Study of Illumination and Erythemal Ultraviolet Radiation under Tree Shade

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Abstract

This paper provides students to the opportunity to study the Physics of electromagnetic radiation and its interaction with the physical environment and also illustrate that Physics exists not only in situ but also outside the laboratory. The amount of erythemal ultraviolet solar radiation in different tree shades are measured at different times of the day and compared with changes in illumination levels and temperature. Lux meter (model LT300), EXTECH instrument, is used to measure the illumination of the light in these measurements. The general tool UV513AB digital UVAB Meter is employed to measure ultraviolet light This experiment is also the description of the application of the light meter and UVAB meter.

Key words: Erythemal UV irradiance, Illumination, Tree shade

Introduction

As radiation passes through the atmosphere, certain wavelengths are absorbed and scattered by the atmospheric gases. Because of these processes, only about 50 percent of the insolation reaches the Earth's surface at sea level. Diffuse insolation is scattered or reflected by atmospheric components in the sky. The proportion of insolation reflected or absorbed depends on the object's reflectivity or albedo. Ultraviolet radiation at all wavelengths (UVA 315 - 400 nm, UVB 280 - 315 nm and UVC 200-280 nm) is found in this insolation. At various altitudes and blocking of different bands of ultraviolet radiation, essentially all UVC is blocked by dioxygen (from 100-200 nm) or by ozone (200-280 nm) in the atmosphere. The ozone layer then blocks most UVB. Meanwhile, UVA is hardly affected by ozone and most of it reaches the ground. Erythema is sunburn, the reddening of the skin when it is exposed to too much UV radiation (UVA and UVB both contribute to erythema). In many cases, the UV radiance is multiplied with the erythemal action spectrum and integrated over the UVA and UVB wavelengths. The result is called erythemal UV radiation. The erythemal action spectrum has been defined by the International Lighting Commission (CIE).

Ultraviolet (UV) exposure to humans is due to sunlight received as direct radiation and diffuse radiation. This diffuse radiation may constitute a significant component to the UV exposure received by humans' eyes and skin as it is incident from all directions and difficult to minimise with the usage of hats, tree shade and shade structures as it can reach surfaces shaded from the direct component. The high diffuse UV component may result in high UV radiant exposures in the tree shade to parts of the body that are not protected from UV radiation that are at all orientations and inclinations, including the vertical.

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The relative comfort level of the environment under test trees was determined by Robert D. Brown and Terry J. Gillespie (1990), using an energy budget 'human thermal comfort' model. Richard et al., (2002) has developed a three-dimensional model to predict the ultraviolet-B (UV-B) irradiance fields in open-tree canopies where the spacing between trees is equal to or greater than the width of individual tree crowns. The first set of quantitative data of diffuse erythemal UV and UVA in tree shade at a sub-tropical Southern Hemisphere latitude over the summer has provided by Parisi et al.,. The amount of sunlight intercepted by a tree varies with the species. Many researchers have investigated the porosity, or transmissivity values of tree canopies, in both summer and winter (Richard et al., 2002). A. Serrano et al., (2006) presents four and one-half years of original records of high temporal resolution ultraviolet erythemal radiation (UVER) measured in Badajoz, Spain. The shaded readings within the tree shade were compared to measurements in full sunshine to provide protection factors (PFs) for each of the trees (Peter Gies et al.,). Despite the intuitive understanding that the shade of a tree with the associated cooler temperatures will reduce the exposure to solar UV radiation, the question is how much protection is provided from the sun in the shade of a tree. In tree shade, a larger proportion of the UV compared to that in full sun may be as a result of the diffuse component due to attenuation and filtering of the direct component. However, no previous research has considered the diffuse UV irradiances in tree shade. In this paper the amount of solar ultraviolet radiation in tree shade is measured at different times of the day and compared with changes in illumination levels and temperature.

