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# A technique for quantifying the reduction of solar radiation due to cloud and tree cover.

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**Abstract**

The micro-climate of a domestic residential landscape can affect both the energy use of the dwelling and the human thermal comfort within that landscape. Radiant energy produced from, or reduced by different landscape elements such as trees, and hard and soft surfaces, directly affects the amount of heat incident on the walls of the residence or on people present in the garden. Quantifying this energy will enable the development of a relative scale of thermal performance for these elements and consequently for the landscape as a whole. This gives a measured consequence for each landscape design, allowing comparisons and hopefully improvements, between and within designs.
Radiant energy is produced from direct or diffuse solar short wave and infrared radiation and longwave radiation from heated landscape elements. This paper presents a technique which has been developed for inexpensively and easily estimating the amount of incident radiation reduced by cloud and by three different tree types. The measurement surfaces of cheap temperature sensors with data logging capabilities (iButtons) were coated with either a white gloss or a matt black paint. White gloss paint has an emissivity of ~0.9 in the longwave spectrum but only ~0.3 in the short wave, whereas matt black paint has an emissivity of ~0.95 for both and can be used to detect both short and long wave radiation. The temperature difference between the two gives a measure of the amount of shortwave radiation or visible light. This enabled measurements of cloud shade and local plant shade, and an estimation of the quantity of that shade when compared with full sky exposed reference iButtons. The iButtons can be mounted concurrently at numerous points around a house envelope or in a landscape, at multiple house locations to determine the quantity of shade provided by different native and introduced plant species.

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## Introduction

The microclimate of a residential landscape can have a significant influence on increasing resilience (social, economic and ecological) and reducing emissions ([1], [2]). The landscape has an effect on the emissions produced by the residence through cooling and heating requirements; shade reduces the amount of radiant heat on surfaces thus reducing absorbed, re-radiated and reflected heat; transpiration from vegetation increases cooling; permeable surfaces increase the amount of water available to vegetation, increasing transpiration rates; trees planted together can create wind breaks, moderating hot or cold breezes ([3], [4], [5],[6]). These effects increase the resilience of the homeowner economically through reduced energy costs, and health-wise through a cooler home environment (lower heat stress) both within the landscape and inside the residence ([1]). Ecosystem services provided by gardens go beyond those of thermal services to include aesthetic appeal, improved air quality, biodiversity, water and wind management, food production and many more ([7], [8]). For example, green landscapes are also associated with reduced stress and increased mental health - substantiating the concept of biophilic design ([9], [10], [11]), however the thermal effects are more easily quantified and in this paper will form a starting point for landscape comparisons.

Comprehensive research has been done on the effects of both shade trees and light coloured surfaces in reducing energy use by homeowners and increasing human thermal comfort. The [12] report from fieldwork, that strategically planted trees and shrubs could typically reduce summer air conditioning costs by 15-35% and up to 50% is some situations; other more recent studies based on both computer modelling and fieldwork have found similar results ([13] show a reduction of 20% due to urban trees and high-albedo surfaces; [2] and [14] show tree shade is associated with reduced electricity consumption in summertime depending on tree location; [15] state that trees can contribute 167kWh/tree of electricity savings). [16], [17] and [3] report reduction in energy use and improvement in Human Thermal Comfort due to green infrastructure. [18] found that trees could reduce heat stress from ‘very strong’ to ‘strong’. [19] found air conditioning requirements were reduced by using rooves of higher total solar reflectance, as did [20]. [21] showed tree shade could reduce surface temperatures of buildings by up to 9°C. This body of knowledge would be improved by measuring and modelling the thermal properties of more types of landscape elements and their relative positions within a residential landscape (particularly where tree shade is not possible) to both reduce energy use and improve human thermal comfort.

[6] studied the effect of using vines to shade the walls of houses. He used thermocouples attached to sheets (10x15cm) of aluminium backed with styrofoam as the “walls” behind the vines and recorded data using a data logger over a period of several years. The aluminium was painted either dark brown or white to simulate dark or light wall colours. In much the same way, this study uses self-logging temperature sensors painted either black or white to examine the incident radiation under conditions of full sun, tree shade and cloud shade. Although instrumentation is commercially available to measure both long and short wave radiation (pyrgeometers; pyranometers), and to measure quality of tree shade (LAI-2200 [22]; hemispherical photography), they are relatively expensive which limits the amount of measurements which can be done concurrently. By designing a cheaper alternative, multiple landscapes can be monitored over different seasons, providing a much larger data set for analysis.

**Nomenclature**

| | |
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| JH | Josh Byrnes’ House |
| SR | solar radiation, includes direct and diffuse |
| LWR | longwave radiation, 3 - 100µm |
| SWR | shortwave radiation, 0.1-3µm |
| $T_B$ | Temperature of the black painted iButton |
| $T_W$ | Temperature of the white painted iButton |