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Seasonal Comparison of Remotely Sensed Relative Forest Ecosystem Temperature Zones With Topography and Forest Biomass in the Clear Springs Wilderness Area of the Shawnee National Forest

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SEASONAL COMPARISON OF REMOTELY SENSED RELATIVE FOREST ECOSYSTEM TEMPERATURE ZONES WITH TOPOGRAPHY AND FOREST BIOMASS IN THE CLEAR SPRINGS WILDERNESS AREA OF THE SHAWNEE NATIONAL FOREST

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ABSTRACT

The use of thermal infrared data to delineate seasonal relative forest ecosystem temperature zones as a tool for forest ecological studies was analyzed. Analysis involved: (1) delineating relative seasonal forest ecosystem temperature zones within the Clear Springs Wilderness Area of the Shawnee National Forest using Landsat Thematic Mapper thermal infrared data; and, (2) quantifying the effect of topography and forest biomass on relative forest ecosystem temperature zones within seasons. Results indicate that slope was statistically uncorrelated with relative temperature zones within any season, aspect was statistically correlated with relative temperature zones during fall and winter, and forest biomass was statistically correlated with relative temperature zones during fall and spring which may indicate the use of thermal infrared data as an aid in identifying forest structure/age.

INTRODUCTION

Temperature zones within a forest ecosystem, a function of age, biomass, density and topographic characteristics, are necessary components of ecological studies of photosynthesis, respiration and evapotranspiration (Sader, 1986). Although accurate and efficient delineation of forest ecosystem temperature zones by point sampling with thermometers is possible for small areas, recording *in situ* temperatures over large or inaccessible areas would be time consuming and inefficient. A more synoptic method, applicable to small as well as large and inaccessible areas, is needed to efficiently map forest ecosystem temperature zones. Once delineated, forest ecosystem temperature zones could play a vital role in forest ecology studies.

Thermal infrared data, a measure of the radiant energy emitted by an object as a function of its kinetic temperature and emissivity, can be used as an indicator of temperature. The use of thermal infrared data to delineate water and terrestrial surface temperature at a synoptic scale, applicable to small as well as large or inaccessible areas, have focused on the use of aerial (LeDrew and Franklin, 1985) and satellite (Kerr et al., 1992) platforms.

Terrestrial surface temperatures derived from thermal infrared data have been used to map winter nocturnal temperature patterns (Chen et al., 1979), snow covered surface temperature (Collier et al., 1989) and the spatial distribution of soil types (Gauthier and Tabbagh, 1994). Thermal infrared data have also been integrated with a geographic information system (GIS) to monitor soil moisture (Shih and Jordan, 1993) and combined with meteorological data to estimate evapotranspiration (Serafini, 1987).

Although thermal infrared data have been found accurate for mapping terrestrial surface temperature (Wukelic et al., 1989), the data must be corrected for atmospheric attenuation (Cooper and Asrar, 1989; Desjardins et al., 1990; Sobrino et al., 1991) and emissivity (Sutherland and Bartholic, 1977; Sutherland et al., 1979; Vidal, 1991) to derive the absolute temperature of terrestrial surfaces. Additionally, empirical models developed to ascertain absolute terrestrial surface temperature are only good for the data and imagery analyzed (Lathrop and Lillesand, 1987).

A preliminary analysis of using thermal infrared data to map relative temperature zones, irrespective of atmospheric attenuation, emissivity and absolute temperature within an unaltered forest ecosystem, was studied by Unger (1995) and Unger and Ulliman (1996). They found that six relative summertime forest ecosystem temperature zones within the University of Idaho Experimental Forest, delineated with resampled Landsat Thematic Mapper thermal infrared data at 30 meters resolution, were robust over time.

To date thermal infrared data have not previously been incorporated and evaluated with a GIS to identify and spatially analyze the effect of topography and biomass on seasonal relative forest ecosystem temperature zones within the Central States Hardwood Forest Region. Once delineated, relative forest ecosystem temperature zones could play a vital role in forest ecology studies.