Material and Methods

Illuminance is measured using a lux meter (Model LT300 EXTECH instrument). Although the measuring method in it itself is accurate, lux readings are deceptive in regards to describing light sensitivity. Whereas a lux meter records the amount of visible light that hits, or illuminates, a given area (incident light). When a lux value is measured in a scene, it only represents the illuminance at the object in focus. For example, the lux value represents the illuminance at the point of the tree or in front of the building. A lux meter is also a device for measuring brightness. Therefore it specifically measures the intensity with which the brightness appears to the human eye. This is different than measurements of the actual light energy produced by or reflected from an object or light source. A lux meter works by using a photo cell to capture light. The meter then converts this light to an electrical current. Measuring this current allows the device to calculate the lux value of the light it captured.

The study used some simple, inexpensive, easy to use the lux meter. The shade ratio, T_S (Parisi et al., 1999) is defined as: $$T_S = \frac{KLUX_S}{KLUX} , \qquad (1)$$

where $KLUX_s$ is the illuminance measured with the lux meter in tree shade on a horizontal plane and *KLUX* is the ambient illuminance to an unshaded horizontal plane. Firstly two trees with shade that is clear of other shade and the trees preferably of two different species are selected for the measurement of the illumination and temperature. These two trees are Mae Zali (*Cassia siamea L*) and Gangaw (*Mesua ferrea L*). These are grown in Lashio University Campus. Gangaw is defined as Tree I and Mae Zali is also defined as Tree II. The measurements are undertaken at 10 o'clock in the morning and repeated at afternoon: 1pm and 4pm in order to investigate the effect of the different solar altitude angles on the UV radiation in the tree shade. These measurements are taken daily. But it is not done on the rainy day. The illuminations under the tree shade and over the tree shade (in the sun) are measured by Lux meter. The temperatures with the thermometer under the shade of the trees and in the sun are also measured day by day. Then the ratio of the illumination levels and the temperatures in the tree-shade and that in sunlight are compared. Measurements were repeated on every day, especially sunny days for the months May (2012) to May (2013) to assess whether the shade cover provided by the trees changed with season as a result of changing foliage and sun angle.

The general tool UV513AB digital UVAB Meter [Dimensions: 5.51 x 1.93 x 1.14 in. (140 x 49 x 29mm) Weight: 3.2 oz. (90g)] is employed to measure ultraviolet light in the range from 280 to 400 nanometers (UVAB). The illumination range of the meter allows us to conduct the most precise quantitative measurements of ultraviolet radiation for radiometry and laboratory requirements. The extensive study examined 6 main species. These six trees are Padauk (*Pterocarpus Sp.*), Gangaw (*Mesua ferrea L.*), Sein pan apya (*Jacaranda ovalifolia R.Br.*), Akyaw (*Plumeria alba L.*), Peinne (*Artocarpus heterophyllus Lam.*), and Pinle kabwe (*Casuarina equisetifolia Forst.*) defined as Tree I, II, III, IV, V, and VI respectively. These six trees are clear of other shade and the trees preferably of different species with a canopy width of approximately 3 m or more. We utilize a day with less than two eights of the sky covered in cloud or at least a period with the cloud free of the solar disc. The following measurements should be undertaken in the morning, for example 10:00 am and repeated at noon in order to investigate the effect of the different solar altitude angles on the UV radiation in the tree shade.

We place the digital UVAB meter at the height of 1m from the ground on a horizontal plane with the white sensor facing up in order to reduce any shading of the sensor. Measure the $UVAB_s$ with the meter at 4 locations (East, West, North, South) in the shade of one tree. Immediately after measure the *UVAB* in full sun with the radiometer at the height of 1m from the ground on a horizontal plane. This measurement should be undertaken at least 2 m from the tree shade. In a similar manner, we repeat the measurement of $UVAB_s$ and *UVAB* for the second tree. The percentage reduction of erythemal UV is calculated by:

$$R = \frac{UVAB - UVAB_S}{UVAB} \times 100\% \,, \qquad (2)$$

where $UVAB_s$ is the erythermal irradiance measured with the UVAB meter in tree shade on a horizontal plane and *UVAB* is the ambient erythermal irradiance to an unshaded horizontal plane. At the same time as the previous two steps, we can measure the ground temperature with Extech HD200 Differential Thermometer (Datalogger + IR) and the humidity with Max-Min Thermo Hygrometer in tree shade and in full sun.

