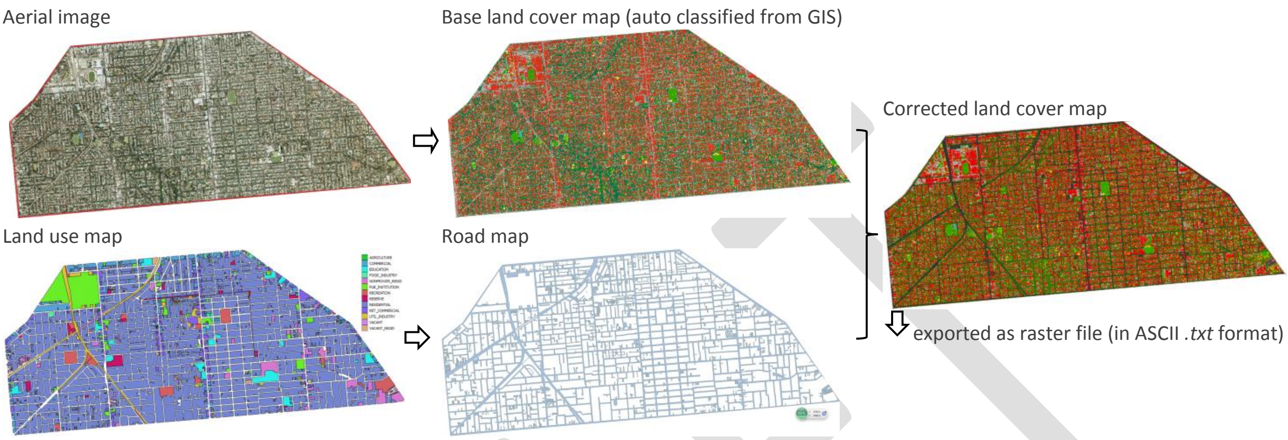


Figure 2 Generation of Land Cover map

Microclimate modelling. The following two tasks were performed:

- Apply the WSC Toolkit to the whole City of Unley to: (1) understand spatial land surface temperature distribution (heat map of Unley) and also (2) validate WSC Toolkit outputs by visualising the heat map of a residential area, a commercial area and a north-south cross-section of Unley.
- Apply the WSC Toolkit to quantify the potential microclimate benefits associated with the Leader Street (City of Unley) WSUD upgrade.

Heat distribution of the City of Unley municipality

City of Unley's spatial distribution of Land Surface Temperature before any implementation of green infrastructure or WSUD strategies was simulated using the WSC Toolkit (Figure 3). Key hot spots are visible in the simulation results: north-west area (box #1, showgrounds with high proportion of roof/concrete surface); the commercial area along the two sides of Unley road (box #4). Interestingly, we also found cooler locations, e.g. recreational areas with irrigated grass (large green spots) and the southern residential area (box #3) with a high density of tree coverage. This land surface temperature map also bears similarities with the 'Hotspots' map derived from tree coverage presented in the green infrastructure strategy for City of Unley (oxygen, 2015a).

Closer investigation of the heat distribution was undertaken for the residential area (box #2 in Figure 3) and commercial area (box #4 in Figure 3), results of which are shown in Table 1. The residential area exhibits higher percentage of tree canopy (39%), which provides cooler places along streets. In comparison, the commercial area contains a higher percentage of roof (41%), road (19%) and concrete surfaces (11%), which lead to higher land surface temperatures. Distribution of LST for the residential area was found to be more even while that of the commercial area was sharper and exhibited higher temperatures more frequently.