The purpose of this study, which continues the work of Unger (1995) and Unger and Ulliman (1996), is to: (1) delineate relative forest ecosystem temperate zones stratified by season within the Shawnee National Forest; and, (2) analyze the effect of forest biomass and topography on the relative forest ecosystem temperature zones within a season.

METHODOLOGY

The applicability of using thermal infrared data to delineate relative forest ecosystem temperature zones, and the effect of topography and forest biomass on their delineation, was assessed within the Clear Springs Wilderness Area of the Shawnee National Forest (Figure 1). The Clear Springs Wilderness Area, which lies in the southwest portion of Southern Illinois, was chosen for its representation of a typical 85-100 percent closed canopy Central States Oak-Hickory forest. A wilderness area was chosen to compare seasonal differences in relative forest ecosystem temperature zones within an unaltered ecosystem.

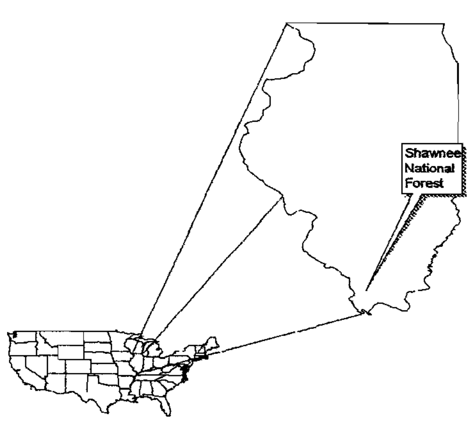

Figure 1. Location of Clear Springs Wilderness Area in Southern Illinois.

Four cloud free Landsat Thematic Mapper scenes representing the Clear Springs Wilderness Area were acquired (Figure 2). Image acquisition dates were May 8 1987, July 11 1987, October 25 1985 and December 25 1984 representing spring, summer, fall and winter respectively. Although every effort was made to purchase a cloud free scene within one calendar year, subsequently described seasonal analysis is scene dependent and unaffected by temporal changes between scenes. All four seasons were chosen to represent full leaf-on, full leaf-off and the two leaf-on/leaf-off transition zones of spring and fall.

From the four original Landsat Thematic Mapper seasonal images a ratio leaf area index image representing the biomass within each season was produced (Figure 3). A near infrared to red ratio leaf area index image per season was chosen for its simplicity and its ability to produce a large spectral difference between extreme forest biomass levels. In addition, a United States Geological Survey 30-meter digital elevation model was used to produce topographic imagery representing percent slope and degree aspect within the Clear Springs Wilderness Area (Figure 4).

The thermal infrared data representing each season within the Clear Springs Wilderness Area were extracted from their respective seasonal Landsat scenes. The histograms representing each season's thermal infrared data were analyzed and delineated into six equal-sized regions (Figure 5). Once the histograms were delineated, all 120-meter thermal infrared data per season were resampled to 30 meters and recoded to create six relative forest ecosystem temperature zones representing the coldest, colder, cold, warm, warmer and warmest temperature zones per season and coded one through six respectively (Figure 6).

The effect of slope, aspect and forest biomass on each seasons relative temperature zones was analyzed by computing the linear correlation coefficient between the mean percent slope, degree aspect and leaf area index value within each season's relative temperature zone per temperature class value.

