User comfort on urban roads

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Abstract: *Urbanization was one of the movements taken by man to impose his super powers on the natural world to make his life more comfortable, ignoring that the trees plays pivotal role in the natural world and also in his life. As a result, it has been responding to the man by changing the climate, creating, daunting challenges of global warming, air pollution, etc. Due to the urbanization of most of the cities in the world, trees were replaced by the infrastructure and accordingly, the users of urban areas were suffered from the discomfort due to high temperature, especially, when they are on the roads. Therefore, man was forced to rethink about replanting, trees on the urban roads. From this research, it was identified the logical relationship between the actual thermal performance of the urban roads and how it feels to the users of the roads, on different hours of the day. Further, this research, emphasized, that having properly planted trees on the roads, can provide the comfort to the users without any disturbance to their activities on the roads, and also contributes to minimize the environmental issues that the world is facing today.*

Key words: *Urban roads, Air temperature, Humidity, User comfort, Tree shading*

1. INTRODUCTION

Climate change has become the most threatening problem that the world is experiencing today. According to Houghton (1997) and Spencer (2010), variations in day-to-day whether are occurring all the time; they are very much part of our life. As a result, the phrase "Global Warming" has become familiar to many people as one of the environmental issues of our day. Further, several studies carried out by different scholars have indicated that the world climate has got hotter during last two decades. Similarly, there is a very significant periodic seasonal variation in the air temperature of the city of Colombo. Figure 1, represents the air temperature distribution of Colombo city from 1901 to 2001. It clearly indicates the deviations of the temperature from the average temperature. The average air temperature of the city for 100 years from 1901 to 2001 is 27.25°C (Manawadu & Liyanage, 2008). The early 1910 to 1960's the temperature has a negative deviation from the average temperature and afterwards the temperature increases year by year.

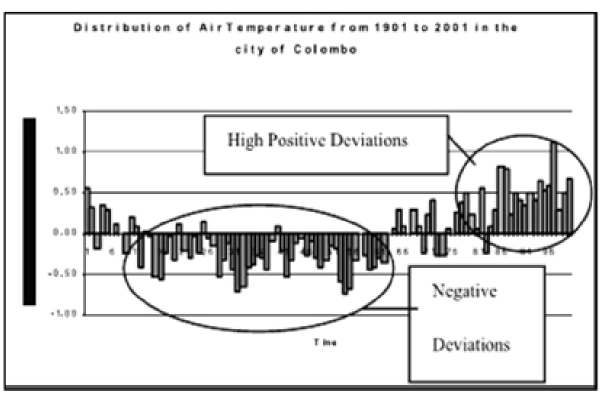


Figure 1 Air temperature distribution Source ; Manawadu & Liyanage, 2008

Figure 2, shows the trend of increasing temperature of the city in recent past. The increase in the temperature is quite rapid and the trend line shows that the temperature increase within the 60 years from 1940 to 2000 is 1° C which is far higher than the global temperature increase. Further, parallel to the temperature increase in city of Colombo and since Sri Lanka is located close to the equator with latitude between 5^0 to 9^0 north's, so there can be direct solar radiation on roads for about five months of the years, at the different times.

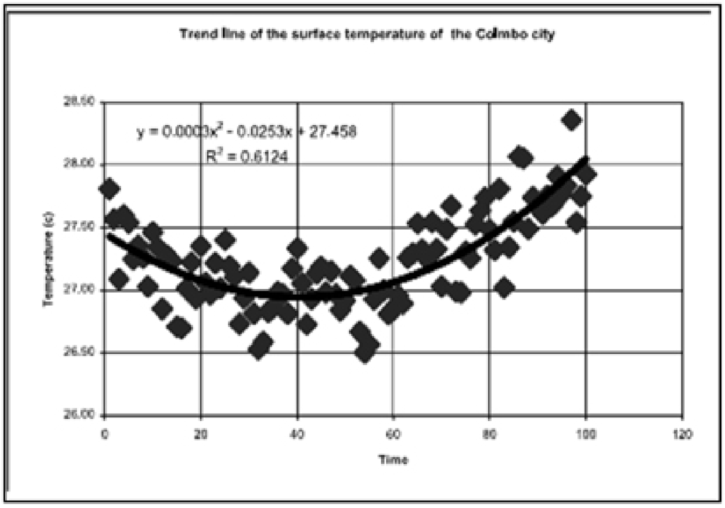


Figure 2 Trend line of the temperature of city of Colombo Source ; Manawadu & Liyanage, 2008

Every day, the road surface will be subjected to direct solar radiation for about half a day. Therefore, screening of sunlight is also important owing to its reduction of direct radiation from the sun during clear days (Manawadu & Liyanage, 2008).

