

# Forage Moisture Variations on Mountain Summer Range<sup>1</sup>

C. M. SHARIF<sup>2</sup> AND NEIL E. WEST

*Agency for International Development Participant and Assistant Professor, Department of Range Science, Utah State University, Logan.*

## Highlight

Diurnal and seasonal differences, as well as site features of slope aspect and shading, were found to be significant variables related to forage moisture content on a mountain summer range in northern Utah. These variations, if ignored in range analysis, can have considerable practical consequence. Therefore, improvements on wet to dry-weight conversion factors have been suggested.

Forage dry-matter data are essential in determining range production. However, time and facili-

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<sup>2</sup>Presently Reader in Range Management, Department of Forestry, Range and Wildlife, West Pakistan Agricultural University, Lyallpur, West Pakistan.

ties are rarely available for samples to be regularly dried during range analyses. As a result, empirical formulae have been adopted by American land managing agencies to derive estimates of dry weights from green forage. An example of such guidelines is given in Table 1. The suggested conversion factors allow for adjustments for different growth forms and growth stages of the plant materials. In the case of browse, leaf texture is con-

Table 1. Agency conversion factors.<sup>1</sup> Air-dry weights expressed as percent of green weight.

Growth form	Growth stage or leaf texture	Air-dry percentage
A. Grasses and sedges	Just before heading	25-30
	Headed out	35-40
	After bloom	45-50
	Seed maturity and past	55-80
B. Forbs	Very lush	15-20
	Flowering	20-25
	Seed time	30-35
C. Browse	Lush leaves (snowberry)	30-40
	Fibrous leaves (oak) and <i>Purshia</i>	35-45
	Rabbitbrush and sagebrush	40-60

<sup>1</sup>Extracted from Exhibit 93.3-B, R-4 Range Analysis Handbook, Forest Service, U.S.D.A., 1966.

Table 2. Percent vegetation cover-exposure relationships in the study area.

Species	Exposures							
	South		West		East		North	
	Unshaded	Shaded	Unshaded	Shaded	Unshaded	Shaded	Unshaded	Shaded
<b>Trees</b>								
<i>Populus tremuloides</i>		85		65		50		70
<i>Pseudotsuga menziesii</i>								10
Total		85		65		50		80
<b>Shrubs</b>								
<i>Symphoricarpos vaccinoides</i>	22	1	32	3	12	4	18	1
<i>Artemisia tridentata</i>	8		4	10	1			
<i>Prunus virginiana</i>	1	13	2	17		8	4	
<i>Chrysothamnus viscidiflorus</i>			4		2			
<i>Rosa woodsii</i>		2	1	1	1	5	1	1
<i>Amelanchier alnifolia</i>		1	1	9		5	4	15
Minor shrubs <sup>1</sup>	2	1		15	1		2	
Total	33	18	44	45	26	23	29	17
<b>Forbs</b>								
<i>Solidago lepida</i>	4		1					
<i>Viguiera multiflora</i>	3	1			1	1		
<i>Lupinus caudatus</i>	1	3	1	1		1	1	
<i>Thalictrum fendleri</i>			9		6	1	5	
<i>Lathyrus pauciflorus</i>		4	1	2	3	14		6
<i>Geranium fremontii</i>		1	2	2	1	3	1	
<i>Smilacina stellata</i>				4				
<i>Delphinium occidentale</i>						1	9	
<i>Senecio integerrimus</i>							4	
Minor forbs	13	8	5	5	9	7	8	7
Total	21	17	10	23	14	33	24	18
<b>Grasses</b>								
<i>Poa pratensis</i>	3	35	17	20	5	6	9	7
<i>Elymus cinereus</i>	12	2		1	5			
<i>Agropyron spicatum</i>	2	4						
<i>Agropyron subsecundum</i>		7		2	7	3	6	2
<i>Bromus marginatus</i>		6		5	2	11	22	23
<i>Arrhenatherum elatius</i>						4	2	1
Minor grasses				1	3	4	1	3
Total	17	54	17	29	22	28	40	36

<sup>1</sup> Minor species contributed less than 2% cover on any given slope(s).

sidered. These factors, although widely used, have no known research backing. In fact, very little literature on the subject of forage moisture variation under rangeland conditions exists.