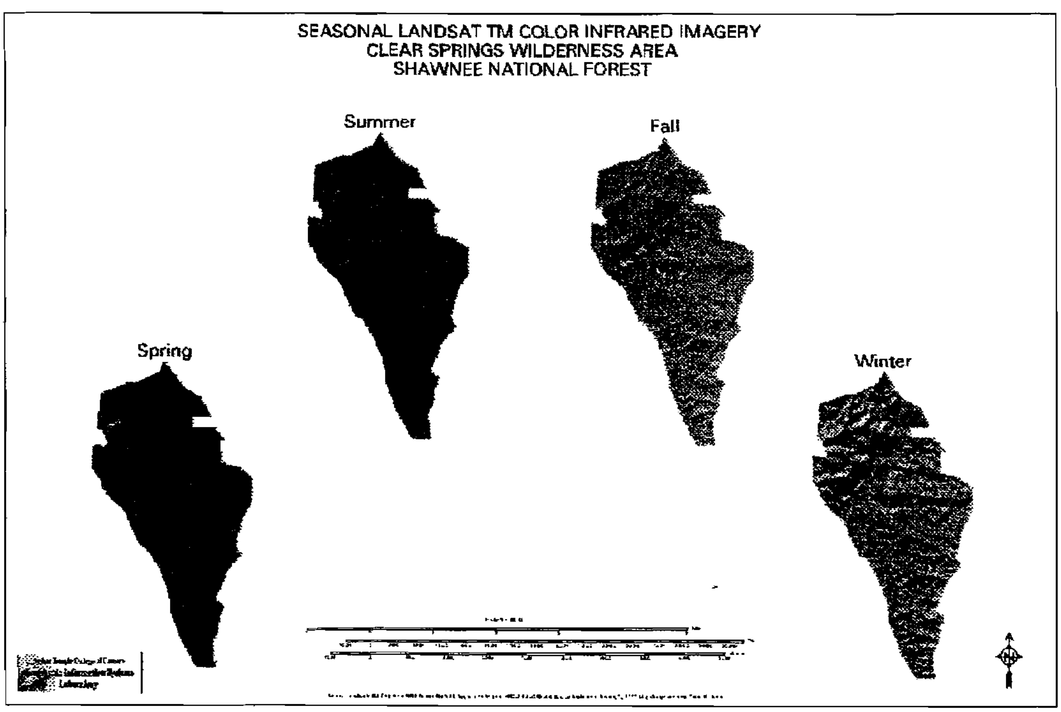

Figure 2. Color infrared imagery representing the Clear Springs Wilderness Area per season.

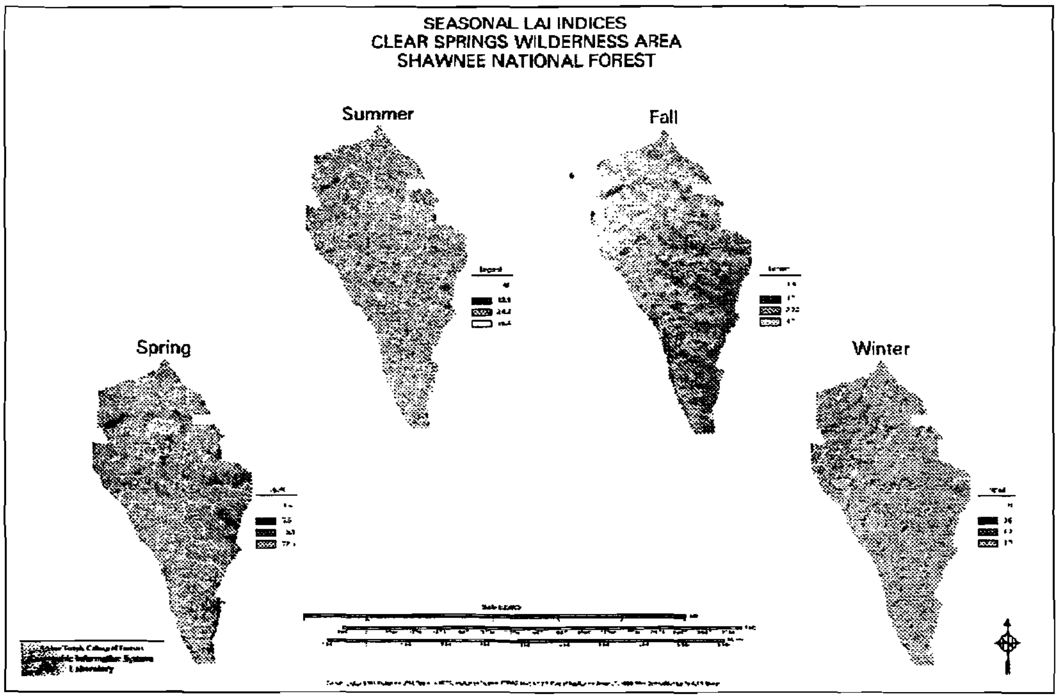

Figure 3. Leaf area index image per season within the Clear Springs Wilderness Area.

