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Trees Investment for Temperature Cooling in Higher Learning Institutions: A case of Ardhi University Campus, Dar es Salaam, Tanzania

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ABSTRACT: The pressure for the increasing enrolment in higher learning institutions in Tanzania has accelerated the proliferation of the gray infrastructures in campuses. However, little is understood for the foregone economic value of ecosystem services from the lost trees due gray infrastructure development. The objective of this study was to assess trees investment for temperature cooling in higher learning institutions: a case study of Ardhi University Campus, Dar es Salaam, Tanzania. The remote sensing techniques, document review, and questionnaire were used for data collection. The study revealed that Ardhi University has trees canopies covering 227,638 square meters. Analysis of the temperature data demonstrated that temperature difference is influenced by abundancy of trees between Ardhi university campus and nearby areas. The average temperature in nearby areas in the afternoon is higher by 2 ˚C to 4˚C compared to Ardhi university campus. 72.4 percentage of students spend four (4) to eight (8) hours in an outdoor tree shaded environment within 12 hours in day time implying that trees shaded environment is important for daily life at the campus. Utilization of the outdoor trees shaded environment has implication of energy savings of 336,823.52 KWh which is equivalent to TZS 120,245,811 (USD 44,535). The study recommends that high learning institutions should invest in green space development with lighting and seating provisions to maximize their use while reducing building users at the campus. Short of that, more buildings are needed to cater for the increasing enrollment. This might be a challenge to majority universities considering that financial resources are scarce.

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Trees control wind and lower air temperatures through shade and evapotranspiration. Trees act as a natural evaporative cooler using up to one hundred gallons of water a day hence decreasing the ambient air temperature (Gago *et al*., 2013; Kremer, 2013). Trees shaded surfaces can be 20–45°F (11–25°C) cooler than the peak temperatures of unshaded materials. Evapotranspiration, alone or in combination with shading, can assist to decrease temperatures by 2–9°F (1–5°C) (Heisler, 1986). Studies have shown that, there is high cost and increase in building energy uses in areas with low trees but also areas with trees which are not strategically planted (Rega *et al*., 2012). The evaporation from a single big tree can produce the cooling effect of 10 room-sized air conditioners working 24 hours. For three or more large trees strategically located on the sunny side of a residence will provide enough shade to lower air-conditioning costs by as much as 30 percent (McPhearson *et al*. 2003). Akbari *et al.* (2003) simulated the impact of tree locations on heating and cooling energy uses. It was found that energy saving used in cooling can range from 2% to over 7%; cooling energy savings were higher for trees shading the western walls windows and part of the building's roof. Thus, tree shades provide significant benefits in decreasing building air-conditioning demand. Tree shaded areas in academic environment are used for different purposes. They are used for beatification, social cohesion, recreation, and learning facilitation (Georgi and Dimitriou, 2010; Thani *et al.*, 2018). Outdoor environments naturally inspire students to be more

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physically active (Pataki *et al.*, 2011; Thompson *et al*., 2012). In outdoor settings, students are more motivated to work together in groups and improve their social cohesion (Wang *et al.*, 2014). They learn to manage communication and cooperate with their friends in a more effective way (Jim and Chen, 2006). Outdoor learning are used for providing children with hands-on experiences in nature. Instead of viewing different types of plants or wildlife on a computer or TV screen, they can see, smell, hear and touch them in nature (Jones *et al*., 2017). Academic institutions have trees planting campaigns to increase shades and beauty. However, the rate is surpassed by the demand for building infrastructures accelerated by the increasing students' enrollments. Thus, impact of trees planting campaigns is not fully realized to achieve maximum trees conservation benefit due to space limitations. In this regards, trees are cleared while paying little attention to value of ecosystem services provided by trees (Union and Conservancy, 2005; Gago *et al*. 2013; Kibassa; Shemdoe, 2016). In recent years, Tanzania has made commendable gains in basic education and there is positive increase in the number of students transitioning to post-primary education. While the country has recorded expansion in basic education enrollment, policy makers advocate the need for the expansion of the subsequent levels of education especially higher education. Thus, public Universities in Tanzania have been expanding their infrastructure capacities within the campus and upcountry in response to the increasing enrollments. However, the assessment on the impact of the expansion on green space conservation is not yet evaluated. Hence, the objective of this study was to assess trees investment for temperature cooling in higher learning institutions at the Ardhi University Campus, Dar es Salaam, Tanzania

