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SEASONAL DIFFERENCES IN CLEAR-SKY NIGHTTIME FORAGE TEMPERATURE IN PROXIMITY TO DECIDUOUS TREES

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Abstract: Considerable research has been done on daytime forage shading by silvopasture trees since solar radiation is required for photosynthesis. However, trees also impact nighttime temperature on clear nights when trees also effectively shade forages from cold skies. Appalachia has a temperate climate and deciduous-tree silvopasture nighttime temperature patterns will differ between spring before tree leaves emerge and summer when trees are in full canopy. Longwave radiation sensors, which simulate forage (surface) temperature, were installed in triplicate at four locations differing in obstruction to open sky by trees. An open pasture site (O) had 90% exposure to open sky during summer. A site within an adjacent closed-canopy second growth mixed hardwood forest (F), with only small canopy gaps, had 10% exposure to open sky. Two intermediate sites within a 15 X 50m gap cleared into the forest had 20 and 40% exposure to open sky respectively (G2 and G4). Air temperature was recorded at 2m at all sites. Temperatures were measured every 10s and hourly averages recorded from 1-Feb.-2008 through 10-July-2008. Summer differences between surface and air temperature in response to radiation cooling during clear night hours were -6.7, -2.9, -1.5, and -0.7^{o}C for sites O, G4, G2, and F respectively. Respective late winter and early spring temperature differences were -6.3, -6.4,-5.7 and -4.3^{o}C. There was a threefold difference between longwave radiation forage cooling at O compared to F in summer compared to early spring. Also, summer surface-air temperature differentials increased linearly as sky exposure increased. During tree leafless periods, temperature differentials were constant down to 40% sky exposure but decreased exponential approaching 10% sky exposure. During periods with full cloud cover there were no site temperature differences between air and surface during either season. These results suggest different forage management strategies in response to different forage nighttime temperatures may be warranted.

Key Words: Appalachia, cloudiness, forage, longwave radiation, silvopasture

INTRODUCTION

Longwave radiation loss at night has been a concern in agriculture and forestry primarily in relation to damage caused by radiation frost. Providing a vegetative cover over plants needing protection minimizes the risk of radiation frost damage since the cover remains near air temperature which is much warmer than a clear night sky (Carsmori ete al., 1996; Scowcroft et al., 2000; Langvall and Orlander, 2001). Radiation frost is a concern at ground surface level since air density increases as it cools so ground surface temperatures can become considerable cooler than the standard air temperature measured with weather stations at 2m height.

A sensor has been developed that measures temperature to which forage canopies are exposed during radiation frost events (Feldhake, 2002). Temperature measured closely tracked forage canopy temperature measured with an infrared thermometer during nighttime. There was a linear relationship between the percent open sky to which forage was exposed on clear nights and the depression of forage canopy temperature below air temperature measured at a 2 m height.

However, clear sky radiation cooling affects biological processes in ways other than frost damage. Other process in silvopasture systems such as forage canopy respiration and tree litter decomposition are affected by temperature. The Q_{10}, (rate of increase in biological processes with 10 degree increase in temperature) has been extensively studied for over a century and itself varies over different temperature ranges (Yuste et al. 2004).

In silvopastures shading of solar radiation by trees results in decreased understory temperatures during the daytime while shading from open sky longwave radiation loss results in increased nighttime temperature.

Deciduous trees provide a changing annual microclimate since the amount of open sky obscured varies greatly between periods with leaf filled tree canopies and periods with bare branches.

MATERIALS AND METHODS

This research was done at the interface of a pasture and mature second growth mixed hardwood forest, dominated by white oak (Quercus alba), red oak (Quercus rubra), red maple (Acer rubra), and yellow popular (Liriodendron tulipifera), in southern West Virginia ($37^{o}46$'W latitude $81^{o}00$'N longitude 860 m.a.s.l.). A 15m wide by 50m deep gap had been previously cleared into the forest from the pasture edge and established with forage to simulate silvopastures with varying degrees of influence from mature trees. Four measurement sites were chosen to give different exposure to open sky. A 90 % exposure site was in the adjacent open pasture (O), a 40% exposure site was in the center of the gap (G4), a 20% exposure site was at the deepest edge of the gap (G2), and a 10% exposure site was within the second growth forest (F).