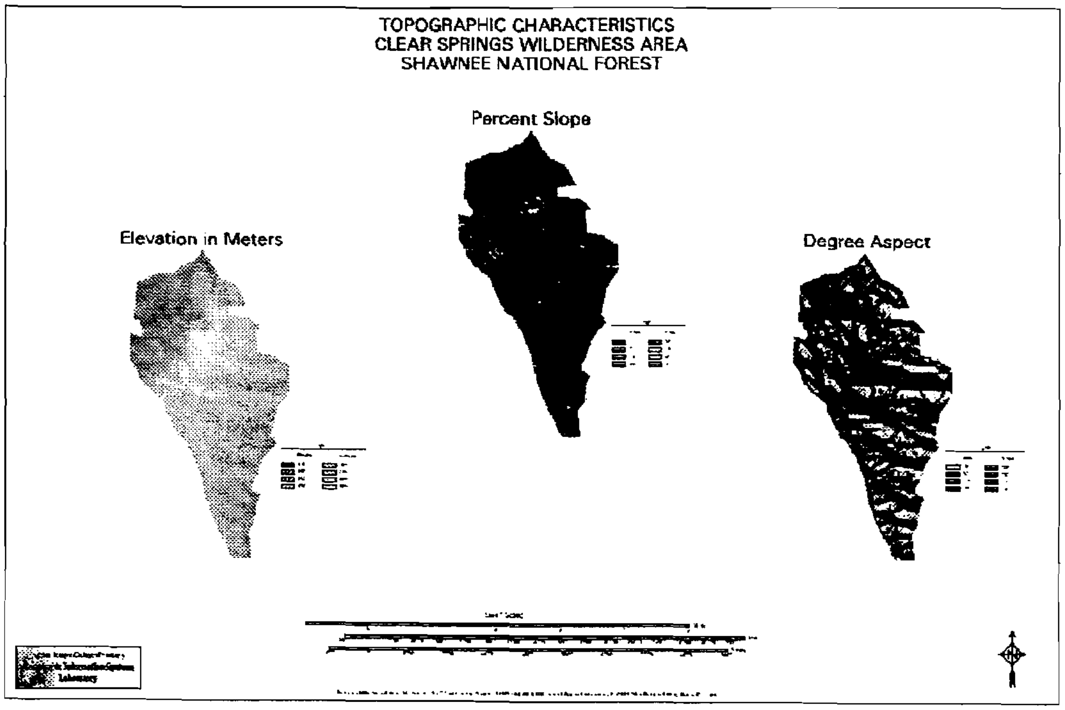

Figure 4. Percent slope and degree aspect models representing the Clear Springs Wilderness Area.