MATERIALS AND METHODS

Selection of study area: This study was sought to be done in other public universities like University of Dar es Salaam, Institute of Social Works, University of Dodoma, Institute of Finance and Management, and Mzumbe University but Ardhi University was the most representative. The choice of the case study was guided by the hot climate, altitude, availability of green shaded environment and availability of a wide range of land and community based programmes connoting that each discipline view the value of green spaces in different ways. The disciplines are Environmental studies, Planning, Land Management and Valuation, Geomatics, Architecture, Real Estate Development, Building Economics, Disaster Sciences and Community Development Studies. Ardhi University (ARU) is located along University Road adjacent to the University of Dar es Salaam and approximately 12 kilometers from Dar es Salaam City Centre (Figure 1). The campus covers an area of 79.78 Ha (797,800 m^2). It has an estimated population of 4,423 including 3,976 students and 447 Staff. Ardhi University experiences a hot and humid tropical climate with two rainfall seasons: an intense one is observed from the month of March to May, and a mild one in November and December. The average annual rainfall is 1,115 mm whereas the average temperature ranges from 18.1°C to 32.1°C.

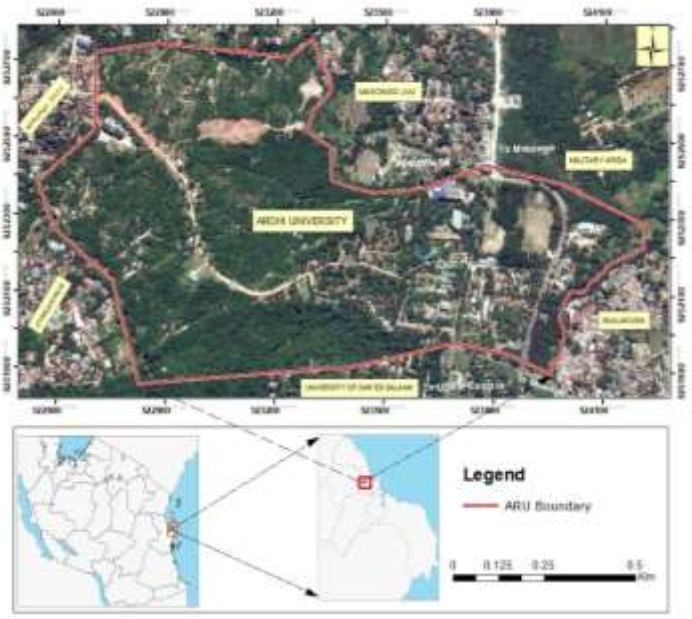

Fig 1: Location of Ardhi University in Dar es Salaam City, Tanzania

Data Collection Methods

Remote sensing: Satellite image was used to determine the total area covered by green space and grey surfaces in Ardhi university campus. It was used to know the orientation of trees planted around the buildings. The data was essential for determining the cooling saving due to presence of trees as well as appropriateness of trees orientation around buildings at the campus.