The earliest investigations of moisture in herbage were made by agricultural chemists concerned primarily with nutritional studies. Salisbury (1848) is credited with the first such analysis; he reported variations of moisture content in two varieties of corn. Atwater (1869) observed different moisture contents in timothy cut at different growth stages. The first bulletin on grass analyses which recognized moisture variations as a result of differences in growth stages was written by Richardson (1889). The effect of time-of-day of clipping on herbage moisture was first reported by Vinal and McKee (1916).

Whitman (1941) reported a gradual decrease in

water content of prairie grasses with growth advancement. The day and night rhythm in range forage plants was studied by Stoddart (1935). He found the lowest levels of plant moisture content occurred during afternoons. The importance of time of clipping was re-established by Curtis (1944), who reported higher moisture percentages in morning and lower values in afternoons. The significance of moisture variations during the day, however, continued to be questioned (Dexter, 1945; Jameson and Thomas, 1956).

We suspected that in addition to the phenological and growth form differences in herbage moisture recognized in agency formulae, it was possible that diurnal variation in the plant material itself and the environmental effects of slope aspect and shading would prove to be significant considerations in areas of dissected topography. Therefore,

a study was designed to evaluate these elements of herbage moisture variation on a typical Intermountain summer range.

### Methods

The study area is near the Tony Grove Guard Station, Cache National Forest, Utah. The study plots were in the Douglas-fir (*Pseudotsuga menziesii*)<sup>3</sup> climatic climax zone of the Wasatch Mountains at elevations of 6,200 to 6,800 ft. Relatively little of the area is covered by the climax dominant since topography, soils, and disturbance greatly influence the present vegetation. Abbreviated percent vegetation cover-exposure relationships are given in Table 2. Values are separate estimates of cover for trees, shrubs, grasses, and forbs on plots.

The plots on westerly exposures occur in sheep summer range, all the other plots are included in cattle summer range. Wildlife browsing is common in all areas.

The experimental area lies in a 25-inch annual precipitation zone. Most of the precipitation is in the form of snow. Summers are usually dry with less than 6 inches of rainfall. July is the hottest month with maximum temperatures between 85 F and 95 F common, at 1 ft above the ground on southern slopes.

The bedrock is largely limestone. A Miocene erosional cycle deposited an irregular pebble and cobble conglomerate (the Wasatch Formation) over the limestone. The northern aspect sites were scoured by several glaciers during the Pleistocene.

Southern slopes are convex but eastern, western, and northern exposures are concave. Southern slopes average 35%, whereas both westerly and northerly exposures have average slopes of 38%. Easterly exposures slope 23%, on the average.

The texture of upper soil horizons on unshaded sites varies from loam to silt loam with loam predominating. The shaded subplot soils are uniformly silt loams. The soils of northern exposures are deep loams derived from glacial till. These soils have adequate soil aeration and excellent water holding capacity. On eastern, western, and southern aspects the soils have developed from Wasatch Conglomerate. These soils are shallow and rich in clay and silt. Tight clays in deeper strata are suggestive of slow permeability, poor aeration, and limited productivity.

Since no species occurred on all slopes in the open and under shade (Table 2), the data were considered by growth form rather than species. Moreover, under field conditions, aspect, shade, time-of-day, and season cannot be isolated as single-factor effects. Factor complexes are involved in determining the moisture content of a given sample of range forage. Nevertheless, certain patterns of variation can be related to different effective environments on the different sites at various times and such data can be used to test the validity of procedures such as those suggested in Table 1.