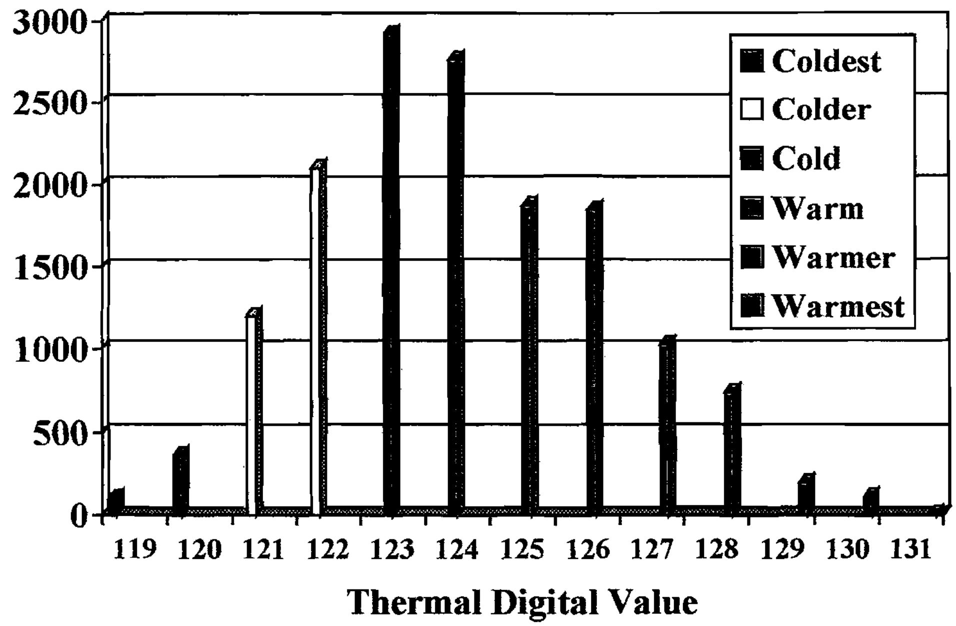

Figure 5. Example of delineating October's thermal infrared data into six equal-sized areas.

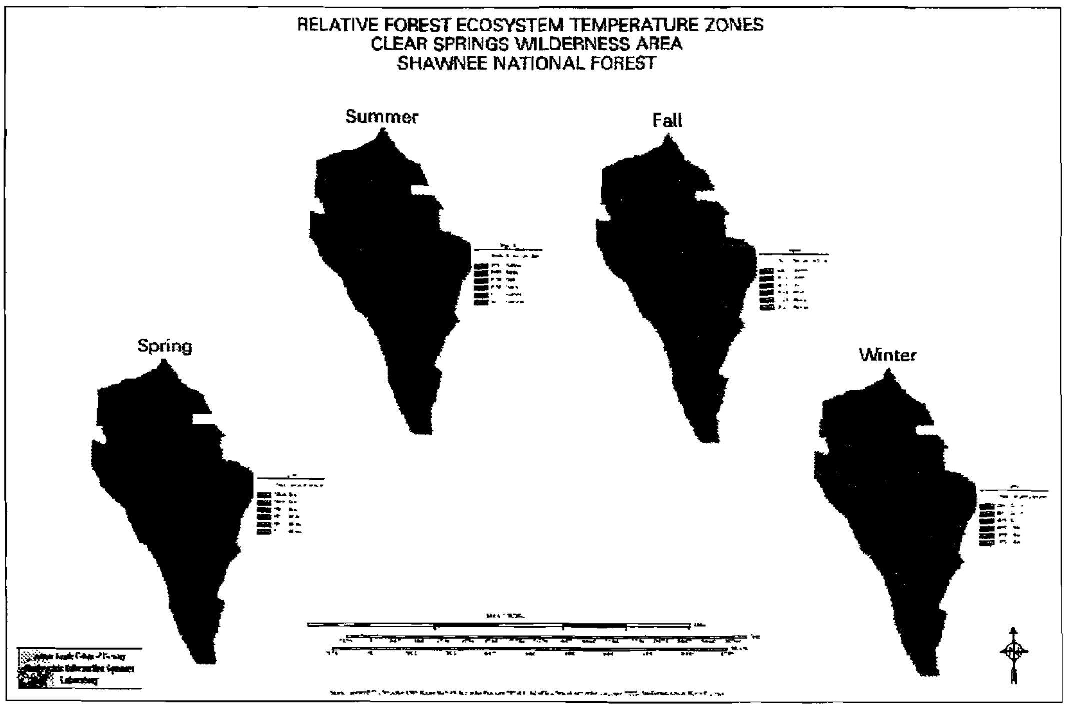

Figure 6. Relative forest ecosystem temperature zones within the Clear Springs Wilderness Area per season.

RESULTS

Results from the effect of slope on relative temperature zones indicate that although the linear correlation coefficients were relatively high and ranged from – 0.66 to – 0.77 for July and December respectively, there was no statistically significant relationship between mean slope and relative temperature zones within a season.

Results from the effect of aspect on relative temperature zones indicate that there was a statistically significant relationship between mean aspect and relative temperature zones for October at 0.05 and December at 0.01. These results indicate that in a forested ecosystem such as the Clear Springs Wilderness Area, as the level of forest biomass in the canopy decreases, aspect will have a greater impact on temperature. It is interesting to note that during the peak summer growing season there was no statistically significant relationship between aspect and temperature that may preclude its use as an aid in forest ecology studies within the Shawnee National Forest.