Document review: Document review was done to collect data on energy consumption from buildings and the temperature of Ardhi university campus and nearby areas such as Sinza, Survey and Makongo. The temperature data were collected from different locations within and outside the university campus by using temperature sensors. The data were used to determine the trend of temperature in Ardhi University and nearby areas. Data on the energy consumption in university buildings was collected from Ardhi University Estate Department particularly the Lands Building which has a separate meter No.00046565. The data were used to determine the contribution of students in energy consumption by comparing the energy used during 16 weeks of a semester and energy uses after closing the semester**.**

Questionnaires: Questionnaires were administered to 98 students from Ardhi university campus (hostel) and those who live nearby areas such as Makongo, Survey, Mwenge, and Sinza. Questions were based on understanding on the role of trees in temperature cooling, how students use available tree shaded spaces during their studies, how important is that use for their studies, what time they spend in trees area, what avoided cost and the value they can infer to ecosystem services provided by trees in university. 58% of correspondents were male and 42% were female in which 30.6% were second year students, 29.6% were third year students also 22% were fourth year students and 17.8% constituted the first year and postgraduate students. Most of respondents were chosen from second year and third year because they are students who spend most of their time in university campus and they have more experience on the environment of university campus compared to first year and postgraduate students. Students who participated in the study as respondents were from different discipline including Environment, Building Economics, Land Management and Evaluation, Community Development Studies, Real Estate, Geomatics, and Architecture. This is because each discipline view the value of green spaces in different ways.

Quantification of Economic Value of Green Spaces in Temperature regulation: In order to estimate the economic value of green space(s) due to temperature regulation service, data used were hours spent in outdoor trees shaded environment within 12 hours daytime in a month (I), rating of electrical appliances that could be used while indoor environment (J), heat transfer coefficient (L), cooling degree days per year (CDDs) (M). The monetary benefit of green spaces due to temperature cooling service (A) was calculated using equation (1) and the variable P was calculated using equation (2), while variable Q was calculated using equation (3)

$$A = (P + Q) \times \text{Tarrif rate} \left(\frac{TZS}{KWh}\right) \quad (1)$$

Where: P=Energy saved due to the use of tree shaded environment within 12 hours daytime (kWh), Q=Energy saved for cooling the building (kWh)

Whereas

$$P = I \times J \quad (2)$$

Where: I= Hours spent in outdoor trees shaded environment within 12 hours daytime (Hours) ×estimated number days in a year and J=Total rating (kW) of electrical appliances that could be used while indoor in environment (Mwageni, 2021).

$$Q = L \times M \quad (3)$$

Where: M= Annual number of cooling degree days (CDD) (˚F days).

Cooling Degree days (CDDs) is a measure of the demand for energy needed to cool a building. It is calculated by subtracting a balance temperature from the mean daily temperature, and summing only positive values over an entire year. The balance temperature used can vary, but is usually set at 65°F (18°C), 68°F (20°C), or 70°F (21°C).This study adopted the balance temperature of 70°F (21°C). Balance temperature is the outdoor temperature at which the building can neither heat nor cool. It is the temperature above which the building needs to be cooled. According to data collected from Tanzania Meteorological Agency, the total maximum number of cooling degree days (CDD'S) was 221 ˚C days (430 ˚F days).

L= Heat transfer coefficient (British thermal unit /square feet (SF) * degrees Fahrenheit * hours (Btu/SF*°F hrs)), calculated using equation (4);

$$L = \left(\frac{1}{\text{R.grey surface}}\right) - \left(\frac{1}{\text{R.canopy}}\right) \quad (4)$$

Where: R is a measure of thermal resistance (SF * °F * hrs/Btu). For Grey surface: R = 11.34 SF * °F *

hrs/Btu. For Canopy: R = 23.4 SF * °F * hrs/Btu (Gallet, 2011).

Data on area (Square Feet) covered by grey surface and canopy surface at the campus were determined by ArcGIS software 10.3.1 by digitizing grey and green spaces from the high resolution orthorectified imagery taken by Ministry responsible for lands. In order to find how cooling savings results in electricity savings (kWh), the Btu units were converted to kWh using the conversion rate of 1 kWh/3412 Btu. Thus, the value of A gives the maximum estimate of the economic value of green spaces due to temperature cooling service.