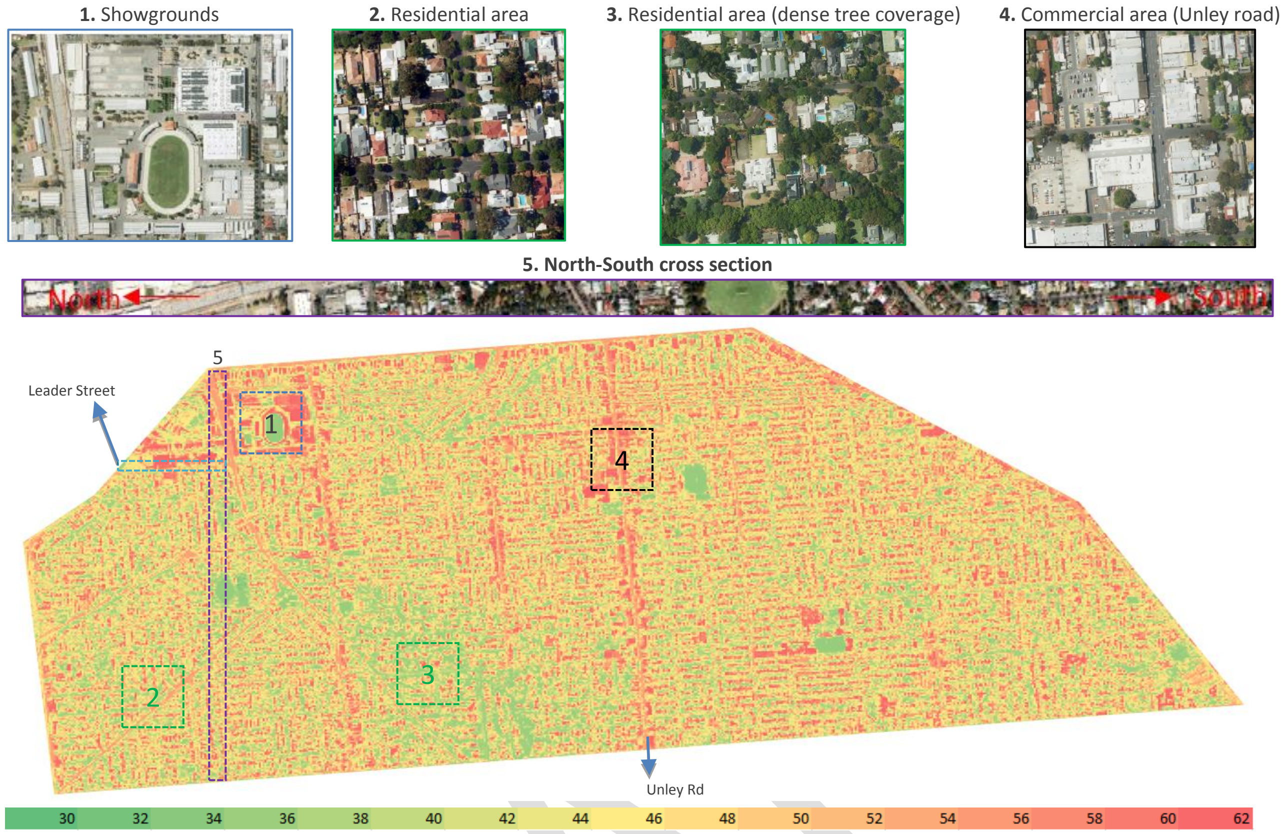
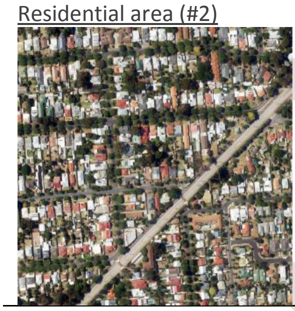


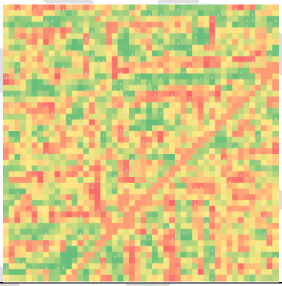
Figure 3 Land Surface Temperature Distribution across the City of Unley

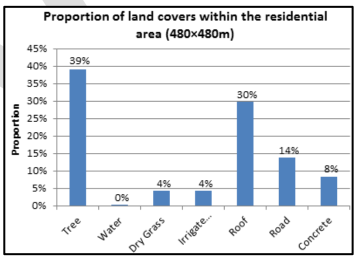
Table 1 Representation of spatial land surface temperature (LST) distributions for residential and commercial areas

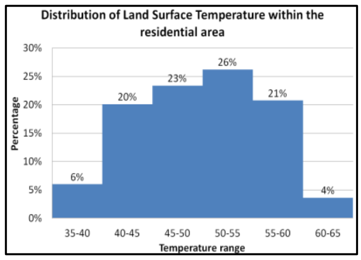
Aerial image | **Visual LST distribution** | **Land cover proportions and LST distribution**

Residential area (#2)