During the summer of 1964, a pilot study was made to determine statistically acceptable sample sizes and replications. Samples of 25, 50, 100, and 200 g of forage were collected at various sites, at different times of day, throughout the season. Three 25 g samples yielded data within 5% of the true dry weight mean. Twelve fenced plots were laid out in 1965, three on each aspect; north, south, east, and west. Every plot consisted of one subplot in shade of natu-

ral tree growth and the other exposed to direct sunlight. Each subplot contained 66 units 1 × 6 ft each with alternate units available for clipping. On every clipping day, 2 plots 1 × 4 ft each were randomly selected and clipped leaving a 1-ft buffer on all sides. Every clipping consisted of 2 sampling operations: one in the forenoon (9 to 11 AM) and the other the same afternoon (2 to 4 PM). Twelve clippings were made at weekly intervals, excepting the last interval which was 2 weeks. The clippings commenced in the third week of June and ended the second week of September 1965, thus covering the entire grazing season. Herbaceous plants were clipped to within 1 inch of the ground surface. In the case of woody plants, however, only current year's twig growth was clipped. The clipped material was separated into three growth forms, i.e., grass and grass-like plants, forbs, and shrubs. Each sample was weighed immediately. In the evening, the samples were taken to Logan and dried in an oven at 80 C for 24 hr.

When the field season was over the samples were placed under uniform room conditions. The dry samples absorbed moisture hygroscopically and were weighed again when they acquired constant weight. The difference between the dry weight and green weight was taken as the weight of moisture and was expressed as percent of dry weight. These procedures were designed to correspond in principle with the air-dry forage-weight method generally used in arriving at management decisions.

An analysis of vegetation on all experimental plots was carried out to determine floristic composition, cover value, and relative species abundance. At every clipping, the phenological stage of clipped species and weather conditions were also recorded.

Analysis of variance of data of this factorial design allowed the effects of the various factors to be separated statistically. Magnitude of the effects of aspect, shade, time-of-day, season, and their interactions have thus been obtained.

### Results

Moisture in plants is dynamic and variable. Nevertheless, moisture content of forage is amenable to some generalizations. For instance, forbs usually contained more moisture than grasses. Grasses were consistently wetter than shrubs. However, the necessity of separating growth forms in dry-weight computations is widely recognized. The other features in our experimental design were the ones which have generally been ignored by other workers.

*Aspect.*—After pooling data collected at all times, at all sites, and analyzing in regard to aspect (Table 3), we found that aspect was, by far, the most important factor-complex relating to differences in plant moisture content. The analyses of variance indicated that the northerly slopes were highly significantly<sup>4</sup> different in moisture content from the remaining slopes for all three growth forms. The northern exposures always possessed plants with

<sup>4</sup>"Significant" implies statistical significance at the 0.05 level of probability. "Highly significant" indicates statistical significance at the 0.01 level.

<sup>3</sup>Nomenclature follows Holmgren (1965).

**Table 3.** Average moisture content (percent of dry weight) of different growth forms related to aspect.

Growth form	Aspects			
	North	South	East	West
Grasses	252	152	171	179
Forbs	362	251	279	284
Shrubs	177	159	163	155

the maximum moisture content. Duncan's multiple-range test indicated that the moisture differential between the eastern, western, and southern slopes was not statistically significant for forbs and shrubs. For grasses the eastern exposures did not differ significantly from westerly exposures. However, samples from southern plots contained significantly different amounts of moisture from those on the eastern and western exposures. Table 3 demonstrates that aspect alone can account for a difference of up to 111% mean moisture content in herbaceous vegetation. For shrubs the variation could range up to 22%.

*Shade.*—A similar analysis of the pooled data showed the increase in moisture, due to the total effects of shade, could be of the average order of 72, 69, and 27% for forbs, grasses, and shrubs, respectively. (Table 4). Shade was evidently more effective in modifying moisture in herbaceous than woody plants. Nevertheless, the variation in moisture content related to shade was highly significant for all three growth forms.

*Time-of-day.*—Average forenoon moisture values were invariably and highly significantly different from those for the afternoon. The decline in moisture by afternoon in forbs, grasses, and shrubs was of the magnitude of 26, 20, and 11%, respectively. (Table 5).