Further, urban heat island effect is a more immediate concern in cities related with impervious surfaces. In the peak of summer in warm climate areas, temperatures of asphalt pavements can reach 77^{0}C (Karen et.al, 2007). In Sri Lanka most of asphalt paved roads are exposed to sun light directly. Asphalt surfaces generally absorb solar radiation in day time and release it overnight. Asphalt absorbs most of the visible light that falls on it. (Asphalt pavements similarly absorb the invisible infrared solar radiation.) Thus the energy in the absorbed sunlight becomes heat in the pavement. Generally the absorption capacity of bitumen surfaces is much higher as it is a black body. Because of that it keeps surrounding warmer than if the bitumen road surface covers with tree shadings. If there are trees overlap streets which shading large proportions pavement it will intercept radiation before it reaches sealed surfaces. So the amount of solar radiation is less which reaches the asphalt surface due to reflection by trees and also some parts of solar radiation are absorbed by trees. Because of that tree shadings reduce the surface temperature of asphalt surfaces and surrounding (Waltz & Hwang, 2011).
According to, Planet Ark Environmental Foundation (2011), basic positive impact of trees is that is help to reduce surface temperature. Most tropical countries are using trees for reducing surface temperature. The urban heat island is in part caused by heat production from cars, heating and air conditioning of buildings, industrial processes, and urban structures that may slow winds and hence prevent heat exchange. However, another main component of the extra heat in cities comes from dry sealed surfaces. Sun-exposed pavement absorbs radiation throughout the day, charging up on heat like a battery, and then releasing it overnight. This release of sensible heat [heat that causes a change in temperature in an object is called sensible heat, (Mcketta, 1992)] keeps the neighborhoods warmer than if the surface was vegetated or shaded. Likewise, one benefit of urban trees, there is the relationship between tree shade and pavement performance (Watson & Labs, 1983).
The aesthetic value of old, large trees has been shown to increase the attractiveness of town streets and the large trees in road side the roads may positively affect the psychology of residents, pedestrians and drivers, including reducing solar radiation which hit the road surface directly, limiting runoff of rain water which can cause to erode the road surface, absorption of urban noise which comes from vehicles, improving human health and reduced psychological stresses (Heisler, 1997). Also urban tree shadings in road side reduce regional air pollutants (Ozone, PM10, NO2, SO2, CO) by 1% to 3% of anthropogenic sources and the major advantage of roadside trees is roadside trees capture more large-size particulate matter than trees not near the road. (Scott, et.al, 1999).These effects have implications for air quality standards. Also vegetative canopies provide a cooling effect on microclimate directly by shading the ground surface and indirectly through transpiration. Therefore many cities have started tree planting programs in order to improve environmental conditions and alleviate the urban heat island effect. (Carol, et.al, 2011) and (Maco, et.al, 2002)

Conversely, one of the problems related to roadside trees is visual disturbance to drivers and pedestrians. This problem is mainly occurred at the junctions and curves. Use of a “clear zones” or lateral roadside space free of rigid obstacles is a major policy related to roadside trees. Yet street trees are often perceived as liabilities due to litter drop, root damage to side walkways, and visibility and security problems created by blocking signs and lighting. Also root of trees can be caused to damage for drainage system. Localized pavement failures are often caused by poor drainage systems. When side drains and culverts silt up, water ponds against the road embankment eventually weakening the lower pavement layers (Gregory, 2005).

2. OBJECTIVES AND THE METHODOLOGY

The objectives of the research;

- To find out, the actual performance of an urban road with and without trees, with respect to temperature and humidity during the daytime.
- To find out, the user satisfaction on urban roads, with and without trees, in different times of the day.
- To understand the relationship between the performance and the level of user comfort on urban roads with and without trees during the daytime.

