Global Journal of Environmental Science and Technology: ISSN-2360-7955, Vol. 4(4): pp 405-412, September, 2016.

Full length Research

Eco-physiological Implications of Cutting *Acacia tortilis* Trees; Evidence from a Kenya Savanna

Elias K. Maranga

Department of Natural Resources, Egerton University, P.O Box 536-20115, Egerton, Kenya

Author's Email: ekmaranga@yahoo.com

Accepted 19th September, 2016

An experiment was conducted in a semi arid ecosystem in south central Kenya to evaluate the impacts of tree clearing on the microclimate beneath *Acacia tortilis* trees that support a dense matrix of *Panicum maximum* Jacq. A randomized complete block design was set up to measure the effects of tree clearing on quantum flux, leaf temperature, transpiration rates and leaf water potential. Maximum values of quantum flux of the order of 1900µmol. m^{-2}s^{-2} and 900 µmol. m^{-2}s^{-2} were observed in the exposed and intact sites respectively. These quantum flux values in the contrasting sites were statistically significant at $p \leq 0.05$.The highest leaf temperature recorded for Panicum *maximum* in the exposed sites was 35C^{0} whereas that in the intact sites was 30C^{0}. Leaf water potential values were lowest in the exposed sites (- 5bars) compared to -2bars in the intact sites. The leaf water potential values in the contrasting micro sites were not statistically significant at $p \leq 0.05$.The highest transpiration rates for *Panicum maximum* were recorded for the exposed sites (6.5µgm^{-2}s^{-1}) compared to 5.2 µmol. m^{-2}s^{-2} for the intact sites. The findings suggest that long term shifts in micro climatic conditions in the exposed habitats are likely to negatively influence photosynthetic rates and primary productivity of *Panicum maximum.*

Keywords: *Acacia tortilis, Panicum maximum*, eco physiology, savanna, microclimate, productivity

INTRODUCTION

African savannas are grassland ecosystems that consist of scattered trees with open canopies. The exact ratio of trees to grasses varies considerably with savanna type (Meanault *et al.,* 1984 and Kinyamario *et al.,* 1995). Most authors agree that the physiognomic structure of savanna remains clearly distinct from that of grassland (Cole, 1986; Belsky *et al.,* 1989; Belsky, 1990, 1994; Mordelet *et al*., 1997; Jeltsch *et al.,* 1996; Higgins *et al.,* 2000; Ludwig *et al*., 2004; Tietjen and Jeltsch 2007 and Muthuri *et al.,* 2009, Murphy and Bowman, 2012, Ward *et al*., 2013). The practical significance of understanding the dynamics of savanna ecosystems in relation to disturbances is increasingly being recognized (Mitchell *et al*., 2000, Dohn, 2015). Natural resource conservationists, semi arid ecosystem managers and other custodians of natural resources require accurate and quantitative scientific information of recurrent disturbances in order to predict the outcome of such stresses on ecosystem recovery or damage and to manage the desired outcomes (Mitchell *et al.,* 2000).

Although a complex web of factors including water, fire, soil texture, deforestation, grazing and nutrients have been invoked to explain the balance between trees and grasses, the question of how trees and grasses coexist over a considerable range of environmental stresses and management conditions has not been resolved (Brooker and Callaghan, 1998 Lortie and Callaway, 2006, Le Roux and Mc Geoch 2010, Bertness and Altieri 2013). Maranga *et al*., (1983) and Kinyamario *et al*., (1995) found that *Panicum maximum* predominantly occurred under the extended canopies of *Acacia tortilis* trees. Tree canopies intercept rainfall; provide forage, litter and shade. These factors may in turn influence the canopy microclimate of soil moisture, light intensity, air temperature, relative humidity, air turbulence and latent heat transport from plant surfaces. It was hypothesized that *Acacia tortilis* canopy microclimates favoured shade tolerant *Panicum maximum* that was dominant in these micro sites whereas the sun tolerant species such as *Chloris* *roxburghiana* preferred the open areas. In order to test this hypothesis, an experiment was designed to investigate the effects of induced perturbations involving clearing of selected experimental *Acacia tortilis* trees on the eco-physiological responses of *Panicum maximum* exposed to the sun (exposed sites) in this treatment. The eco-physiological variables measured included quantum flux, leaf temperature, leaf water potential and transpiration rates. In the control, *Panicum maximum* was allowed to grow in its natural shade micro sites under *Acacia tortilis* canopies (intact sites). The objective of this investigation was to evaluate the impacts of cutting *Acacia tortilis* trees on the understorey microclimate that sustains a rich flora of *Panicum maximum* and consequent implications on the eco physiology and survival of this species.

