

RELATIONSHIPS BETWEEN CLIMATIC VARIATION
AND GRASSLAND BIOMASS ON THE NORTHERN RANGE OF
YELLOWSTONE NATIONAL PARK

Mark S. Boyce
Evelyn H. Merrill
Department of Zoology and Physiology
and
Ronald Marrs
Department of Geology
University of Wyoming
Laramie

Objectives

Summer range is not thought to be limiting to elk because abundant, high quality forage is available whereas a shortage of forage usually exists on elk winter ranges. Nevertheless, summer nutrition and fat reserves acquired on summer ranges influence growth, survival and reproduction of ungulates (Klein 1965, Verme 1963, 1965, Julander et al. 1961). The enormous area of summer range for the Northern Yellowstone elk herd renders detailed field surveys impractical. This study was initiated to evaluate the feasibility of using LANDSAT satellite imagery to (1) characterize vegetation communities on summer range from LANDSAT multispectral scanner (MSS) data and digitized vegetation maps of Yellowstone National Park, (2) predict plant production within grassland types and (3) correlate elk population characteristics with fluctuations in plant production and weather.

Methods

Computer compatible tapes (CCT) for LANDSAT MSS data for 9 years within the period 1972-1986 were obtained and catalogued into the University of Wyoming's Cyber Computer Library. The 1987 LANDSAT imagery of the Park was taken on 5 August during a period of less than 30% cloud cover. Computer programs were written to dump the LANDSAT MSS data in interleaved and sequenced band EDIPS format from the CCT to a format suitable to use in the LANDSAT Multi-Image Processing System (MIPS).

Vegetation classification

Classification of major habitat types on elk summer range using LANDSAT MSS data is in progress. Co-registration of digitized Yellowstone National Park habitat maps and LANDSAT MSS data using the MIPS image processing system has proved impractical and a supervised classification approach using the original vegetation maps is being pursued. Reflectance values from a total of 200 pixels within vegetatively

homogeneous sites, of not less than 20 ha in size, have been identified on Yellowstone National Park vegetation maps. Spectral signatures for these training sites are being determined from 1972 LANDSAT MSS data which has been smoothed using a low-pass filter (3 x 3 pixels). These data will be subjected to discriminant analysis to obtain vegetation classification functions.

Grassland production

The feasibility of predicting vegetation production within grasslands from LANDSAT MSS data is being determined using 1987 LANDSAT spectral information and ground vegetation sampling. Vegetative production during 1987 was sampled from 9-21 August at 24 sites (<12 ha) on 3 major elk summer ranges (Mirror Plateau, Norris/Cache-Calfee Ridge Complex, Buffalo Plateau) and at 2 high elevational sites on Mt. Washburn. Sites were classified as to physiographic features and habitat types based on habitat maps and descriptions received from the Park. Green biomass of 3 forage classes (forbs, graminoids and shrub current annual growth) were estimated using a capacitance meter or, in areas into which the capacitance meter could not be transported, from indices of plant volume (canopy coverage x average height). A total of 270 microplots were clipped to derive regression models for predicting green plant biomass from capacitance readings and/or volume indices. Clipped plant material was separated into green biomass by forage class and litter, oven dried at 100 degrees C for 24 hours and weighed to the nearest 0.01 gram.

Spectral reflectance values of the 4 MSS bands at the 26 sites sampled were identified in the 1987 LANDSAT data by co-registering a portion of the 1987 LANDSAT scene and IR photos on which the 26 sites were mapped. Reflectance signatures of the 26 sites have been recorded.

Results

Vegetation classification

Classification analysis of major habitat types based on LANDSAT imagery has not yet been completed. However, a procedure for delineating timbered areas from grassland/sagebrush-grassland sites has been developed based on principal components analysis. This procedure has been used to create a vegetation "mask" designed to identify and extract LANDSAT spectral information only from grassland/sagebrush-grassland areas designated as elk summer range. This "mask" will be used on LANDSAT imagery for the period 1972-1987 for predicting total grassland production on elk summer ranges during these years.