Results and Discussion

The sample results in Figure 1 and 2 provide the illumination levels and temperature in the tree shades and in the sun along with the respective ratios of tree shade to sun for both trees in the morning, at noon and in the evening. In these results the ratio of the illumination levels being mostly lower for the Tree II (Mae Zali) compared to the Tree I (Gangaw). The ratio of the illumination level for Tree I are lower than Tree II were found in some evening (4pm). The ratios of illumination level for Tree I are nearly equal for Tree II were found in many days. Tree I (Gangaw) is more leaves and well shad than Tree II (Mae Zali).

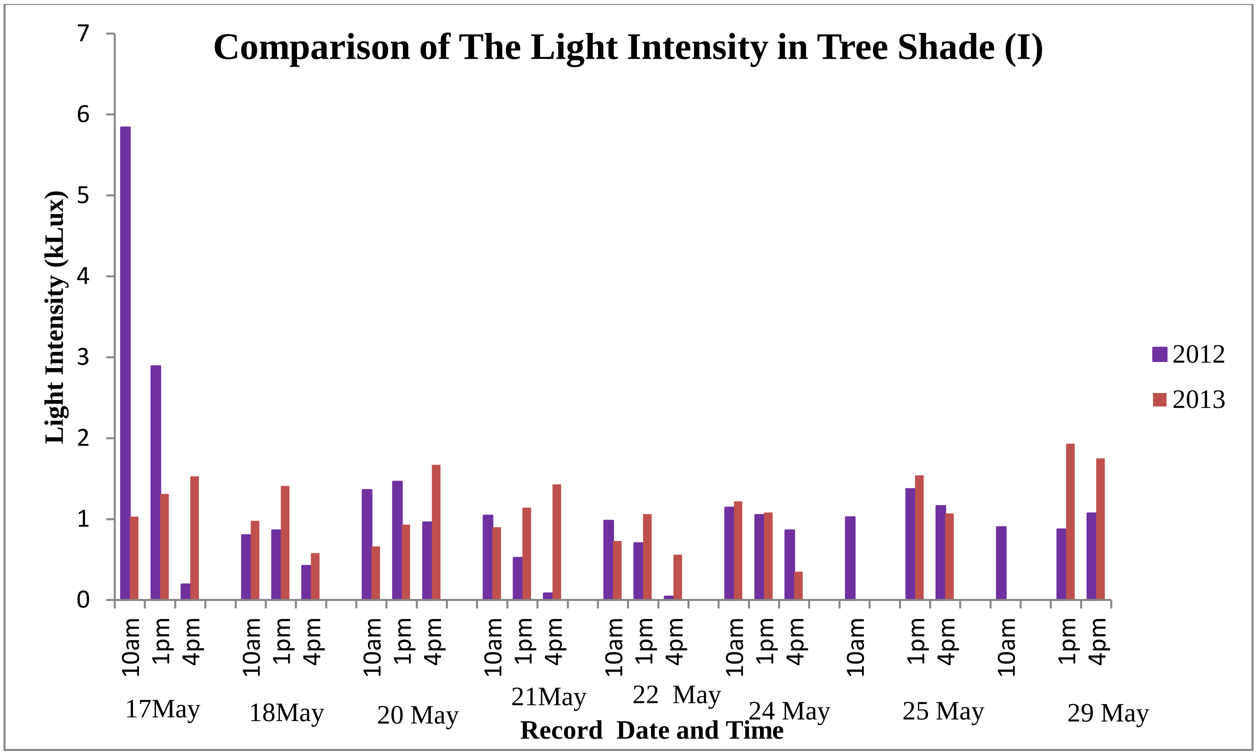

Fig. 1 Comparison of the Light Intensity in Tree Shade I (May 2012 and May, 2013)