*Seasonal Variation.*—Seasonal variation as a factor effecting forage moisture was highly significant. Duncan's multiple-range test indicated that at least the first four and twelfth clippings all differed

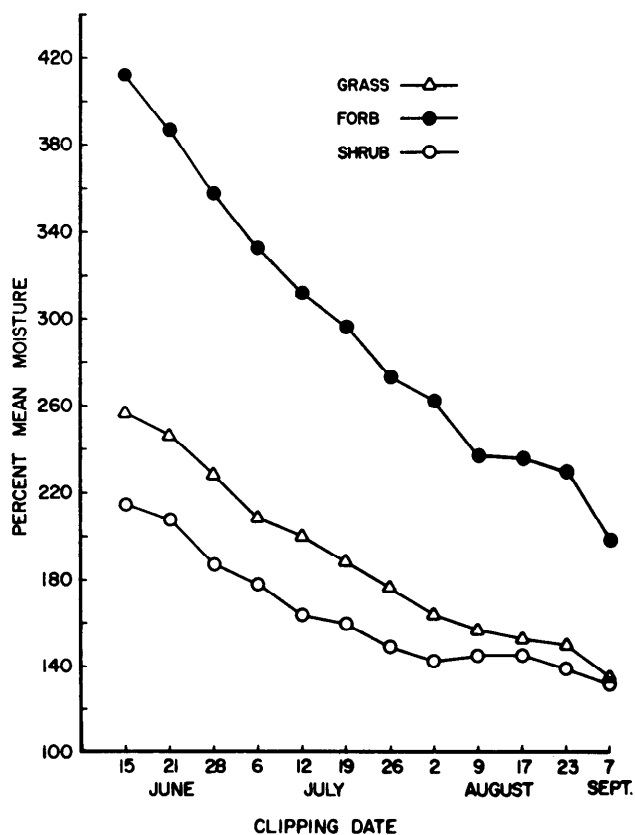
**Table 4.** Average moisture content (percent of dry weight) of different growth forms, on various aspects related to shade.

Growth form	Shade	Aspects				Additional moisture under shade				
		N	S	E	W	N	S	E	W	Over-all
Grasses	Shaded	291	179	209	215	78	53	76	72	69
	Unshaded	213	126	133	143					
Forbs	Shaded	407	295	305	314	89	89	51	61	72
	Unshaded	318	206	254	253					
Shrubs	Shaded	191	171	177	169	27	24	28	27	27
	Unshaded	164	147	149	142					

**Table 5.** Average moisture content (percent of dry weight) of different growth forms related to time-of-day of clipping.

Growth form	Time-of-day	Aspects				Additional moisture in forenoon				
		N	S	E	W	N	S	E	W	Over-all
Grasses	AM	264	159	183	188	24	13	24	18	20
	PM	240	146	159	170					
Forbs	AM	376	262	292	298	27	23	25	28	26
	PM	319	239	267	270					
Shrubs	AM	183	164	170	161	11	10	14	11	11
	PM	172	154	156	150					

significantly from the other clippings within each growth form in moisture content (Fig. 1). The fifth through eleventh clippings did not have as pronounced differences. Forbs underwent the steepest relative decline with the highest initial moisture content and greatest loss (215%) through the season. Grasses showed an intermediate initial content and an intermediate rate of decline with a loss of 122% over the season. A gradual decline of 82% was registered for shrubs during the season. Shrubs had the least moisture content in the first clipping.