Grassland production

Twenty-one grassland and 5 sites dominated by sagebrush-grassland were sampled during August 1987 (Table 1). This is less than half the number of sample sites we had originally desired. However, logistical

Table 1. Summary of site characteristics where plant production was sampled during August 1987.

Plot #	Date Sampled	Plot Location	Habitat ¹ Type	Elevation (feet)	Aspect (degrees)	Slope (90%)
1	8/9/87	Mt. Norris	FN	7840	260	20
2	8/9/87	Mt. Norris	TFG	8000	185	13
3	8/10/87	Mt. Norris	FNG	7600	200	10
4	8/10/87	Mt. Norris	TA	8200	190	32
5	8/10/87	Mt. Norris	FNG	8200	110	33
6	8/11/87	Mt. Washburn	FA	8740	240	37
7	8/11/87	Mt. Washburn	FA	8700	280	22
8	8/12/87	Opal Creek	DW	8750	312	15
9	8/13/87	Opal Creek	DW	9060	Flat	0
10	8/13/87	Opal Creek	FD	9000	103	18
11	8/13/87	Opal Creek	FD	8900	150	23
12	8/13/87	Opal Creek	DC	8800	Flat	4
13	8/14/87	Specimen Ridge Trail	FN	9150	200	21
14	8/14/87	Specimen Ridge	FD	9150	90	5
15	8/14/87	Specimen Ridge	FNG	8800	120	30
16	8/16/87	Buffalo Plateau	FA	6400	250	5
17	8/16/87	Buffalo Plateau	TF	6700	240	20
18	8/17/87	2B-1 Camp-Ground	FNG	8900	180	15
19	8/17/87	Little Buffalo Creek	FD	8820	180	3
20	8/19/87	Soda Butte	TF	6620	Flat	0
21	8/19/87	Lower Lamar Trail	FA	6640	Flat	0
22	8/19/87	Lower Mt. Norris/Lamar Trail	FNG	6690	277	7
23	8/20/87	Cache-Calfee	FN	8120	312	8
24	8/21/87	Cache-Calfee	FN	7920	267	4
25	8/21/87	Cache Calfee	FN	8200	277	8
26	8/21/87	East Wabb Springs	FNG	7240	317	6

constraints prevented more extensive sampling in the time frame dictated by phenological change in the vegetation. Capacitance meter readings provided more precise estimates of green biomass than did visual estimates of plant volume (Table 2).

Total plant production ranged from 527 to 3154 kg/ha on grassland sites and 482-1978 kg/ha on sagebrush-grassland sites (Table 3). Graminoids comprised more than 60% of the total vegetative production on grasslands, except on the Buffalo Plateau in the area above campground 2B-1. Forbs comprised more than 70% of the plant biomass at this site (Table 3). Current annual growth of sagebrush comprised 18-40% of total plant production on the sagebrush-grassland sites.

At present, we have compared estimates of grassland production with 3 vegetation indices based on spectral ratios which are commonly used to enhance variations in the vegetation component of LANDSAT spectral data. These indices include the normalized difference (ND), leaf area index (LAI) and infra-red/red band ratio (IR/RED) (Curran 1983, Crist and Cicone 1984, Crist and Kauth 1986). Correlations among these vegetation indices and field estimates of total plant biomass on all sites have been weak with the strongest correlations observed between vegetative indices and forb biomass. Further development of algorithms for predicting total plant production is in progress.

Climatic data

Weather data for the years 1972-1986 have been compiled and computerized for 3 weather stations.

Elk population characteristics

Data analysis on elk population characteristics has been initiated but is not yet complete. We anticipate further data compilation and analysis after a trip to Yellowstone National Park in early February.

Conclusions

Since data analysis is still in progress, it is inappropriate to suggest conclusions at this time. Initial correlations between total green biomass on all sites and vegetation indices derived from LANDSAT imagery have been weak and may reflect differences in phenology since increases in photosynthesis will increase spectral reflectance regardless of the amount of biomass (Carnegie et al. 1974). However, additional analysis is in progress.