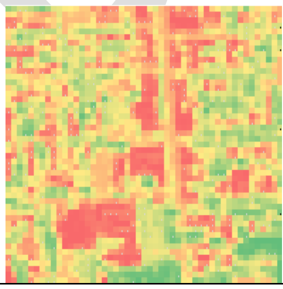


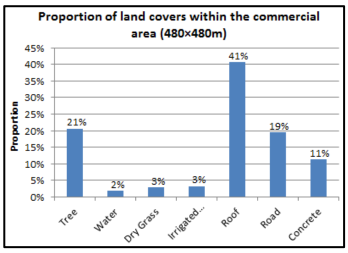


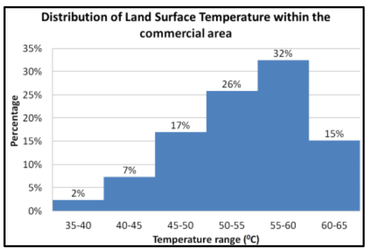




Commercial Area (#4)







Additionally, result of the land surface temperature variation across a north-south section (box #5 in Figure 3) is presented in Figure 4. This cross-section transects a range of different land uses (e.g. industrial – showgrounds – commercial – residential – reserve – residential –recreational – residential). A significant land surface temperature variation across this section was found (see Figure 4), particularly in the transition from green areas to built-up land.

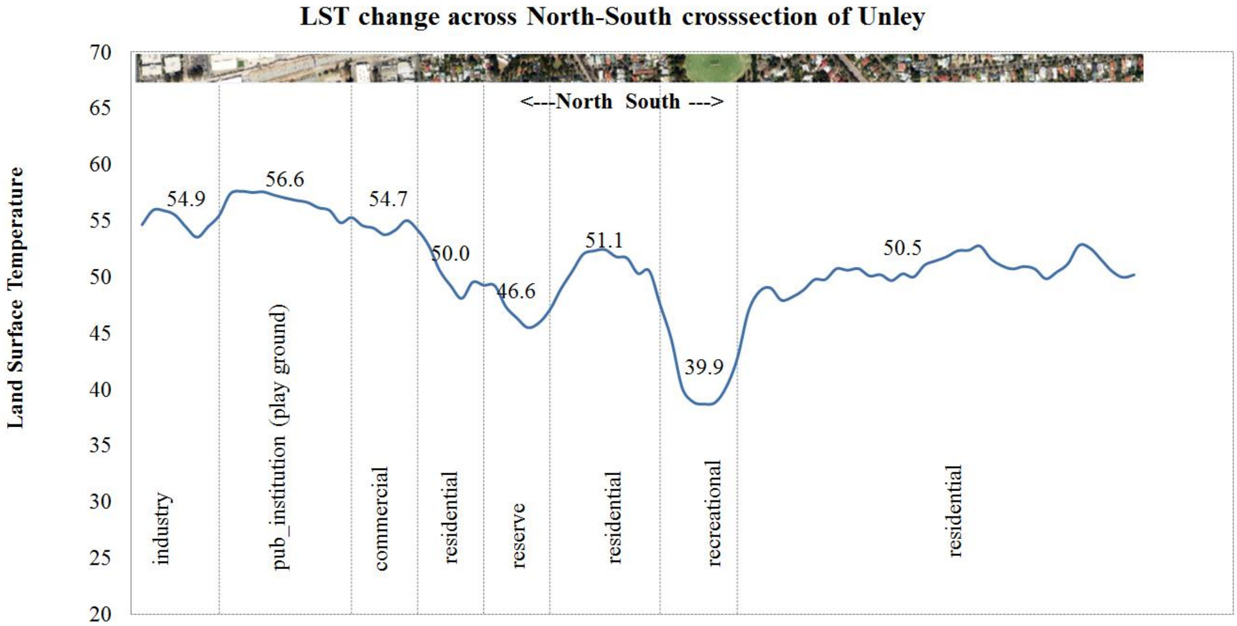


Figure 4 Land Surface Temperature (LST) (moving average) change across the north-south cross section (average temperature indicated in each section)

The excellent representation of heat spots (in terms of land surface temperature) over the whole City of Unley municipality provides high confidence of the WSC Toolkit in assessing local microclimate. The heat map itself can assist the planning of green infrastructure or WSUD interventions, e.g. the placement of trees at hot spots. It also provides the basis for assessing the microclimate benefits when green infrastructure and WSUD strategies are implemented. The following section will look into a WSUD upgrade of Leader Street in City of Unley, to quantify the microclimate benefits associated with the WSUD implementation.

Leader Street upgrade case study for evaluating microclimate benefit

Context and proposed upgrade

Leader Street (1.1 km) extends from Anzac Hwy (Forestville) in the west and Goodwood Rd (Goodwood) in the east (location in Figure 3; street overview in Figure 5 a). The street separates a residential district in the south from dense commercial area in the north, which comprises a large warehouse (Section 1), shops and restaurants (Section 2), showgrounds and farmers' market (Section 3).