RESULTS AND DISCUSSION

Tree shaded areas and their uses at Ardhi university campus: Data from satellite image indicated that tree shaded areas at Ardhi University constitutes 227,638 square meters, Grey surface (Roads, paved surface and buildings) covers about 35,126 square meters and open space covers an area of 12,616 square meters. Trees at Ardhi University is dominated by natural species and are used for recreation, parking and learning purposes. Figure 2 shows the spatial distribution of land cover while Figure 3 shows typical uses of green spaces within the campus area.

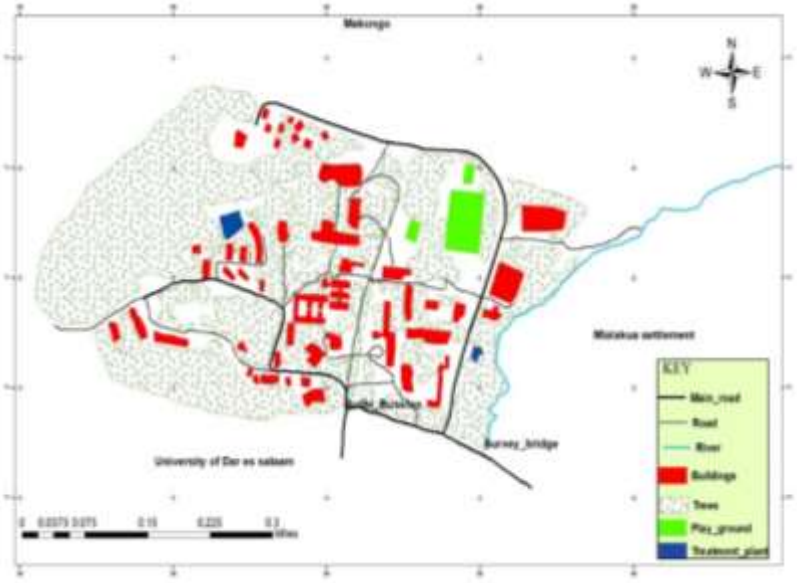

Fig 2: Spatial distribution of land cover at University campus

Fig 3: Uses of green spaces at Ardhi University campus

Analysis of Temperature differences at Ardhi University campus and nearby areas: The study revealed that there is a significance difference of temperature in Survey area, Sinza Kijiweni, and Ardhi

university campus at 8:00 am, with p-value 3.07 *10^{-10} which is less than 0.05. By considering three stations; Survey, Sinza Kijiweni and Ardhi university campus at 8:00 am, Sinza Kijiweni had an average temperature of 31˚C which is high compared to Survey station (30.41 ˚C) and Ardhi university campus (29.7 ˚C) (Figure 4). This implies that the morning temperature is lower at Ardhi University compared to Survey and Sinza areas due to evaporation cooling effect provided by trees and advantage of having large number of trees which block incoming solar radiation.

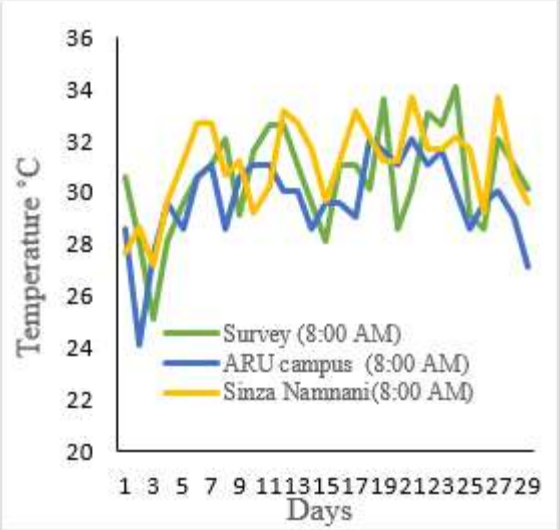

Fig 4: Temperature differences in Sinza, Survey and Ardhi University campus

According to temperature data of Makongo mnara wa voda, Makongo msikitini and Ardhi University campus (Figure 5), the morning temperatures were almost similar since all stations are located in areas surrounded by trees. Makongo mnara wa voda had lower average temperature of 28.92 ˚C compared to average temperature of Ardhi university 29.73 ˚C and Makongo msikitini 29.62 ˚C.

