Banisteria, Number 13, 1999
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Climate Characteristics of the Big Levels Region, Augusta County, Virginia

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INTRODUCTION

Navarra (1979) defined climate as the specific set of statistics that describe weather conditions during a specified interval of time. It is the most important abiotic factor influencing the distribution of plant and animal communities and species (Holdridge et al., 1971; Vernberg & Vernberg, 1970). Major weather factors that comprise climate include, but are not limited to, temperature, precipitation, air pressure, humidity, wind, evapotranspiration, and solar radiation (Thornwaite & Mather, 1955). Topography and geographic location greatly influence climate characteristics of a given area (Sartz, 1972). Climate has been cited as influencing species distribution in Virginia (Woodward & Hoffman, 1991).

The Big Levels region (Fig. 1) located in Augusta County, Virginia, occurs in the Blue Ridge physiographic province (Bailey, 1980) and is characterized by mountainous terrain between the Shenandoah Valley to the west and the Piedmont province to the east. The Big Levels area is affected by both oceanic and continental weather patterns due to its elevated position on the Blue Ridge (Woodward & Hoffman, 1991).

Climatic information is difficult to obtain at a local level due to the cost of monitoring and compiling weather information. Such data should be compiled over extended periods of time, however, few studies are conducted at a temporal scale of sufficient length to assess climate patterns adequately. The closest National Oceanic and Atmospheric Administration (NOAA) weather station to Big Levels is located in Montebello, over 400 m lower in elevation. This station only records precipitation data. Regional climate can be estimated and modeled by using a geographic information system (GIS) (Ford, 1982; Cooter et al., 1993; Pakeman & Mars, 1996; Scalet et al., 1996). Klopfer (1997) provided estimates of landscape-scale temperature, precipitation, potential evapotranspiration (PET), and moisture for Virginia. In this paper I describe the climate characteristics of the Big Levels region and illustrate the unique climate diversity of the area relative to the rest of Virginia.

MATERIALS AND METHODS

I estimated mean monthly temperature, precipitation, PET, and annual moisture at each 300 m x 300 m pixel in Virginia. I estimated temperature and precipitation by inverse-distance interpolation from 30 years of data collected by NOAA (Owenby & Ezell, 1992) for weather stations in Virginia and nearby stations in neighboring states (Klopfer, 1997). I adjusted estimates for differences in elevation before interpolation with an adiabatic cooling rate. This rate was calculated by dividing the difference in temperature by the difference in elevation for the highest and lowest of the five closest weather stations surrounding each pixel (Klopfer, 1997). I estimated monthly PET using the method described by Thornwaite & Mather (1957). An index of moisture was obtained from monthly temperature estimates and PET (Carter & Mather, 1966). I evaluated the accuracy of temperature and precipitation estimates by comparing estimates to actual data from NOAA stations not used in the estimation process. PET estimates were compared to PET calculated from NOAA station data.

All GIS operations were performed on a Microsoft Windows-based personal computer. The GIS software used was TNT-Mips (MicroImages, Inc., 201 North 8th Street, Suite 15, Lincoln, Nebraska 68508-1347). All statistical computations were performed in SAS (SAS Institute Inc., Box 8000, SAS Circle, Cary, NC 27511-8000). Base digital elevation data were obtained from the United States Geological Survey.