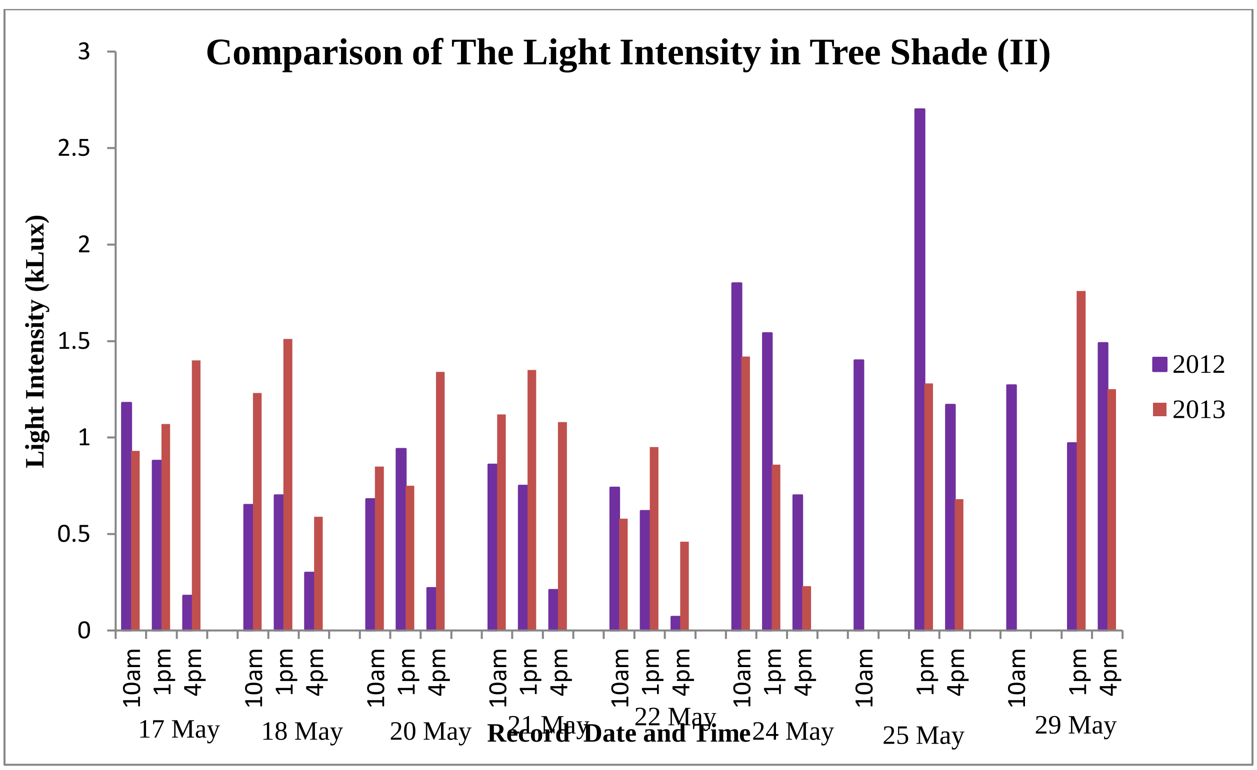

Fig. 2 Comparison of the Light Intensity in Tree Shade II (May 2012 and May, 2013)

The studies are performed in Lashio University campus situated in Longitude 22°57’ N and Latitude 97°44’W in the northern hemisphere. This location is put in the Sunrise Sunset calendar software and calculated for four months; May, June, July and August, 2012. In May, the calculated results of solar noon times are 12:57pm and 12:58pm in measuring days. In June, the calculated results of solar noon times are 1:00pm, 1:01pm, 1:02pm, 1:03pm and 1:04pm in measuring days. In July, the calculated results of solar noon times are 1:05pm, 1:06pm, 1:07pm and 1:08pm in measuring days. In August, the calculated results of solar noon times are 1:07pm, 1:06pm, 1:05pm, 1:04pm, 1:02 and 1:01pm in measuring days. According to these results the light intensity is more at noon time 1:00pm.