**FIG. 1.** Moisture variations in different growth forms over the season.

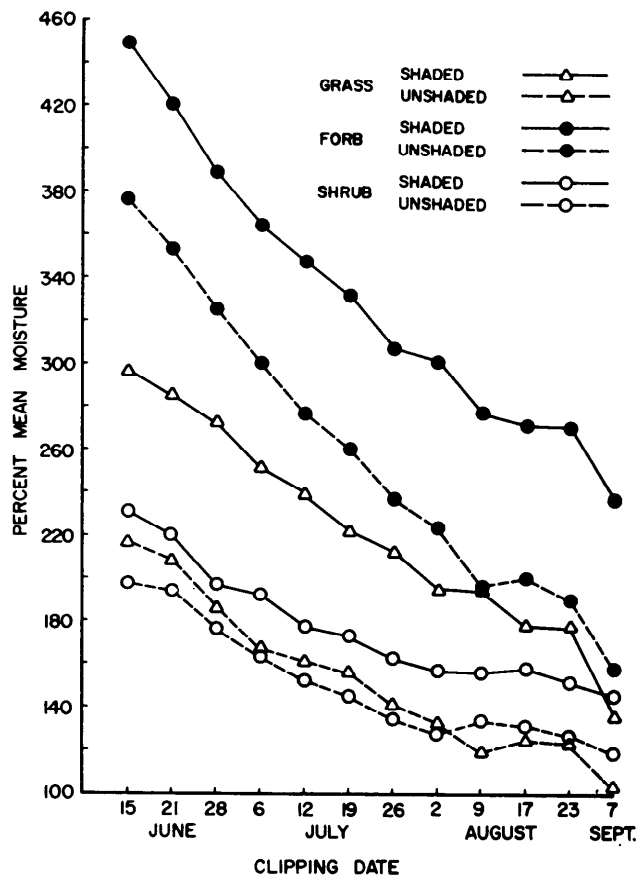


FIG. 2. Moisture variations in different growth forms over the season as affected by shade or lack of shade.

*Interactions.*—Besides the ecological features of aspect, shade, time-of-day, and season which had highly significant relationships to forage moisture content, the following interactions were also found to be highly significant.

1. Grasses: (a) Shade  $\times$  time-of-day, (b) Aspect  $\times$  season, (c) Shade  $\times$  clippings, and (d) Aspect  $\times$  shade  $\times$  season.
2. Forbs: (a) Aspect  $\times$  season, and (b) Aspect  $\times$  shade  $\times$  season.
3. Shrubs: (a) Shade  $\times$  time-of-day, and (b) Aspect  $\times$  season. In addition the aspect  $\times$  shade  $\times$  time-of-day interaction was significant.

Some of these interactions can be illustrated here. For instance, aspect  $\times$  shade interactions are shown in Table 4. Samples from the four exposures showed different moisture content with and without shade. Grasses and shrubs from the southern exposures showed the minimum differences under the two situations. Maximum variation for grasses was found on northern exposures.

Aspect  $\times$  time-of-day interactions are illustrated in Table 5. Forage samples from the four aspects reacted differently with respect to the time-of-day

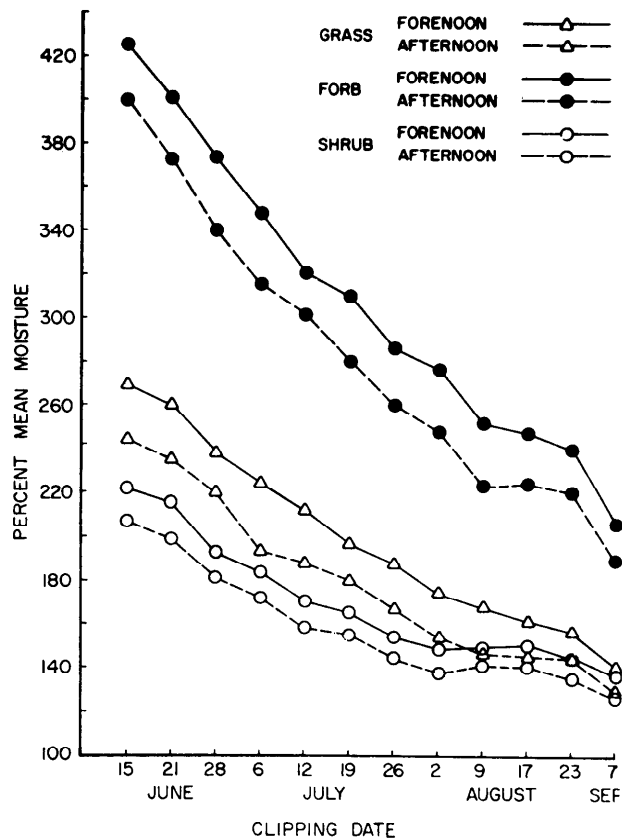


FIG. 3. Moisture variations in different growth forms over the season as affected by time-of-day of clipping.

when they were collected. The minimal values for moisture content in all three growth forms came invariably from the afternoon samples collected from southern exposures. Maximum values came invariably from morning clippings taken on northern slopes.