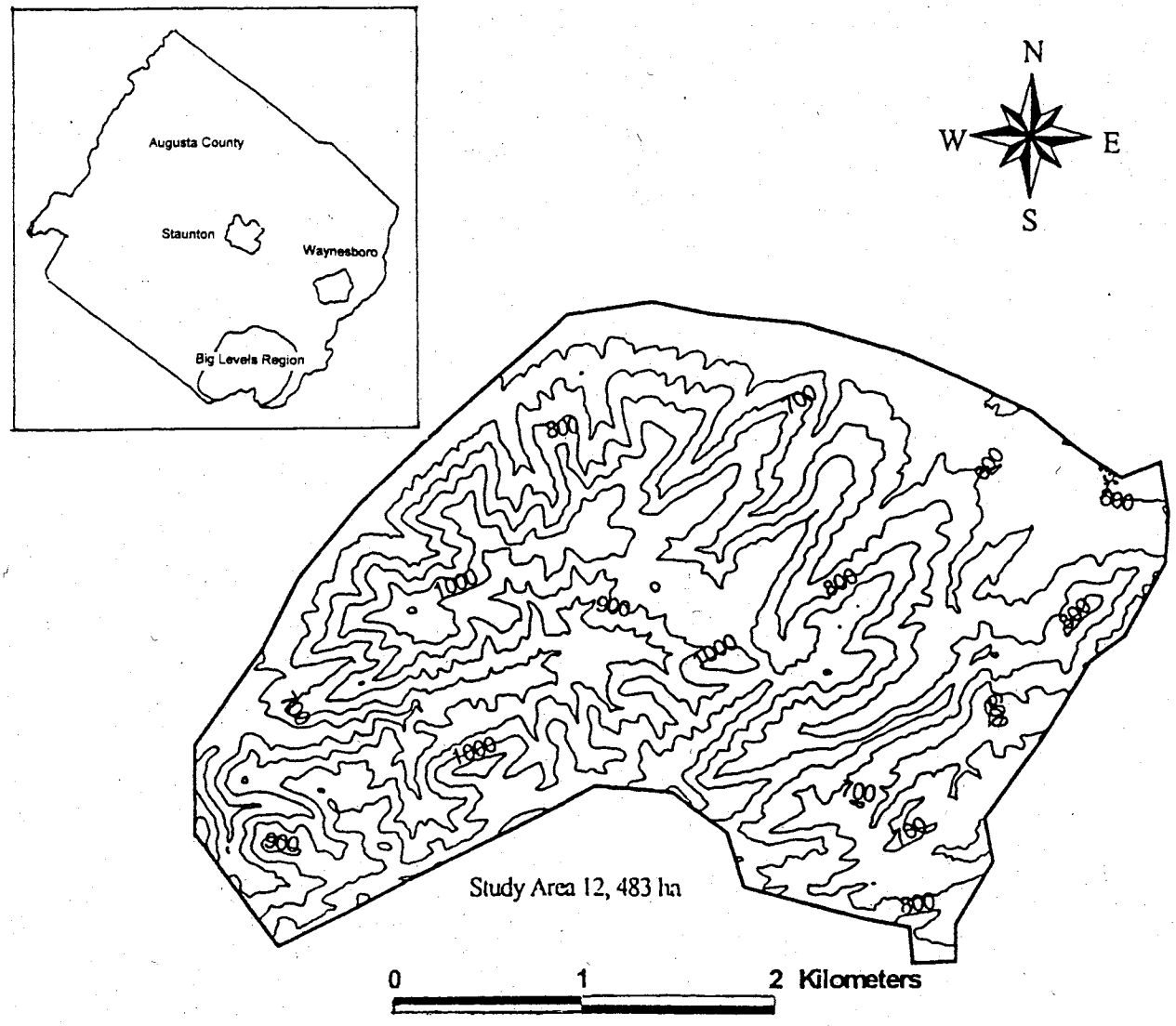

Fig. 1. The elevation contours (m) of the Big Levels region. Climate estimates reported correspond to the boundary depicted above.

Climatic characteristics reported for the Big Levels region were taken from the entire state climate data set shown in Fig. 1 (approximately 12,500 ha). I tabulated minimum, mean, and maximum values for mean monthly temperature and precipitation, and compared climate characteristics of Big Levels to those of the entire state.

RESULTS

Mean monthly temperatures for the Big Levels region ranged from a minimum of -10.5°C in January to a maximum of 21.9°C in July (Table 1). Within a given month, the range of mean monthly temperatures for Big Levels averaged 8.5°C, but mean monthly temperatures in October differed by 10°C. The Big Levels region is on average 6°C cooler then the mean monthly temperature calculated for the state (Table 1). Mean monthly temperature is closely tied to elevation, with higher elevation areas remaining below freezing well into March.

Mean monthly precipitation ranged from 66 mm in January to 107 mm in July (Table 2). Mean monthly precipitation in the Big Levels region did not vary dramatically within any month (maximum of 10 mm in August), and did not differ greatly from state averages for any month (mean difference of 7 mm).