Result demonstrate that the abundance of trees and increase in elevation influence Makongo mnara wa voda to have a slightly low temperature as compared to Ardhi university campus. Statistical analysis of afternoon (1:00 pm) temperature data of Sinza Kijiweni, Survey area and Ardhi University campus indicated that there were marked difference in average temperature and maximum temperature in various location with p –value 0.002998 implying that that there is significance differences in temperature at Sinza, Survey and Ardhi University. Average temperature at Sinza Kijiweni was higher by 2˚C compared to Survey area and was higher by 4˚C compared to Ardhi University (Figure 6). The reason is that Sinza area doesn't have enough trees around streets to provide enough shade and cooling effect to buildings. In noon hours, Ardhi University had lower temperature due to advantage of tree shades which prevent heat gain to the surface and buildings around university campus. This helps to cool the environment of campus in the afternoon. Also the impact of evapotranspiration in the afternoon helps to provide humid air at the campus.

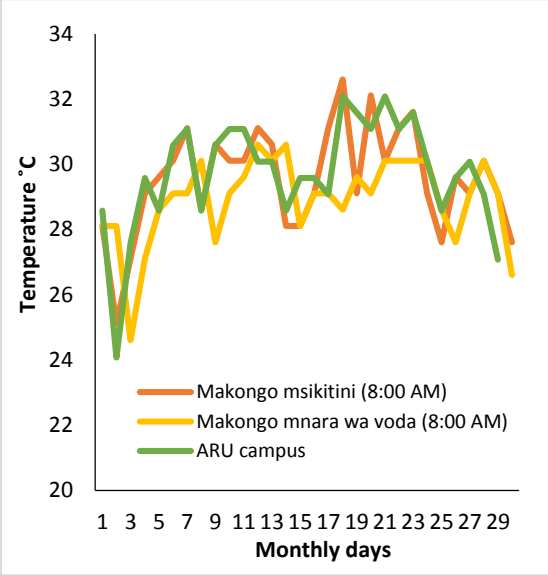

Fig 5: Temperature differences between Makongo areas and Ardhi University in the morning.

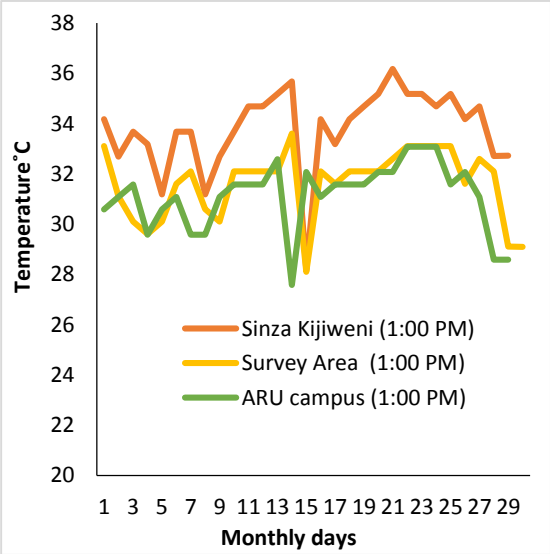

Fig 6: Temperature differences in Sinza kijiweni, Survey area and Ardhi university campus.

By considering the temperature data of Makongo Msikitini, Makongo Mnara wa voda and Ardhi University in the afternoon there is slightly change in

air temperature. Dense canopies avoid high solar radiation to be in contact with the surface. There is significance difference in ambient temperature of Ardhi university campus compared to Makongo areas. The slight difference of temperature among locations was due to tree canopies (Figure 7). The highest average temperature (31.71˚C) was observed in Makongo msikitini whereby the lowest average temperature (29.73˚C) was observed at Ardhi University campus due to abundance of trees distributed within the university area.