The Leader Street Upgrade Concept Plan Report (Oxigen, 2015b) suggests a combination of bio-swales, rain-gardens and trees for implementation (Figure 5). Rain-gardens supporting trees at 15m intervals will be established on both sides of the Zone 1 and Zone 2 (west of the railway line) and on the southern side of Section 3. Trees (without rain-gardens) will be planted at 8m intervals on the northern side of Section 3. Bio-swales will be constructed at each intersection (Figure 5).

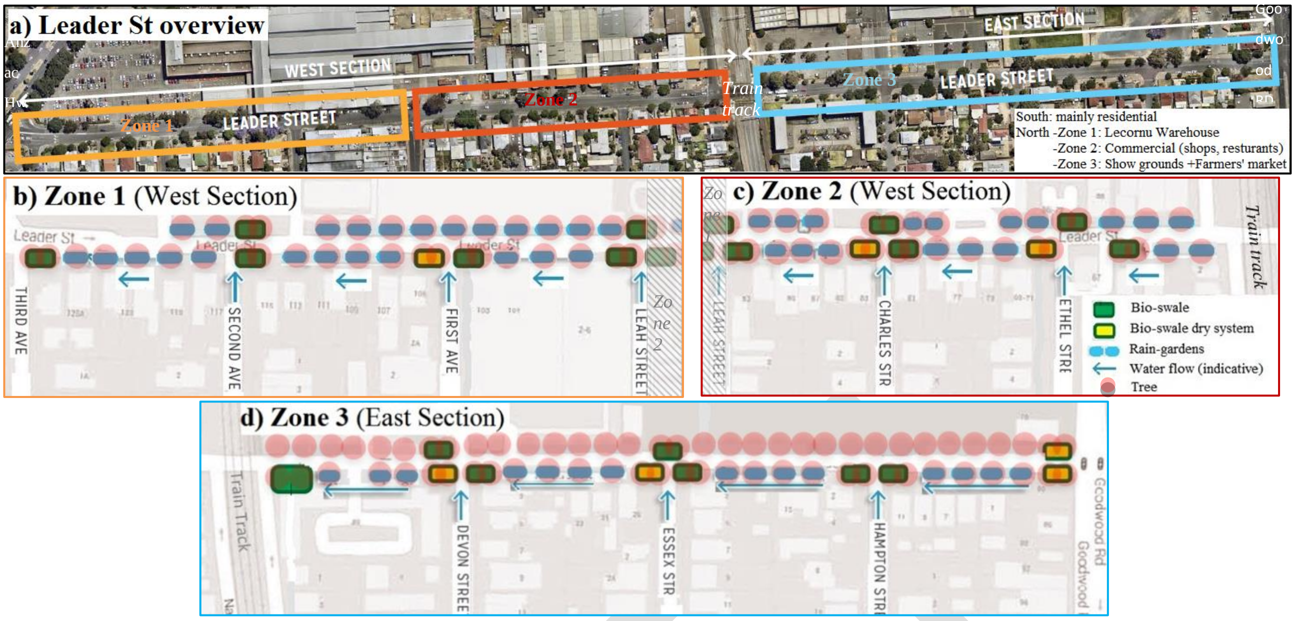


Figure 5 Leader Street Water Sensitive Urban Design elements (a. Leader St Overview; b. Zone 1; c. Zone 2; and d. Zone 3)

Assessing the benefit of WSUD on urban microclimate

The *Microclimate – Extreme Heat Module* of the WSC Toolkit was set up specifically for the Leader Street. Simulating the Leader Street upgrade in the WSC Toolkit involved changing land covers within the road reserve (e.g. installation of a rain-garden; Figure 5) and, from an urban heat perspective, projecting other changes above the ground surface (e.g. a tree canopy) onto the land cover map. The water-sensitive scenario comprised a 4% increase in surface-level green infrastructure (i.e. rain-gardens, bio-swales), as well as a 5% increase in hard surfaces shaded by tree canopy. This change in land cover influenced land surface temperatures (and, consequently, air temperature) along the street. Land surface temperature distributions before and after the street upgrade (following tree canopy establishment) are presented in Figure 6.