Results from the effect of forest biomass on relative temperature zones indicate that there was a statistically significant relationship between mean forest biomass levels and relative temperature class for May and October at the 0.01 levels. As in the case with aspect, there was no statistically significant relationship between forest biomass and relative temperature zones during the peak-growing season that may preclude its use as well from forest ecology temperature studies for areas similar to the Clear Springs Wilderness Area.

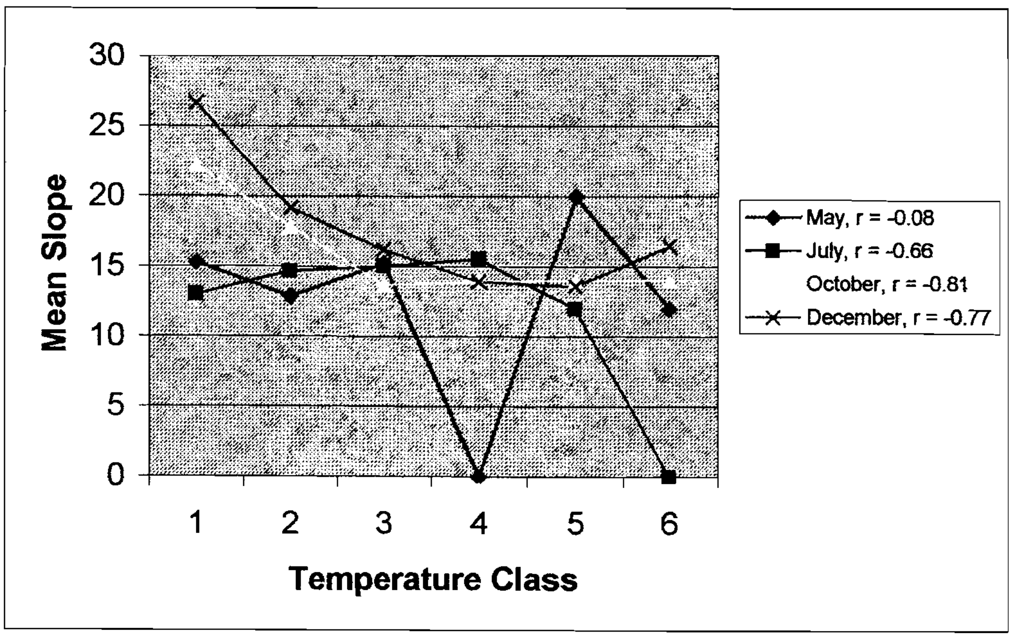

Figure 7. Linear correlation coefficients between mean slope within each relative temperature zone and relative temperature class value per season. No statistical significance per season.