MATERIALS AND METHODS

Study Sites

The experimental plots were located in a semi arid ecosystem in south central Kenya on the Kenya Agricultural and Livestock Research Organization (KALRO), National Range Research Centre, Kiboko. The study location was characterized by scattered trees of *Acacia tortilis* with large umbrella shaped canopies. The experimental *Acacia tortilis* trees often reached a height of 5metres with canopy diameters exceeding 10 metres. The dominant grasses consisted mainly of *Panicum maximum* associated with the canopy micro sites of *Acacia tortilis* trees and sun tolerant grasses such as *Chloris roxburghiana*, *Themeda trandra*, *Digitaria milanjiana*, and *Cenchrus ciliaris.* Interspersed with *Acacia tortilis* trees were isolated bushes with dominants such as *Commiphora riparia, Commiphora africana, Acacia senegal, Acacia mellifera, Grewia bicolor* and *Duosperma species.* Bimodal rainfall regime is typical of the study area. Well-defined precipitation periods include the long rainfall season from March to May and the short rains from October to December. These wet periods are interrupted by a short dry season between June and September. The mean annual rainfall for Makindu surface weather station about 3 kilometres from the study locations is 600mm (based on 70 years of rainfall data). Ambient air temperatures range from 28.6 ^{o}C (mean maximum) to 16.5 ^{o}C (mean minimum). The lowest temperatures occur in July (8.8 ^{o}C) and the highest in February (36.1^{o}C). Relative humidity varies between 78% at 0600 GMT and 47% at 1200 GMT. Soils are acri-rhodic ferralsols, deep and reasonably well drained (Michieka and Van der Pour, 1977). Detailed ecological site description may be found in Michieka and Van der Pour, (1977). Significant water stress during the dry season coupled with tree felling and herbivory characterizes the ecological dynamics of the study sites.

Field Experimentation

Field studies were conducted on four micro sites. Two of these micro sites represented the control where *Panicum maximum* coexisted with *Acacia tortilis* beneath the canopies of these trees. *Acacia tortilis* was removed in the other two micro sites to simulate conditions in the sun. Environmental measurements of quantum flux, coupled with measurements of leaf temperature, leaf water potential and transpiration, of *Panicum maximum* in the intact sites and exposed sites were monitored in the course of the bimodal dry and wet phases. Quantum flux was measured by means of a cosine corrected quantum sensor. Leaf temperature and transpiration rates were measured by a Li- Cor LI- 1600 steady state porometer. Leaf water potential was determined by means of a pressure bomb (Scholander, 1964).

Quantum flux, leaf temperature, leaf water potential and transpiration data was statistically analyzed using analysis of variance methods (Little and Hills, 1975). Duncan Multiple Range Test was used in separating means that were statistically different at $p \leq 0.05$.

RESULTS

Quantum Flux

The diurnal course of quantum flux during the wet season (April) between 1.00pm and 7.00pm in the intact micro sites indicated that the maximum value of 900μmol m^{-2} s^{-1} (900μEm^{-2} s-^{1}) occurred at 3.00pm (Figure 1). The maximum quantum flux value in the micro sites where *Acacia tortilis* were cleared was 1900 μmol m^{-2} s^{-1} (1900μEm-^{2}s^{-1}). These quantum flux values in the contrasting sites were statistically significant at $p \leq 0.05$. During the dry phase in June (Figure 2) quantum flux peaked at 4.00 pm. Maximum values during this period were 400 μ mol m^{-2} s^{-1} (400μE$m^{-2}s^{-1}$) and 1000μ mol m^{-2} s^{-1} (1000μ$m^{-2}s^{-1}$) for the intact and cleared sites respectively.

Leaf Temperature

Diurnal patterns of leaf temperature in the course of the wet phase (April) exhibited maximum values at 4.00 pm. The maximum leaf temperature for *Panicum maximum* in the intact sites and exposed sites was 30^{o}C and 35^{o}C (Figure 3a). During the dry phase in June (Figure 3b) maximum leaf temperatures for *Panicum maximum* obtained at 5 pm were 28^{o}Cand 32^{o}C for the intact sites and exposed sites respectively. The lowest leaf temperatures ranging between 20 ^{o}C and 24 ^{o}C were recorded at 1.00 pm and 7.00 pm respectively in June, whereas those in the wet phase (April) oscillated between 19^{o}C and 24.8 ^{o}C.