Temperature and precipitation of the Big Levels area were combined in a climatograph (Fig. 2) to illustrate the difference between the Big Levels local climate and the

Table 1. Average of 30-year mean monthly temperature (° C) and differences for Big Levels and Virginia.

	Big Levels			Virginia			Difference		
Month	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max
January	-10.5	-5.4	-1.9	-11.4	0.7	5.2	-0.9	6.1	7.1
February	-8.6	-3.8	-0.3	-9.5	2.3	6.3	-0.9	6.1	6.6
March	-2.2	-2.1	5.0	-4.1	7.3	10.3	-1.9	9.4	5.3
April	-0.6	5.3	9.4	-2.0	12.2	15.5	-1.4	6.9	6.1
May	6.7	12.1	15.3	4.4	17.0	20.5	-2.3	4.9	5.2
June	11.7	17.0	19.7	9.5	21.3	24.3	-2.2	4.3	4.6
July	14.2	19.2	21.9	12.1	23.5	26.3	-2.1	4.3	4.4
August	14.0	18.5	21.1	10.4	22.9	25.8	-3.6	4.4	4.7
September	7.9	13.8	17.0	5.4	19.3	23.0	-2.5	5.5	6.0
October	0.4	7.4	11.0	-2.4	13.3	17.5	-2.8	5.9	6.5
November	-4.7	1.2	5.2	-5.7	8.2	12.4	-1.0	7.0	7.2
December	-6.6	-2.5	0.5	-7.4	3.1	7.8	-0.8	5.6	7.3

state climate. PET and precipitation were compared in a water balance graph (Fig. 3). This pattern is typical (Thornwaite & Mather, 1955) of humid regions of the continent.

DISCUSSION

GIS-based landscape climate modeling provided sound estimates for all climate variables modeled in this study. Until more comprehensive climate data are recorded in this and other regions of the State, GIS climate modeling can provide reasonable, economical, and effective estimates for specific areas without long-term data. Mean monthly temperature estimates for Virginia were accurate within 1 °C and precipitation estimates were accurate to within 13 mm (Klopfer, 1997). I assume that the accuracy of the estimates for the Big Levels region reflect that accuracy. Unfortunately, the estimates were verified with NOAA weather stations that are typically located in urban centers and at relatively low elevations. Thus, reported accuracy of temperature and precipitation may not be as accurate for the Big Levels regions due to its elevated position relative to the surrounding weather stations.

Although mean monthly temperature varies across the Big Levels region, precipitation does not. This could be a result of including elevation differences in the temperature estimation procedure but not in the precipitation estimates. Topographic influences on precipitation within the Big Levels region, if present, were not incorporated in this study. The Big Levels region appears to receive more rain than the state average in Winter and Spring seasons,

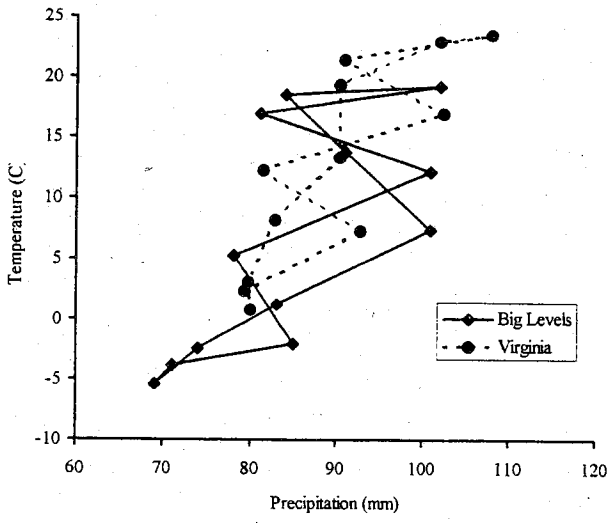

Fig. 2. Climatograph illustrating that the Big Levels region is colder and wetter than the rest of Virginia. Note the relative position of the two polygons, with the Big Levels polygon skewed slightly right and lower on the X and Y axes, respectively.

Table 2. Average of 30-year mean monthly precipitation (mm) and differences for Big Levels and Virginia.