The following methodology was developed to achieve the objectives of the research:

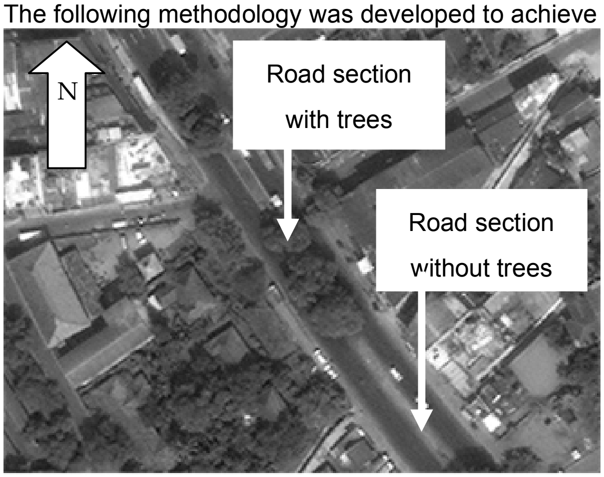


Figure 3 Selected road sections

As in Figure 3, most suitable urban road section, with morning and evening heavy traffic and also having shaded and un-shaded areas in close vicinity was selected, in between Katubadda and Rathmalana, concentrating on same location ,close to each other, to get more accurate field measurements. Further, the selected road was oriented to north-west and south-east directions. Required measurements were taken, throughout the day starting from 9.00 am to 4.00 p.m. in every one hour interval, with respect to temperature and humidity of the road and these measurements were taken, above 1m from the road surface and about 100 m from each road sections on the same day.

A questionnaire survey was conducted to come across, how users of urban roads feel, on having trees on the roads. The analyzed sample size was randomly selected 261 and that represented both, pedestrians and drivers. The questionnaire enclosed 6 sections; the first section was to identify the user and to understand the first impression on trees on urban roads, second section was created to comment on the trees on the road in more optimistic manner, third section was highlighted with the problems of having trees on the road, fourth section was to understand the level of comfort that experiencing by the user, when driving or walking under a tree canopy, fifth section was to comment on the visible distance affected by trees and the final section was to mark the hours of the day, that user feel more discomfort on a urban road, spanning from 7.00 a.m to 7.00 p.m.

Finally, the readings that were taken with respect to temperature and the humidity on a urban road with and without shade was compared with the findings, with respect to the personal feelings of the user, that were surveyed from the questionnaire.

3. ANALYSIS AND FINDINGS

3.1 Actual thermal performance of the road sections

Temperature and humidity measurements were taken in both road sections with and without trees, from 1m above the road surface and 100m away from each road sections.

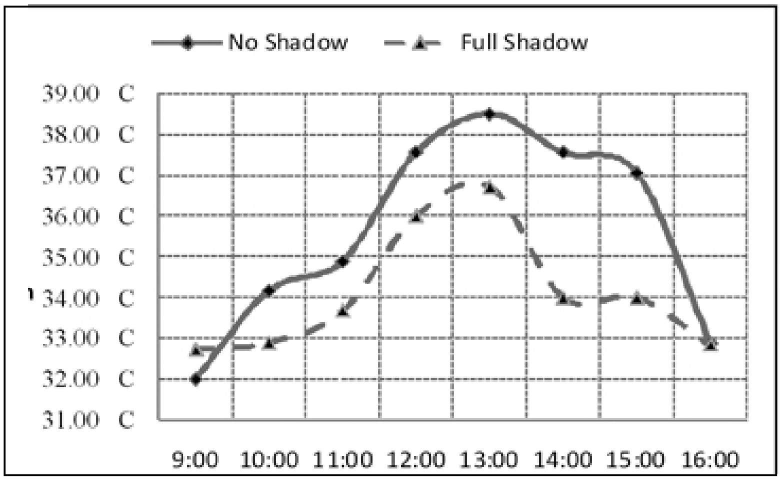


Figure 4 Air temperature variation

According to Figure 4, the peak temperature is obtained during 13:00 hour and the peak value is 38.5°C in the no shade area and 36.75°C in the full shade area and air temperature difference is 1.75^{0}C. Further, when compared the two graphs it was clear that, the temperature drop down between 14.00 hour to 15.00 hour has drastic difference when compared to the other hours of the day and it was around 3.5^{0}C.