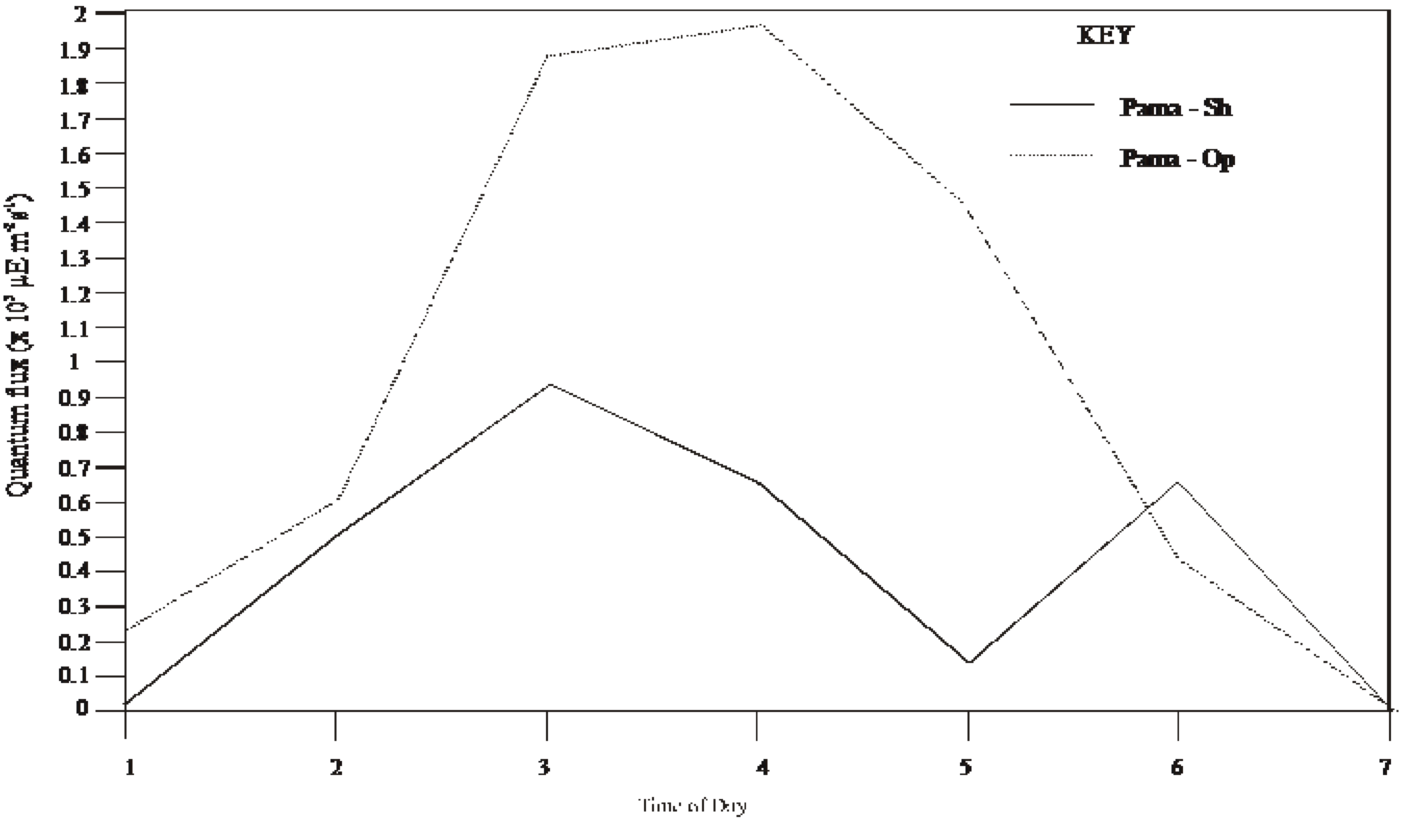

Figure 1: Diurnal course of quantum flux in the shade (Pama- sh –trees intact) and sun (Pama- Op-trees cleared) micro sites in April