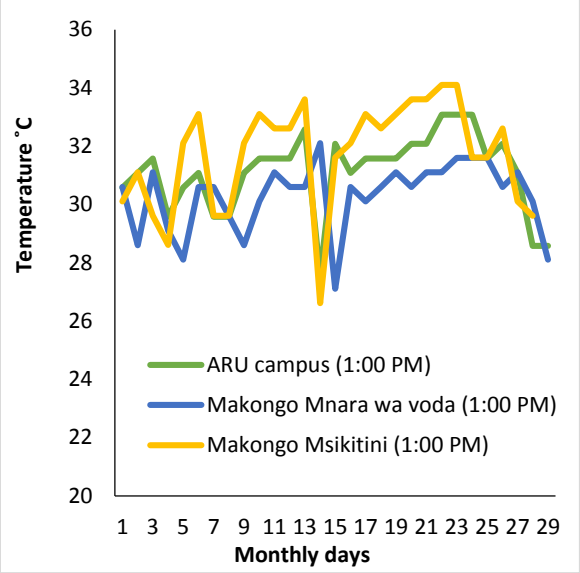

Fig 7: Afternoon temperature differences between Ardhi University and Makongo areas.

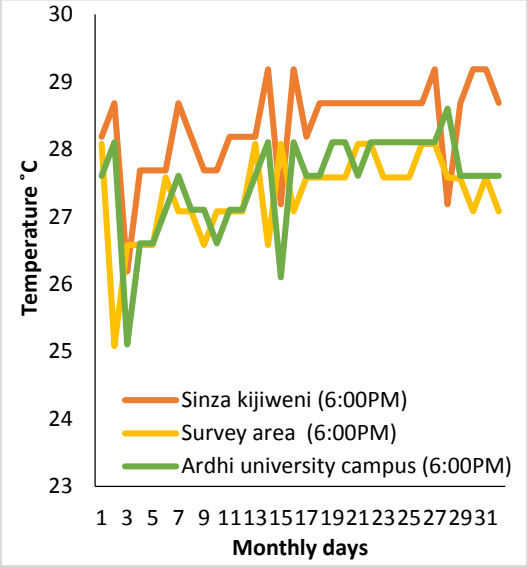

Fig 8: Temperature differences observed in evening hours.

Data on temperature recorded in the evening indicate that there was difference of 1˚C in evening temperature of Sinza Kijiweni when compared to evening temperature of survey and Ardhi university campus. There is very small change in evening temperature between Ardhi university campus and Survey area (Figure 8). This implies that during the evening the areas experience the sunset but Sinza wa slightly higher because of the presence of paved surfaces compared to Ardhi University and Savei.

*Students perceptions on Air temperature within Ardhi university campus and nearby areas***:** Students' perception was found to concur with scientific data previously presented. Majority of the respondents (96.7 %) consider that air temperature within Ardhi University campus is cool compared to outside campus areas during the day time implying that many trees in campus provide the cooling effect. The shade and transpiration process keeps campus area relatively cool compared to area around university which have less trees. Reasons for low temperature at Ardhi University campus was that the campus has an advantage of having large area covered by trees which contributes to low ambient air temperature. The tree shades cover university buildings and outdoor environment, hence preventing the direct heat gain by radiation from the sun. Also, open space found within the university campus is another reason for the university campus to have temperature difference compared to nearby campus areas. In addition, the location of university campus at an observation hill contributed to temperature differences.