However, comparison of these temperature readings clearly indicates, the impact of the trees and the shade, on the urban roads and how they reduce the temperature

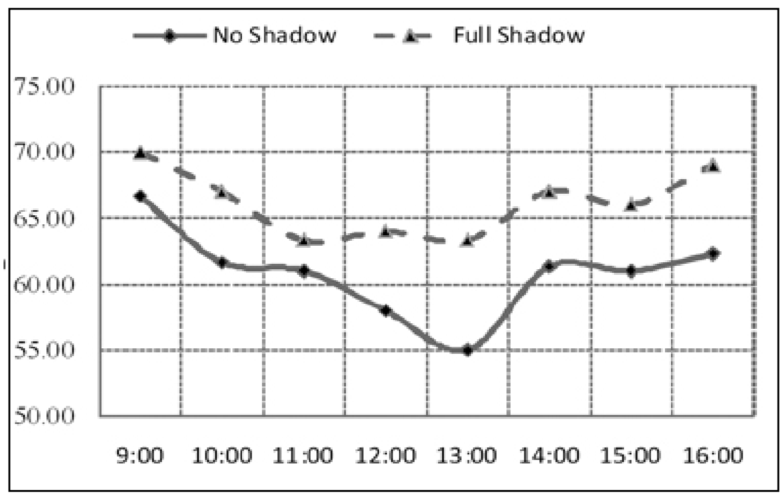


Figure 5 Humidity variation

According to Figure 5, urban road section with full of trees and shades were high in humidity with compared to urban road section with no trees and shades. However, during morning and evening the humidity in both road sections were high and the lowest humidity reached at 13.00 hours. When considered the road section with full shade, the humidity varies from 67% to 55% at 9.00 hours to 13.00 hours and again it increased up to 63% by 16.00 hours.

Likewise, in no shade area the humidity was high as 70% at 9.00 hours and it was decreased up to 64% during the day time and again it was increased up to 69% at 16 hours. However, when compared both graphs, it was clear that at 13 hours, the full shaded road section was high in humidity of 8 % than the road section no shade.

3.2 Survey on user satisfaction on urban roads

According to the questionnaire, stated in Appendix A[1], the 6 sections were separately analyzed to understand the macro picture in more broader and accurate manner. The section 1 was to understand the user and whether the users prefer to have the trees on urban roads or not. When, analyzed the data, according to Figure 6, 7 and 8, it was identified that from the surveyed sample, majority represented a 55% of male population and most popular category was the pedestrians and it was 66 %. From, remain of 34% of drives, 56% have driving experience more than 5 years.

[1] Appendix A is available with the corresponding author to be obtained upon request.

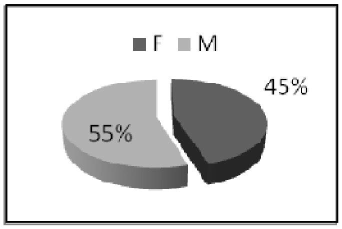


Figure 6
Sample composition on gender

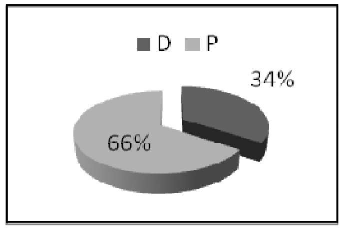


Figure 7
Sample composition user category

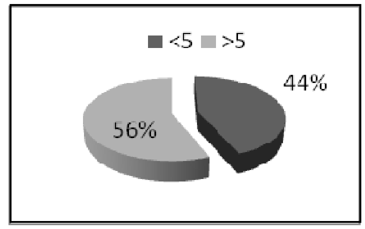
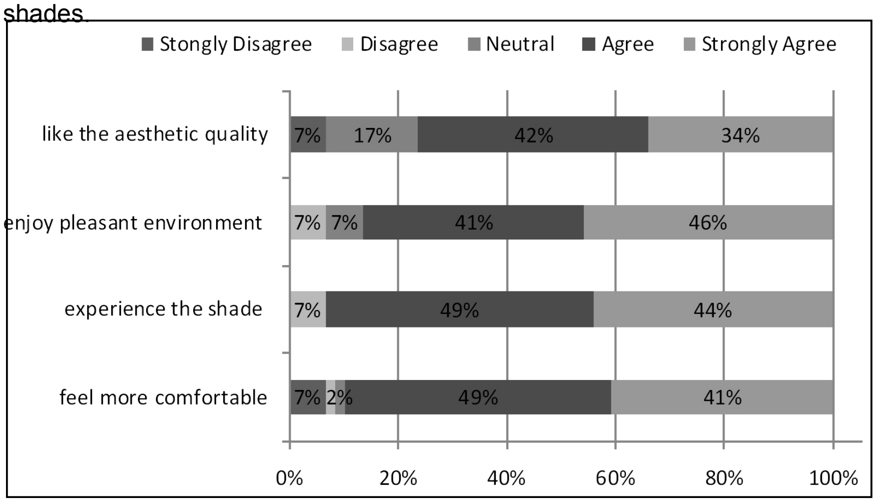


Figure 8
Sample composition driving experience

Section 2 of the questionnaire, was designed to understand optimistic thinking of users regarding trees, on the road and on how they feel when they experiencing such urban roads with full of trees and shades.