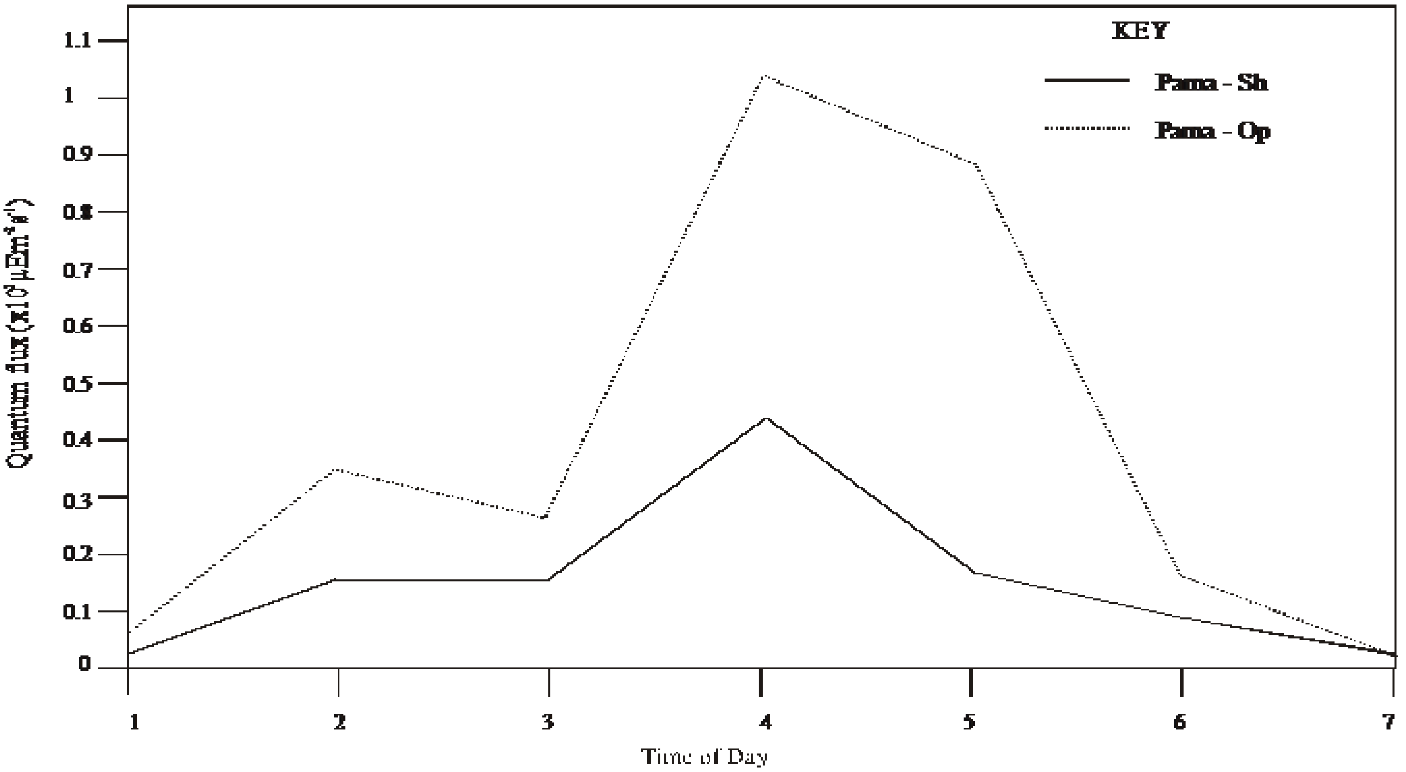

Figure 2: Diurnal course of quantum flux in the shade (Pama- sh-trees intact) and sun (Pama- Op-trees cleared) micro sites in June