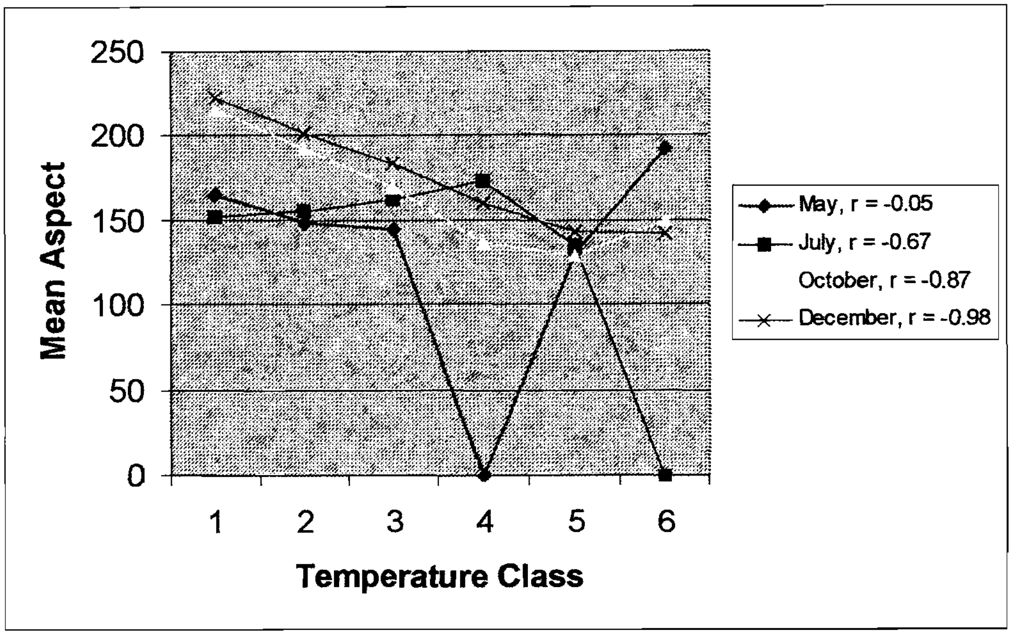

Figure 8. Linear correlation coefficients between mean aspect within each relative temperature zone and relative temperature class value per season. Statistically significant for October at 0.05 and December at 0.01.

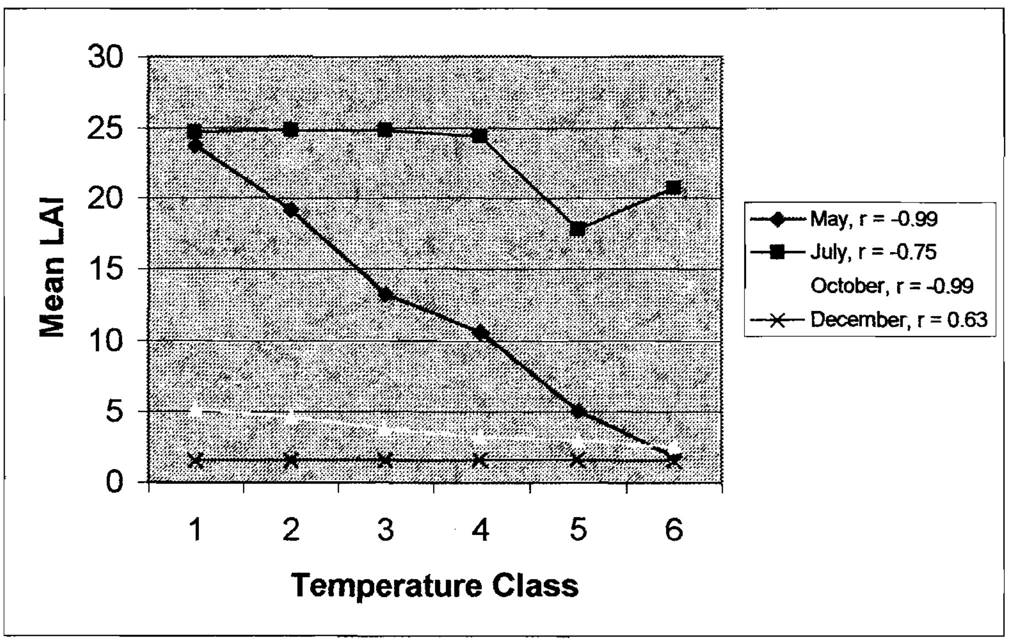

Figure 9. Linear correlation coefficients between mean biomass within each relative temperature zone and relative temperature class value per season. Statistically significant for May and October at 0.01.

SUMMARY

The original intent of this project was to assess the effect of forest biomass and topography on relative forest ecosystem temperature zones for forest ecology studies. Although results indicate that forest biomass and topography were statistically uncorrelated with a Central Hardwood Oak-Hickory forest's relative temperature zones during a forests peak growing season which may preclude their use in forest ecology studies in similar areas, results also indicate that the delineated relative temperature zones were statistically correlated with forest biomass during the leaf-on/leaf-off transition seasons of fall and spring. The statistical significance between relative temperature zones and forest biomass during leaf-on/leaf-off transition may be an indicator of stand structure and/or age when the emitted energy received by the Landsat series of satellites represents the transitional states between growth and death when stand structure is most apparent remotely and not hidden behind a closed canopy in the summer nor non-existent canopy in the winter.

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