According to Figure 9, significant majority user population was agree on the comfort, shade, pleasantness and aesthetic quality on the urban roads with trees. Further, equal 7% of users who experience discomfort on the shady roads and who doesn't experience any aesthetic quality of urban roads with trees.

Figure 9 Preference to have trees on urban roads

Section 3 of the questionnaire, reasoned out the problems of having trees on urban road. According to Figure 10, there were some users, who were strongly disagreed, that the amount of daylight fallen on the roads get reduced due trees on the roads and at the same time no one is strongly agreed on that as well. Further, some uses don't think that road signs get hidden by the trees. However, when compared all four types of problems that can create from trees, majority of 48% agreed on the idea, that most road blocks are creating during rainy season due to fallen trees and branches.

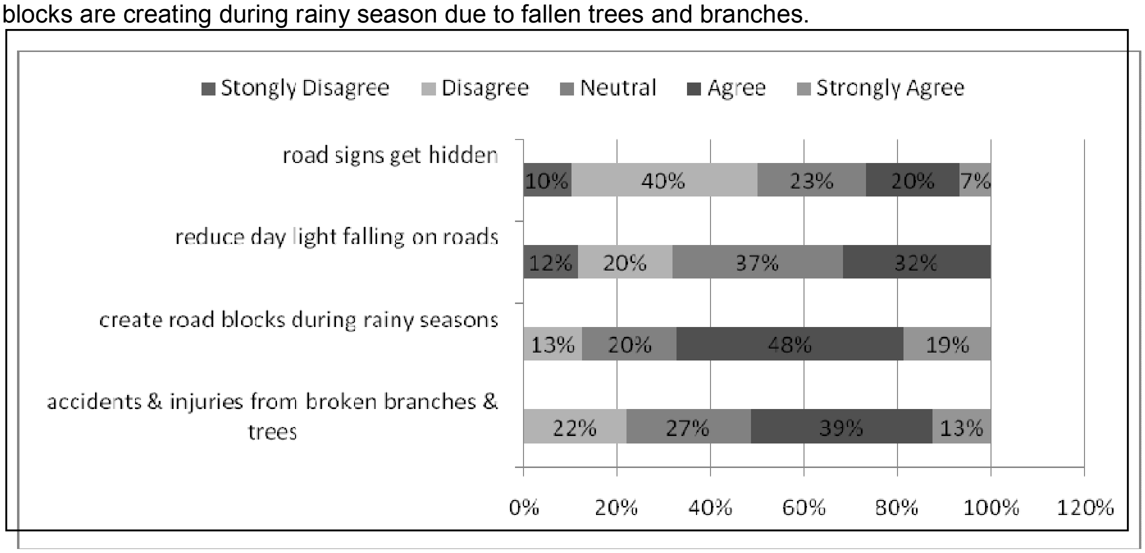


Figure 10 Problems of having trees on urban roads

The level of comfort that users can experience on a shady urban road was analyzed under section 4. When analyzed the Figure 11, majority of 47% strongly agreed that they feel more relaxed on an urban roads under a tree canopy and also 20% on air pollution reduced by the tree on urban roads. However, very less population thought that, they feel forbidden, tired and not safe on shadowy urban roads. At the same time, 64% of majority population disagreed, the idea of tiredness when walking or driving under a tree canopy.