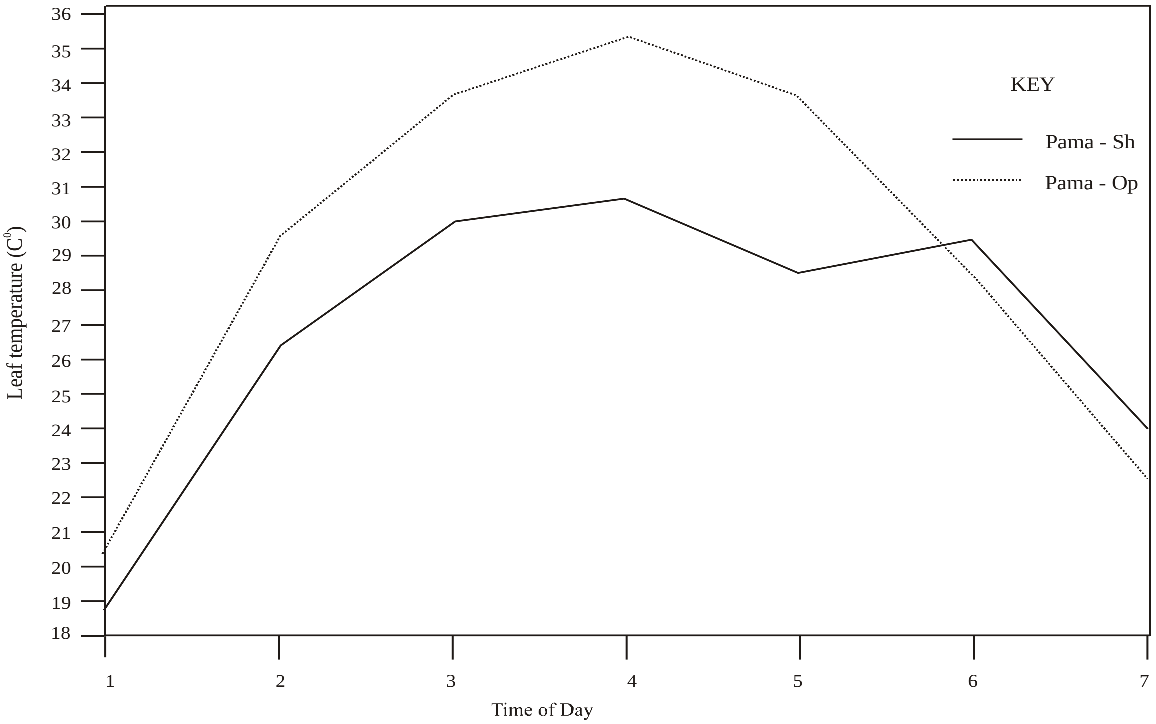

Fig. 3a. Diurnal patterns of leaf temperature in the shade (Pama-sh and Sun (Pama -op) micro sites in April

Figure 3a: Diurnal patterns of leaf temperatures in the shade (Pama- sh-trees intact) and sun (Pama – Op-trees cleared) in April

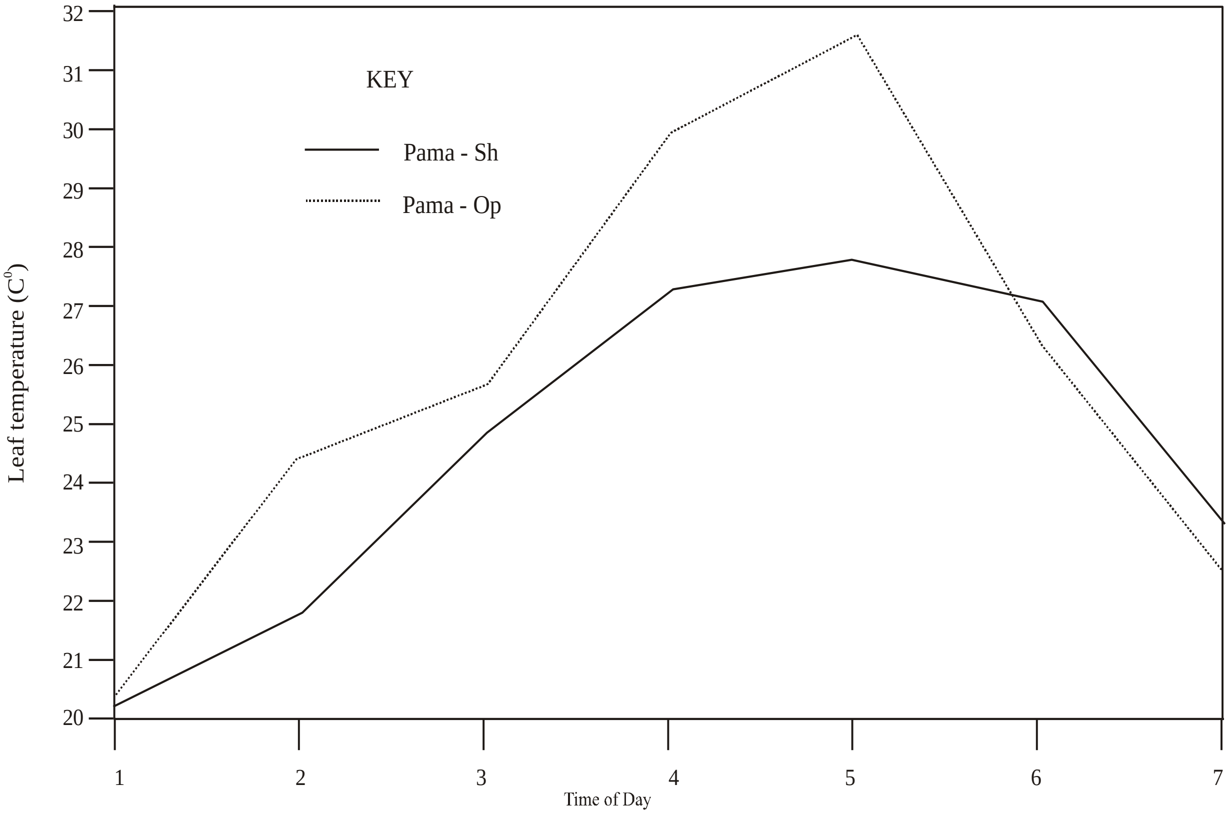

Fig. 3b Diurnal leaf temperature in the shade (Pama - Sh) and sun (Pama-op) Microsite in June