	Big Levels			Virginia			Difference		
Month	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max
January	66	69	73	50	79.9	110	-16	10.9	37
February	67	71	75	51	79.3	109	-16	8.3	34
March	82	85	89	68	92.7	128	-14	7.7	39
April	76	78	80	60	81.5	116	-16	3.5	36
May	99	101	105	82	102.5	131	-17	1.5	26
June	77	81	84	69	90.9	118	-8	9.9	34
July	99	102	107	78	108	141	-21	6	34
August	90	84	100	74	102.1	140	-16	18.1	40
September	87	91	95	70	90.3	135	-17	-0.7	40
October	97	101	106	67	90.4	133	-30	-10.6	27
November	81	83	86	66	82.8	132	-15	-0.2	46
December	71	74	77	53	79.7	115	-18	5.7	38

and less rain during the Fall (particularly in October). In Summer (June - August), the maximum amount of precipitation is less than the state mean for the same months.

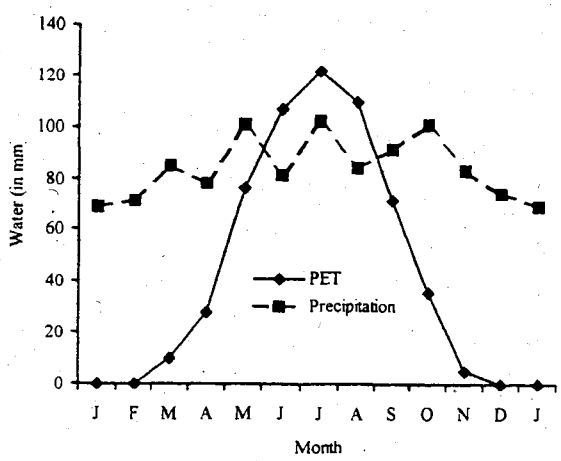

Fig. 3. Annual water budget for the Big Levels Region. In months where PET is lower than precipitation ground water is recharged to capacity. Excess water runs off until PET is greater than precipitation, then ground water is used to meet evapotranspiration requirements. When PET falls below precipitation ground water is recharged.

This corresponds to the slight water deficit evident in Fig. 3.

The Big Levels region has a complex climate that is cooler and wetter than most other areas in Virginia. The size of the region is relatively small yet has a range of temperatures capturing half of the variation observed over the entire state in any given month. For comparison, the range of annual mean temperature for the Big Levels region (7.8°C) was larger than ranges observed for the Mount Rogers area (5.7°C), the Burkes Garden area (3.9°C), and the region encompassing Massanutten Mountain and central Shenandoah National Park (6°C). This difference is especially important when the size of the land areas from which the ranges were derived are considered. The range of temperatures reported for Big Levels was from a land area of 12, 483 ha. This area is very small compared to the areas used for Mount Rogers (148, 233 ha), Burkes Garden (24, 843 ha), and Massanutten-central Shenandoah National Park (288, 744 ha).

This variation creates unique conditions for certain plant and animal communities typically restricted to higher elevations or more northerly latitudes. The geographic distribution of plant communities has been shown to be largely a function of temperature and precipitation (Waring, 1969; Holdridge et al., 1971; Whittaker, 1975;

Bailey, 1980; Woodward, 1990). The Big Levels region provides climatic habitat for communities not found in either the Shenandoah Valley or the Piedmont. Studies of local plants, amphibians, reptiles, and invertebrates support this view (Flemming & Van Alstine, 1999; Mitchell & Buhlmann, 1999; Roble, 1999). When viewed at a large scale (50,000 – 100,000 ha), the Big Levels region, combined with the regions immediately adjacent to it, is the most climatically diverse landscape in Virginia.

ACKNOWLEDGEMENTS

I would like to thank Dr. Robert H. Giles, Jr. for his guidance while completing the climate estimation work for Virginia. I also wish to thank Jeff Waldon of the Fish and Wildlife Information Exchange and the Virginia Gap Analysis Project for sponsoring this research, and Dr. Joseph Mitchell for the invitation to submit it. The author's M.S. thesis is available in its entirety over the Internet at http://scholar.lib.vt.edu/theses/available/etd-7197-113632. The author may also be contacted at sklopfer@vt.edu for electronic reprints.

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