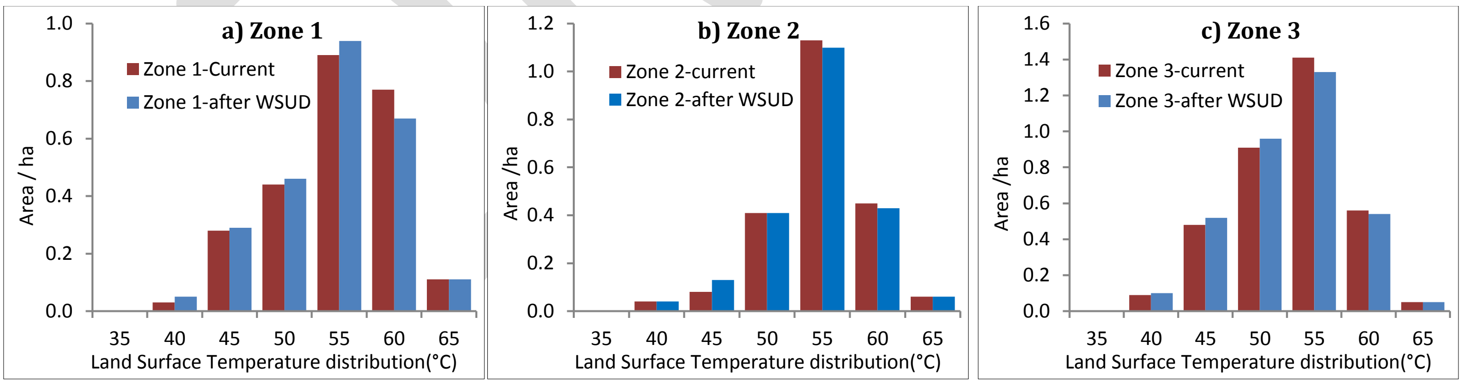


Figure 6 Land Surface Temperature reduction distribution of the current Leader Street and after WSUD implementation and establishment.

Figure 7 shows the simulated extent and degree of land-surface cooling: (a) after the street upgrade, and (b) following establishment of the tree canopy. All three zones are combined in this figure, which shows land-surface temperature reductions of up to 3 ^{o}C across 41% (0.8 ha) of the site as a result of changes to land cover. Following establishment of the tree canopy associated with the street upgrade, 35% (0.7 ha) is reduced by 0-3 ^{o}C and 16 % (0.3 ha) by 3-6 ^{o}C.

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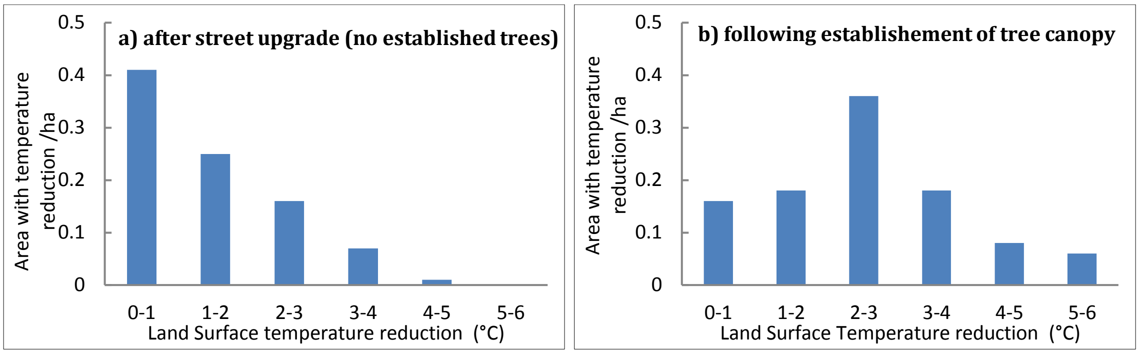

Figure 7 Land surface temperature reductions: (a) after street upgrade, and (b) following establishment of the tree canopy.

Figure 8 shows the spatial influence of the street upgrade on land surface temperatures. Reductions of up to 6 ^{o}C on extreme heat days can provide considerable cooling benefit to people utilising this street. The higher land-surface temperature reductions (5-6 ^{o}C) are predominantly achieved at the intersections where large bio-swales or rain-gardens incorporating trees were implemented.

Figure 8 Land Surface Temperature reduction along the Leader Street (following full establishment of tree canopy)

Stormwater captured and treated by rain-gardens and bio-swales will support the health of trees within these systems through passive watering and maintaining soil moisture. In addition to microclimate benefits, the WSUD elements will contribute to a reduction in excess stormwater volumes stormwater and an improvement in the quality of water discharged from the street, which can be assessed using other modules of the WSC Toolkit.

Summary

The spatial distribution of land surface temperature can be well represented by the WSC Toolkit. The upgrade of Leader Street into an active healthy living street incorporating water sensitive urban design features can improve the local microclimate through the reduction of land-surface temperatures by up to 6 ^{o}C during extreme hot summers.

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