At each site three radiation frost potential (RFP) sensors (Feldhake 2001) were installed. These sensors provide a temperature value representative of a 10 cm height forage canopy temperature. The sensors are comprised of a copper-constantan thermocouple epoxyed to the bottom center of a 5.3 cm square sheet metal that is thermally isolated from the metal rod to which it is attached for placement into the ground. A shielded thermocouple placed at 2m height gave a reference air temperature at each site. Measurements from all sensors were recorded using a Campbell 21X data logger (Campbell Scientific, Logan, UT) at 10 s intervals with 5 min and hourly averages.

RESULTS

The difference between under-tree surface and air temperature is influenced not only by the amount of sky obstruction by tree vegetative parts (leaves and branches in summer, branches only in winter) but also by cloud cover. At the open pasture treeless site (O) the summer surface-air temperature differential ranged from a maximum -8 ^{o}C to 0 ^{o}C on heavily overcast nights (Fig. 1). The distribution for each hour across all summer dates was fairly uniform reflecting the distribution of cloud cover in this humid-climate area. There tended to be a smaller surface-air temperature differential near dawn since this area commonly has fog which acts like cloud cover.

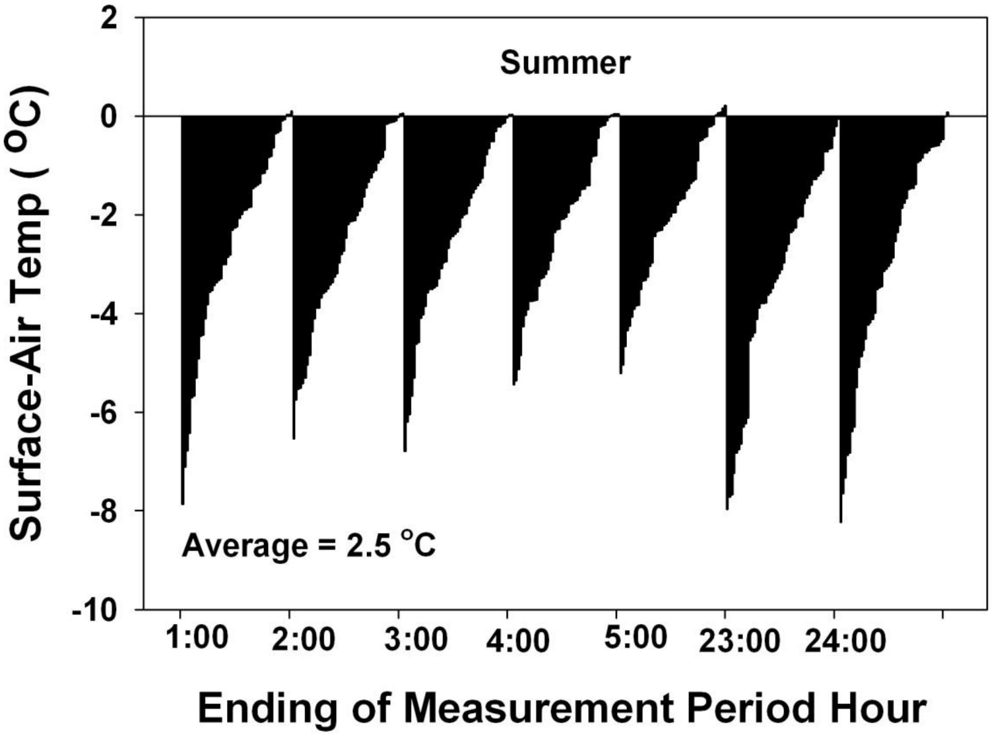

Figure 1. Distribution of hourly surface-air temperature differences for the open (O) site for the period 22-May-2008 through 10-July-2008.

In winter there are sometimes positive surface-air temperature differentials likely because the ground is covered with largely senesced grass and without transpiration the ground will heat more on sunny days relative to during summer (Fig. 2). The largest surface-air temperature differentials are around 8 ^{o}C as in the summer however the distribution is skewed toward smaller surface-air temperature in general relative to summer suggesting a greater degree of nighttime cloudiness.