In May 2012 the maximum illuminations of the light are 101.4kLux at noon and 108.1kLux at morning. In this time the illumination of light in tree shade is nearly 1kLux. The minimum illumination is 2.12kLux in evening. In June 2012 the maximum illuminations of the light are 100.8kLux and 101.3klux at noon. In this time the illumination of light in tree shad is also nearly 1kLux. The minimum illumination is 8.97kLux in evening. In July 2012 the maximum illuminations of the light are 129.2kLux and 103.9kLux at noon. In this time the illumination of light in tree shad is nearly 1kLux. The minimum illumination is 8.9kLux in morning. In August 2012 the maximum illuminations of the light are 106kLux, 102.5kLux and 100.5kLux at noon. In this time the illumination of light in tree shade is also nearly 1kLux. The minimum illumination is 17.7kLux in morning. The ratio of the illumination levels in the tree shade compared to full sun is less.

A sample result is provided in Figure 3. In this case, the absolute diffuse UV irradiances on a horizontal plane averaged over all of the trees in tree shade and in full sun are provided for the morning, noon and afternoon. The diffuse UV irradiances in the tree shade are higher at noon by 48% and 20% respectively compared to the average of the morning and afternoon irradiances, most likely due to the higher noon irradiances. The results show that there is a higher amount of UV in the shade of the Padauk tree I compared to the other trees. This is due to the dense foliage of the other tree compared to the Padauk tree. Therefore the results obtained may vary from these according to the types of trees employed. The UV shade ratio for all the trees is expected to be higher at noon compared to the morning due to the additional scattering by the cloud at noon increased the proportion of diffuse radiation. However, this is not the case with the sample results provided in Figure 4. The reason is that in this case, there was approximately one half of the sky covered in cloud with the solar disc clear of cloud in the morning compared to a clear sky for noon readings. Consequently, in this case, the longer atmospheric pathlength in the morning resulting in a larger amount of molecular scattering and a higher relative proportion of diffuse UV radiation.

The general trend of the Percentage reduction of erythemal UV as a function of the illuminance shade ratios in the relevant shade trees are shown in Figure 5. The illuminances of the shade trees influence the amount of solar UV radiation that reaches pedestrians. This is due to the higher amount of diffuse radiation at the shorter wavelengths. The illumination levels in the tree shade do not necessarily provide an indication of the skin damaging UV in the shade. The cooler temperatures in the tree shade do not necessarily mean there is no skin damaging UV in the shade. The temperature is a result of the infrared electromagnetic radiation that is at the longer wavelength end of the spectrum compared to visible and UV radiation. Consequently, the temperature may not provide an indication of the UV radiation.

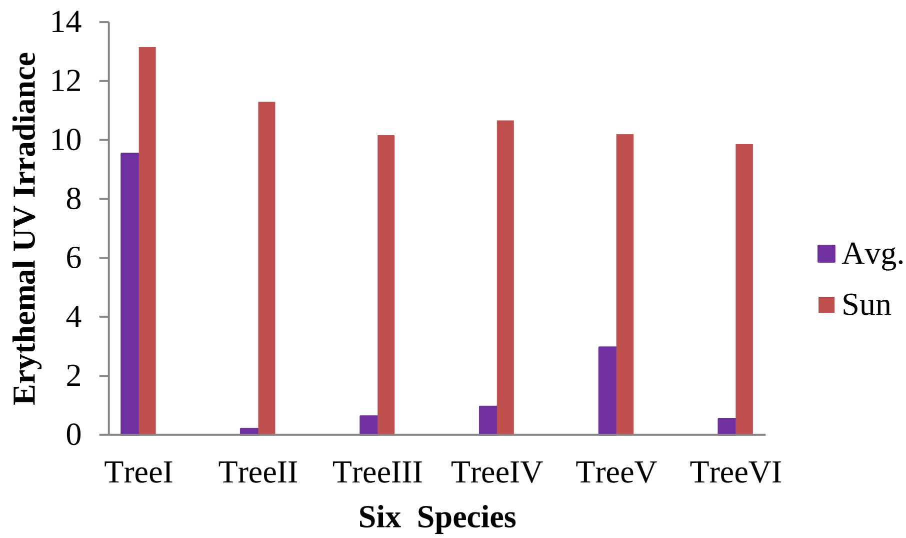

Fig. 3 The erythemal UV irradiances in the tree shade of the six types of trees in full sun for noon times of the day.