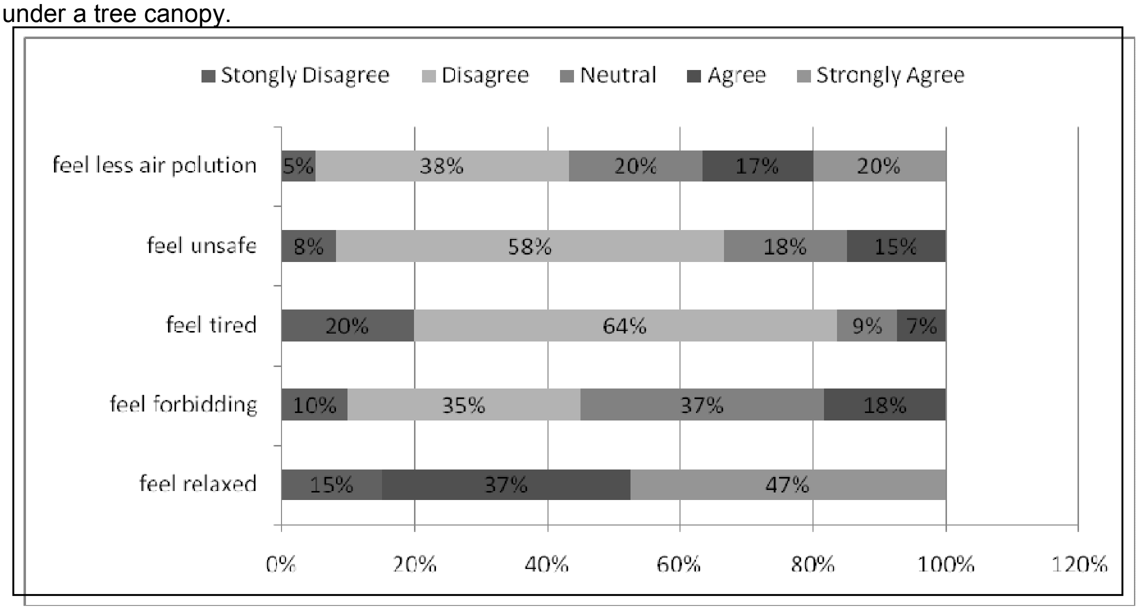


Figure 11 Level of comfort under a tree canopy

Section 5 of the questionnaire was concentrated on the visible clarity under tree canopy. According to Figure 12, 42% of majority strongly agreed that, trees on bends and curves can reduce the visible clarity of urban roads and 40% have neutral experience on that and no one strongly feel that when shadows of the trees falls on to the windscreen, create difficultness to drive. Further, majority of 52% disagreed, the idea that, lower branches of trees block the visible distance.