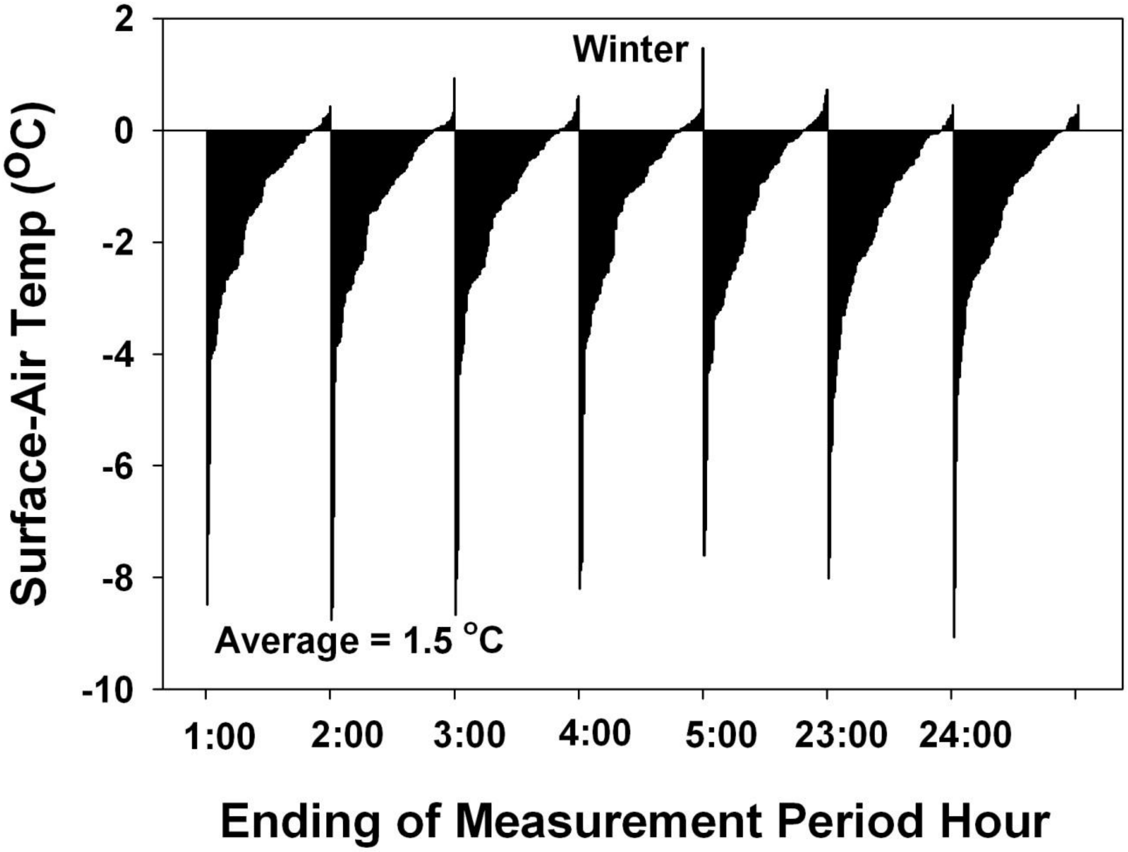

Figure 2. Distribution of hourly surface-air temperature differences for the open (O) site for the period 1-Feb-2008 through 20-April-2008.

In order to analyze tree influence on nighttime surface-air temperature differential, the 36 largest hourly differentials for summer and winter respectively were averaged. When plotted as a function of summertime percent open sky for each site, a very different relationship results for each season. The summer response is linear as theory predicts (Fig. 3). In winter, however, the surface-air temperature is not impacted by trees until approaching down to the 20 percent summer open sky value when it begins to increase exponentially. There are likely two factors contributing to this relationship. The first is that in proximity to trees wind movement is suppressed more than in an open field allowing a more stable boundary layer which facilitated more efficient radiative cooling of the surface. This offsets some of the re-radiation of thermal energy from sparse tree branches. The second factor is that trees exposed to open sky will produce more leaves relative to branches thus a closed forest will have more branches to re-radiate thermal energy and decrease the surface-air temperature differential.