Figure 3b: Diurnal leaf temperature in the shade (Pama- sh-trees intact) and sun (Pama- Op-trees cleared) in June

Leaf Water Potential

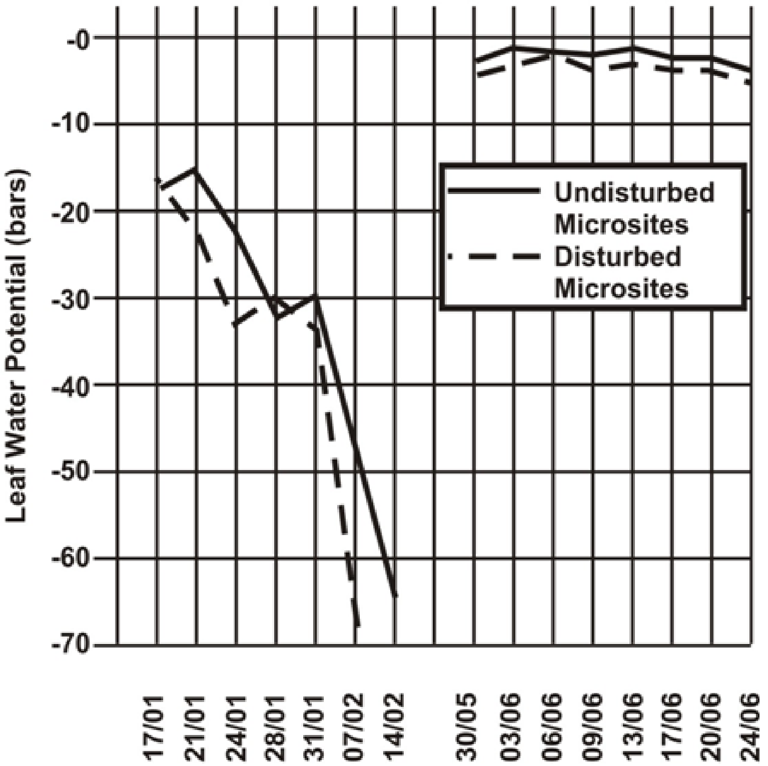

Figure 4: Leaf water potential in the disturbed microsites (trees cleared) and undisturbed microsites (trees intact) for *Panicum maximum* at the study sites, KALRO, Kiboko, Kenya

The seasonal cycle of leaf water potential for *Panicum maximum* in the exposed sites and intact sites exhibited a declining trend associated with the progression of the dry cycle (Figure 4). In the course of the bimodal short rainfall and long rainfall season, *Panicum maximum* in the intact sites exhibited relatively higher leaf water potentials (lower water stress) compared to *Panicum maximum* in the exposed sites. The leaf water potential values in the contrasting microsites were not statistically significant at $p \leq 0.05$.The differences in leaf water potential between *Panicum maximum* in the exposed sites and intact sites remained fairly small in the course of the wet season. At this time, leaf water potential for *Panicum maximum* oscillated between -2.0 bars and –5.0 bars. *Panicum maximum* in the exposed sites exhibited the lowest leaf water potential of the order of -70 bars whereas that in the intact sites recorded values of the order of –63 bars at the peak of the dry season in February (Figure 4).

Transpiration

Diurnal trends of transpiration rates in the course of the progression of the dry season (soil moisture declining phase) indicated that that there was a coupling effect associated with soil water availability. Soil moisture declines were associated with decreases in transpiration rates in the exposed sites and intact sites

(Figure 5). Increases in soil moisture supplies in the course of the wet season (April-May) were occasioned by concomitant increases in transpiration rates. *Panicum maximum* in the exposed sites transpired more profusely compared to *Panicum maximum* in the intact sites (Figure 5 and 6). Maximum transpiration rates were achieved earlier in the day during the wet phase (April) compared to the dry season (June), Figure 5 and 6.Maximum transpiration rates for *Panicum maximum* in the intact and exposed sites were 5.2 µg $m^{-2}s^{-1}$ and