Table 2. Regression models for predicting green herbaceous plant biomass (HERBIO, g/2ft^{**2}), forb biomass (FORBIO, g/2ft^{**2}) graminoid biomass (GRASSBIO, g/2ft^{**2}) and current annual growth of shrubs (CAG, g/2ft^{**2}) from capacitance meter readings [shrub, (SHCAP) and herbeceous plant (HCAP) compacitance reading], and plant volume indices (FORBVOL, GRASSVOL) on sites sampled in Yellowstone National Park. The natural logarithm is denoted by ln.

Y	Regression Model	S.E.	R ^{**2}	N
ln CAG	= 0.062 + 1.081 SHCAP	0.439	0.86	143
HERBIO	= 4.262 + 0.598 HCAP	8.607	0.73	133
FORBIO	= 2.509 + 0.014 FORBVOL	3.223	0.453	202
GRASSBIO	= 4.504 + 0.011 GRASSVOL	9.006	0.626	240

Table 3. Green biomass (kg/ha) and bareground canopy coverage (%) at 26 plots sampled 9-21 August 1987 on elk summer range in Yellowstone National Park.

Plot Number	Total Biomass	Total Herb	Browse	Forb	Grass	Bare-Ground
1	616.7	580.2	36.5	167.1	413.1	22.2
2	1978.7	1193.6	785.1	366.1	827.5	10.6
3	3153.9	3153.9	0	297.8	2856.2	3.3
4	885	638.7	246.3	183.7	455	34.4
5	960.2	960.2	0	267.6	692.6	31.7
6	673.4	638.1	35.3	203.5	434.6	2.6
7	1032.2	1032.2	0	138.9	893.3	2.1
8	1077.4	1077.4	0	269.6	807.8	3.9
9	694.8	694.8	0	178.5	516.3	7.1
10	1087.3	1087.3	0	323.7	763.6	6
11	838.6	838.6	0	276.6	561.7	12
12	1151.6	1151.6	0	257	894.7	6
13	1536.8	1536.8	0	371	1165.9	2.4
14	1020.3	1020.3	0	249.8	770.5	2.9
15	1627.9	1627.9	0	481.5	1146	6.3
16	576.8	530.8	46.2	60.8	469.9	46.5
17	1180.8	964.7	216.1	224.4	740.3	11.9
18	907.5	907.5	0	714	193.2	47.7
19	946	946	0	260.9	685.1	3
20	481.9	363.5	118.4	80.2	283.3	6.4
21	1030.5	963.4	67.2	143.3	820.1	1.6
22	1293.3	896.5	396.8	142.6	753.9	2.7
23	684.9	684.9	0	212.2	472.7	6.2
24	526.5	526.5	0	202.3	324.2	2.6
25	778.5	778.5	0	236.8	541.7	4.5
26	1246.5	1246.5	0	282.2	964.3	11.9

Literature Cited

- Curran, P. J. 1983. Estimating leaf area index. Photogrammic Engineering and Remote Sensing. 40(12):1709.
- Crist, E. P. and Kauth, R. J. 1986. The tasseled cap demystified . Photogrammic Engineering and Remote Sensing 52(1):81.
- Crist, E. P. and Cicone. 1984. The tasseled cap and Thematic mapper. Photogrammic Engineering and Remote Sensing 50(3):343.
- Julander, O., W. L. Robinette and D. A. Jones. 1961. Relation of summer range condition to mule deer herd productivity. J. Wildl. Manage. 25:54-60.
- Klein, D. R. 1965. Ecology of deer range in Alaska. Ecol. Monogr. 35:259-284.
- Verme, L. J. 1965. Reproduction studies on penned white-tailed deer fawns. J. Wildl. Manage. 29:74-79.
- Verme, L. J. 1963. Effect of nutrition on growth of white-tailed deer fawns. Trans. N. Am. Wildl. Nat. Res. Conf. 28:431-443.