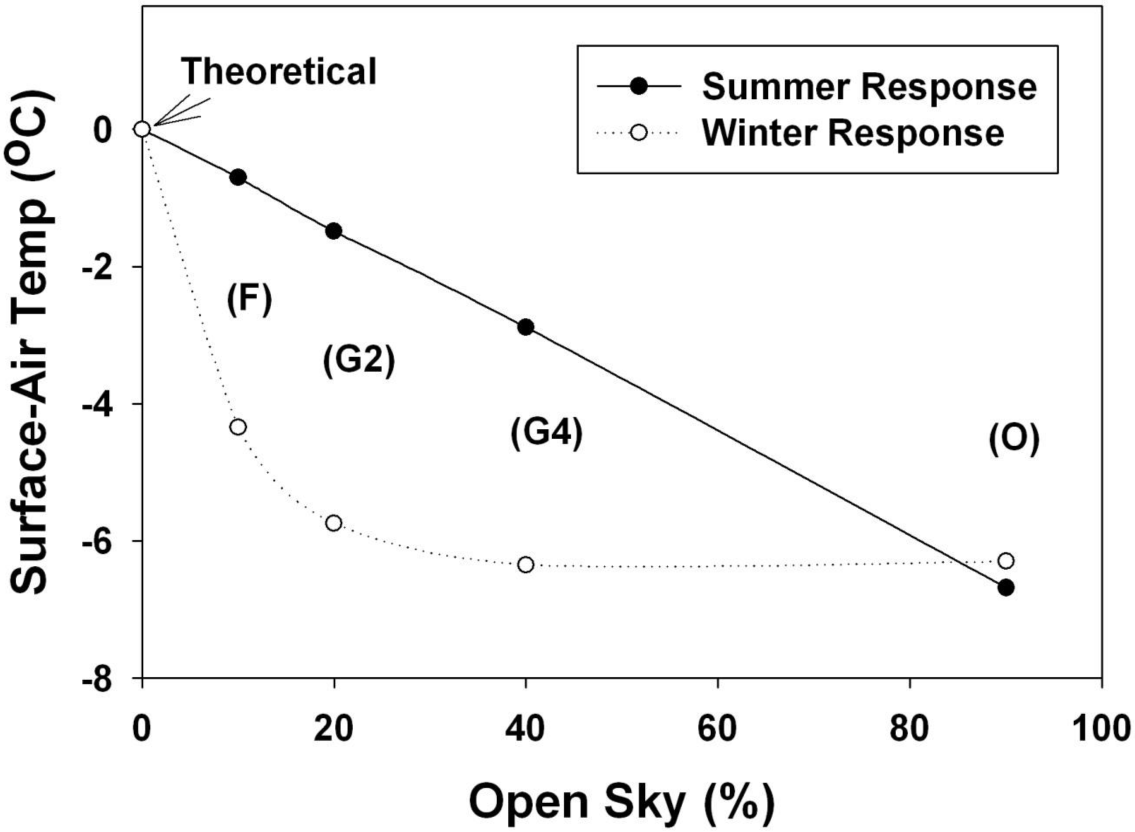

Figure 3. Average clear-sky surface-air temperature differences for summer and winter at the four measurement sites designated as forested (F), 20% open sky (G2), 40% open sky (G4), and open field (O) along with the theoretical complete sky obstruction value.

CONCLUSIONS

In the humid Appalachian region, there are more relatively clear sky nights that allow cooling of forages in open fields in summer than in winter. Deciduous tree silvopastures provide a linear increase in forage canopy temperature with sky obstruction relative to open fields in summer which can contribute to higher nighttime plant respiration. Nighttime warming under trees will also decrease dew deposition and impact the hydrologic budget and possibly the incidence of disease. During the winter deciduous trees have little impact on the nighttime surface-air temperature differential although the effect increases rapidly at very high tree densities. During cloudy periods trees have little impact on surface-air temperature differential during both summer and winter. These results suggest different forage management strategies during summer in response to different forage nighttime temperatures may be warranted depending on local frequency of clear skies.

Disclaimer: Mention of equipment does not imply endorsement by USDA-ARS but is supplied to inform readers of how data was acquired.

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