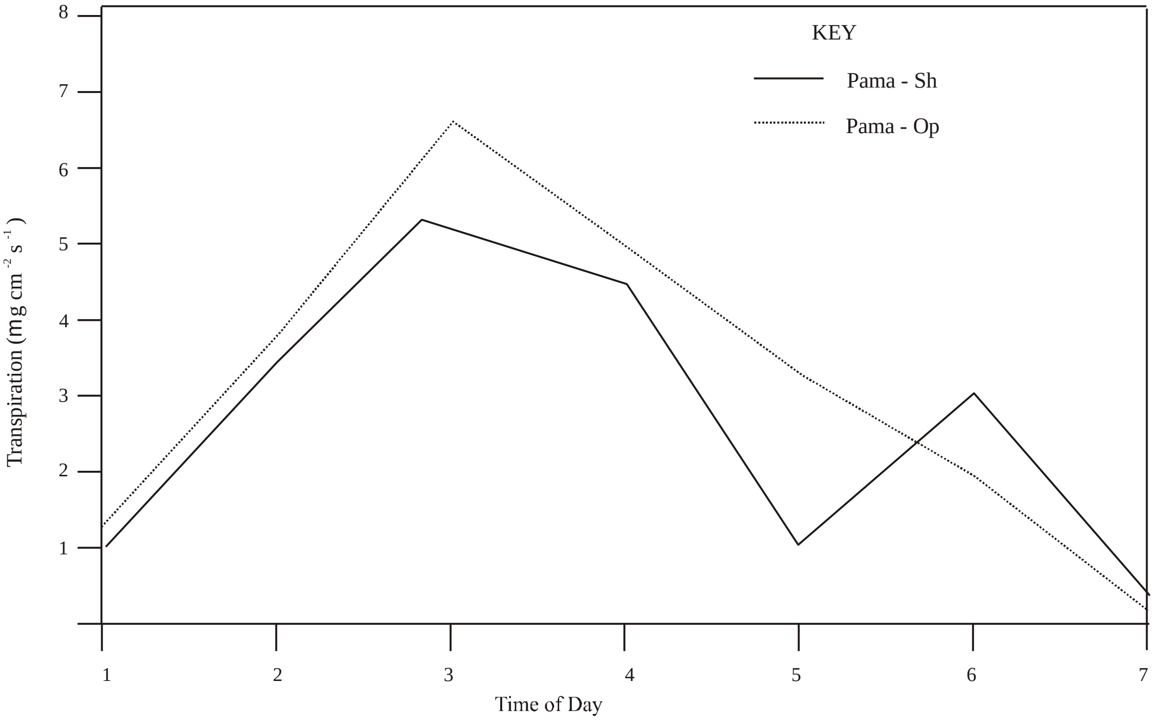

Figure 5: Diurnal transpiration rates of *Panicum maximum* in the shade (Pama- sh-trees intact) and sun (Pama –Op-trees cleared) in April (wet phase)