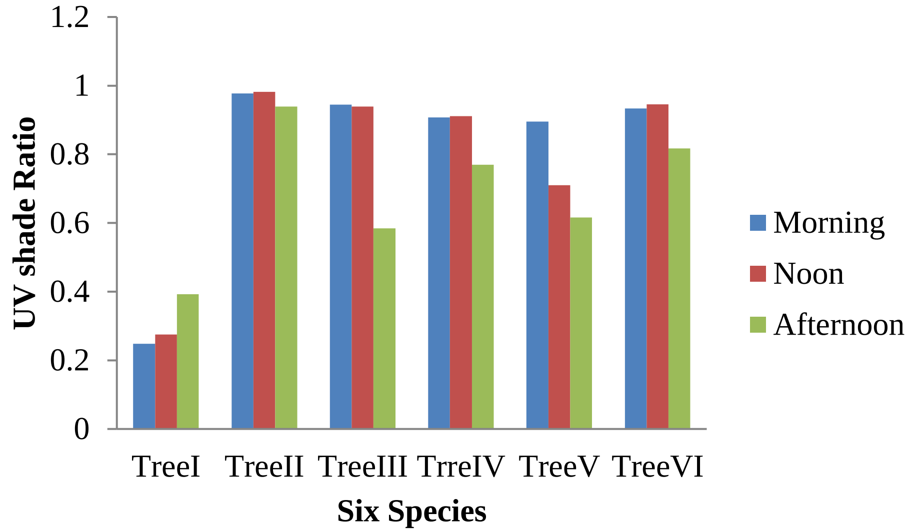

Fig. 4 The UV shade ratio of the erythemal UV irradiance in the tree shade compared to the relevant full sun.

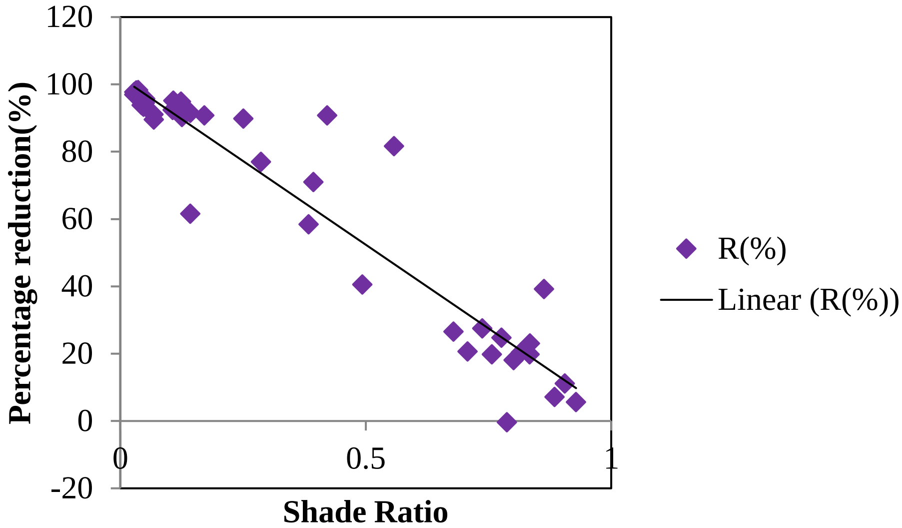

Fig. 5 Percentage reduction of erythemal UV as a function of the illuminance shade ratios.

Conclusion

The use of different forms of shade is an essential part of a UV minimization strategy. While shade reduces the direct component of global (direct and diffuse combined) UV, the proportion of diffuse UV present in the shade can still be significantly high. The research presented in this paper tends the next researches to provide an assessment of the levels of erythemal UV that people can be exposed to while utilizing the shade of a commonly employed shade structure. An experiment is described to expose students in a 'hands-on' manner to the physics of instrumentation, measurement, electromagnetic radiation and in particular UV radiation. The students will have no difficulty in setting up the apparatus themselves and they will obtain reliable results within a normal school practical period. Additionally, the students will undertake a scientific experiment relevant to everyday life.

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