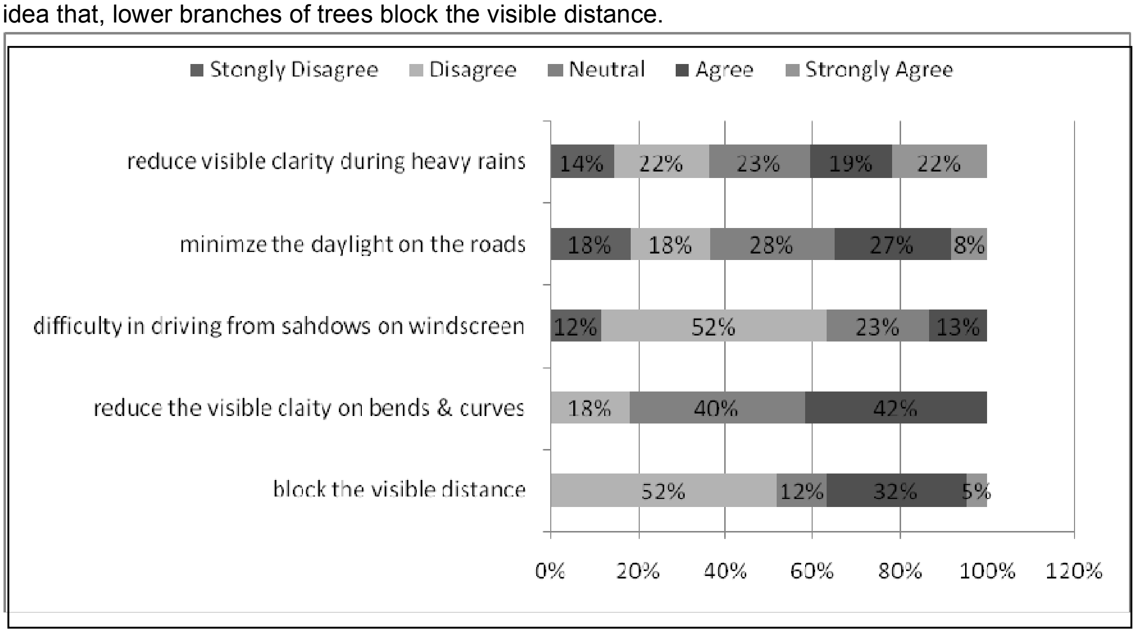


Figure 12 Visible distance under a tree canopy

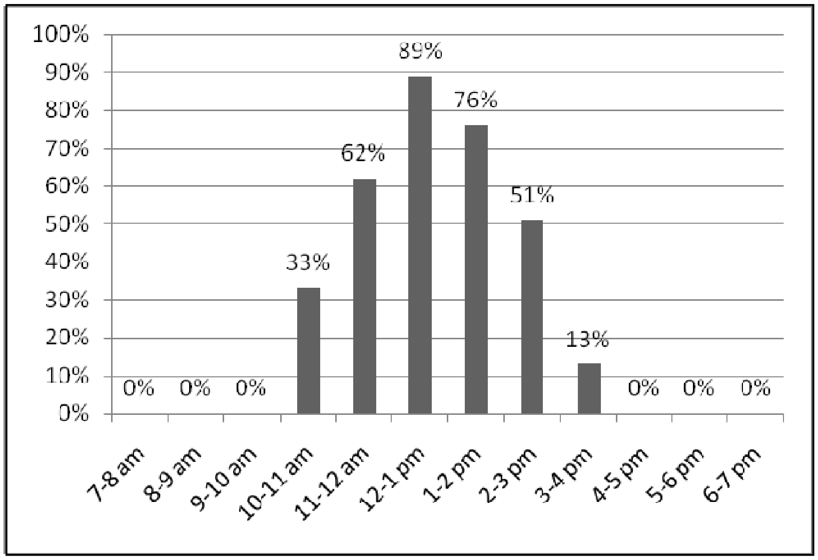


Figure 13 Discomfort hours of the day with respect to user

The section 6 was entirely based on to identify the most discomfit hours of the day for users on urban roads. From the Figure 13, it was spotted that, the discomfort start from 10.00 am to 4.00 p.m and majority of the sample population commented that 12.00 to 1.00 pm is the most uncomfortable hour of the day.

4. DISCUSSION

Figure 14: Satellite image of Colombo

When carefully analyzed the satellite image of Colombo, it can be seen that majority area was covered by infrastructure with very less greenery and also with the contribution of high number of vehicles; the tendency of heating up the environment was highest in Colombo as an urban area. Therefore, necessity of having shades on urban roads especially in Colombo, are very important and critical aspect, that have to be considered by the users in the area.

During the research, the actual thermal performance of the urban roads with and without trees were analyzed from the readings that were taken on the effecting variables for thermal performance; temperature and humidity and findings were compared with user's responses with respect to their personal feelings and experiences.

From the Figure 4 and 5, it was cleared that, the temperature increases and humidity decreases during the day, starting from 10.00 a.m to 4.00 p.m. Though, there was a variation between the road section with shade and without shade, the thermal performance of both road sections indicated the same. When this was compared with the Figure 13, the user experienced the discomfort of the day starting from 10.00 a.m to 4.00 p.m, and that proves the thermal performances of the urban road with the actual discomfort that user experience on the urban road has a strong association.

However, from this research, it was recommended to carry out further analysis to find out, whether, the actual thermal performance of an urban road with fully shaded, continuous tree canopy and entirely deserted road with no trees at all, falls within the comfort zone and how the user responds on the same roads with respect to level of comfort.

5. CONCLUSION

From the entire analysis, carried out during the research, it was proved that, users prefer to have shades on urban roads rather than experiencing deserted roads without any shades. Though, the trees provide higher humidity level, they also reduce temperature and that makes the users who travels on the roads, covered by trees, more comfort than travelling in a road without trees. On the other hand, according to point of views of some users, even though the trees provide maximum comfort, there are some problems of having trees on urban roads such as; road blocks during rainy seasons, reduction of visible clarity, accidents and injuries due to lower and broken branches and trees, etc. However, these can be reduced by giving adequate attention and implementing appropriate maintenance procedures by relevant authorities. Therefore, by reducing the negative impacts of trees on urban roads and encouraging properly maintained tree canopies on them, other than the comfort, that will also contributes to control the critical environmental issues such as global warming and air pollution; most daunting challenges of the world today.

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