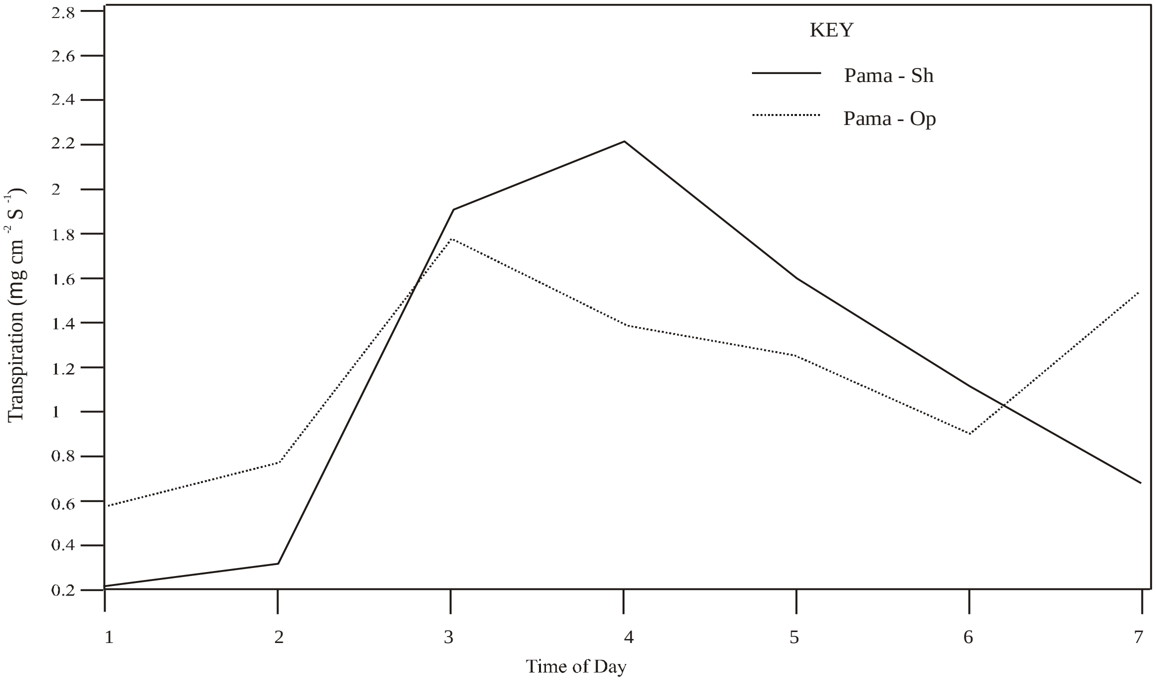

Figure 6: Diurnal transpiration rates of *Panicum maximum* in the shade (Pama- sh-trees intact) and sun (Pama- Op-trees cleared) in June (dry phase.

6.5μgm^{-2} s^{-1} in the dry phase respectively.

DISCUSSION

Seasonal and diurnal patterns of quantum flux, leaf temperature, and transpiration use of water and leaf water status indicated that there were significant shifts in environmental conditions and physiological responses of *Panicum maximum* in the intact sites and exposed sites. The relatively lower quantum flux values for the intact and exposed sites in June compared to April for similar micro sites is due to latitudinal changes in the perpendicularity of the sun's rays associated with the shifts of the equinoxes. Differential heating of the earth's surface arising from receipt of higher quantities of quantum flux in April compared to June is clearly demonstrated in the higher maximum temperatures for *Panicum maximum* for the same period in the contrasting micro sites. The strong coupling in the relationship between soil moisture availability and transpiration trends of *Panicum maximum* in the exposed and intact sites suggested the significance of soil profile moisture availability and profile partitioning in relation to the use of water supplies by the shallow rooted graminoid species. This is indicated by the achievement of maximum transpiration rates early in the day during the wet season when moisture is not limiting compared to the dry phase when the wetting front has moved away from the zone of maximum root density. Differences in the seasonal soil moisture cycle in the contrasting micro sites means that the relatively stable soil moisture supply into the dry phase for the intact habitats permits *Panicum maximum* in these sites to remain physiologically active over a longer period compared to *Panicum maximum* in the exposed sites. A detailed study of the implications of the extension of physiological activity into the dry season in the intact habitats in relation to net CO_2 assimilation rates, nutritive quality and digestibility is needed to verify these hypotheses. Kinyamario *et al.,* (1995) in studies of the eco-physiology of C_4 grasses found that *Panicum maximum* that grew under the shade of *Acacia tortilis* in Kenya exhibited a higher water use efficiency and net carbon assimilation rate in contrast to the C_4 grasses adapted to sun micro sites. Maranga *et al*., (1986) reported that *Chloris roxburghiana*, *Digitaria milanjiana*, and *Digitaria macroblephara* were common outside the canopy of *Acacia tortilis*. The difference in the distribution of these grasses was attributed to differences in micro environmental conditions.

Some studies relating leaf water potential to diffusive resistance in grasses have identified a threshold level of leaf water potential below which stomata close rapidly (Sala, *et al.,* 1981; Barnes and Harrison, 1982, Surendar *et al*., 2013). Although a critical threshold was not evidently obvious in the data presented it was clear that transpiration rates diminished with decrease in leaf water potential indicating a possibility of stomata limitation associated with increased diffusive resistance at low water potentials.

Since stomata oscillations are in part controlled by quantum flux, CO_2 concentration and water relations (Schulze *et al*., 1972, Schmitt Wulff 1993, and Schluter *et al.,* 2003), it may be surmised from the data of this study that long term shifts in micro environmental conditions of light energy, temperature and water relations are likely to influence CO_2 assimilation trends, productivity patterns and longevity of understorey grasses.

CONCLUSION

Panicum maximum in the exposed micro sites where *Acacia tortilis* had been removed exhibited higher quantum flux, leaf temperatures, leaf water stress (lower water potential) and transpiration rates. These findings suggest that long term shifts in micro environmental conditions of light energy, temperature, and transpiration use of water in the exposed habitats is likely to negatively influence CO_2 assimilation rates, primary productivity and longevity of *Panicum maximum.*

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