Factors influencing students to use the tree shaded environment: It was reported that students use tree shaded environment for their private studies, group discussions, recreation and social interactions. 47.9% of students reported that they use tree shaded environment as they provide thermal comfort during afternoon hours and it is the most important factor that encourage students to use the tree shaded environment within university campus. Also 39.8% of students stated that they use the tree shaded environment as a conducive and quiet environment that helps students to concentrate during private studies. One student happened to report that "*Students stay in outdoor tree shaded environment while waiting for class sessions and some get exposure to outdoor environment help them to decrease stress and worries. Also, in outdoor tree shaded environment, students are more motivated to work together in groups, which help them to improve their academic performance".* 11.2% of students use the outdoor tree shaded environment because of busy class rooms especially during university examination period whereby most of classes become busy. Also, university class rooms and libraries are not enough to accommodate the whole

number of students. On other hand 1% of the respondents reported that they use outdoor tree shaded environment for social interaction and entertainment like watching football matches. The results indicate that trees have greater importance in academic institutions because they provide the alternative environment for studies and recreation.

Time spent in outdoor trees shaded environment by students within 12 hours day time: The results show that 56% of students spend an average of four (4) hours in outdoor tree shaded environment within 12 hours in day time hours followed by 23 % who spend 6 hours and 21% who spend 8 to 10 hours in outdoor trees shaded environment. The result further revealed that the 21% percent of students are the dissertators who don't have class session within 12 hours' day time. This group includes students who stay outside the university campus. They use outdoor tree shaded environment when they are waiting for class sessions and when they do preparation for examinations. This proves that tree shaded environment is important for students' daily life at the campus. Students living within university campus use outdoor environment for their private studies and working together in group discussion constitute the 79%. This time spend in outdoor environment have an advantage of reducing class room congestion which can lead to increase in energy uses in university buildings.

Energy saving due to tree shades and students' tendency of using outdoor environment during day time: The study revealed that tree canopies surface (2,450,268 Square Feet) can save an annual electricity cooling saving in Ardhi University amounting to 336,823.52KWh per year equivalent to TZS 120,245,811 (USD 44,535) per year. On the other hand, data collected from Estate Department at Ardhi university show that an average electricity bill per month from the selected building (Lands Building) during semester time and after closing semester were TZS 2,337,271 (USD 865) and TZS 1,327,062 (USD 492) respectively. This implies that an average electricity bill of TZS 77,909.05 is incurred per day and TZS 3,246.2 (USD 1.2) per hour. Thus, for students who spend an average of 4 hours in outdoor environment, the university saves an electricity cost amounting to TZS of 389,520 (USD 144) per hour and TZS 1,558,080 (USD 577) per semester. Similarly, students who spend an average of 6 hours in outdoor tree shaded environment save TZS 584,280 (USD 216) per month and TZS 2,337,120 (USD 866) per semester in Lands Building energy uses if at all no electrical appliance shall all be switched off while in outdoor.

On other hand, students were asked what would happen if there were no green spaces at the campus. One of the students reported that "*If there were no tree shaded environment at university campus, there will be no comfort-ability of staying outside during the day time and the students couldn't use the outdoor environment for their studies in day time especially in the afternoon and instead they could use much of their time in indoor environment…*." This has implication of energy use as they will use fans, phones and computer charging, and lighting in rooms with low light intensity. Results from the questionnaire survey indicated that 36.73% of students would prefer to spend between 7-9 hours in indoor environment during day time if there were no outdoor tree shaded environment while 28.57% could spend between 10-12 hours in indoor environment during the day time. Students who reported to spend between 2-4 hours constituted 15.31% whereby 19.19% could spend between 5-7 hours inside building. Based on the rate of electricity cost per hour in lands building (TZS 3, 246Tsh/ hour), students spending average of 8 hours in indoor environment could increase an electricity bill amounting to TZS 779.040 (USD 289) per month and TZS 3,116,160 (USD 1,154) per semester.

Conclusion: Trees in academic institutions make the landscape attractive and cool. Green space investment helps universities to reduce building users at the campus connoting a reduction of building energy consumption. With increasing students enrollment, the development of outdoor green spaces with lighting and seating provisions is inevitable, otherwise universities should build as many buildings as possible of which is impossible with scarce financial resources they have. The information from this study is useful to decision makers to evaluate trade-offs between courses of action under scarce land resources. The information also useful architects, environmentalists, planners and real estate departments in green space design and development.

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