Shade expressed itself even in clippings made during the forenoon and afternoon of the same day. Shaded and unshaded conditions accounted for an average of 13, 2, and 4% of the overall variation in water content of grasses, forbs and shrubs, respectively. The higher moisture content under shade persisted throughout the season (Fig. 2). Among shrubs the difference was 33% in the initial clipping, and shrank to 26% in the final clipping. Grasses had an initial difference of 79% but decreased to 43% at the end of the season. Forbs showed little interaction of this type with 73% additional moisture at the first clipping increasing to 78% at the last clipping.

Differences between the forenoon and afternoon forage moisture persisted throughout the growing season (Fig. 3) with the differential being consistently greatest for forbs, intermediate for grasses, and least for shrubs. The seasonal decrease of moisture was most pronounced for forbs. Grasses showed less rapid loss of moisture than forbs but

a faster rate than the strikingly slow rate of decline of moisture in shrubs.

The average moisture content of the three growth forms at most clipping dates differed significantly on different aspects. Southern slopes showed the lowest moisture values, most of the time, for all three growth forms. In the final clippings however, the minimal values occurred on eastern slopes for herbaceous plants but western slopes for shrubs. The northern aspects consistently had higher moisture values for grasses and forbs. Shrubs from the northern slopes generally contained more moisture than those on other aspects.

In the first clipping, the maximal value for shrubs (average of northern aspects) was 129% of the minimal value (average of southern aspects). The corresponding ratios for grasses and forbs were 212% and 171%, respectively. In the final clipping the maximal to minimal ratios were 156, 135, and 127% for grasses, forbs, and shrubs, respectively.

### Discussion

The pattern of moisture contents observed is caused by a complex of biological and environmental differences contributing to each set of data. Different species of different abundance and phenology occur on the various aspects under shaded and unshaded conditions. Major differences in species occurrence and abundance are itemized in Table 2. Phenological development of all species was generally earliest on the southern aspects and progressively later on west, east, and north slopes. Phenology, as well as species composition, was affected by shade or lack of it. Moisture content was also related to the date and time-of-day clippings took place. The major environmental complex influencing the results was obviously aspect orientation of the sites to solar radiation. Forage moisture content can be directly or indirectly related to different energy budgets (Kozlowski, 1964).

However, it was not our purpose to discuss causation. Rather, since the study area is a summer range similar to those for which many range conservationists collect range analysis data, we have attempted to apply our findings to improving the overgeneralizations or "rules of thumb" found in Table 1.

There is some indication of significant species and even intraspecific herbage moisture differences, however, the plot approach has limited such inferences. Although time-of-day was highly significant statistically, this consideration is relatively less important than aspect or shade and could be ignored along with species differences in the immediate improvement of factors for estimating dry weights from green plant material in non-research applications.

Suggested simplified conversion factors for deriving dry weights in the study area are set out in

Table 6. Improved green weight to air-dry weight conversion factors, in percent.

Aspect	Phenological stage <sup>1</sup>	Grass		Forbs		Shrubs	
		U <sup>2</sup>	S <sup>2</sup>	U	S	U	S
North	Just before heading	24	20	18	16	31	—
	Headed out	31	25	25	19	33	31
	After bloom	—	—	—	—	—	36
East	Just before heading	32	28	22	20	34	—
	Headed out	40	33	24	22	36	36
	After bloom	—	—	—	—	—	41
South	Just before heading	39	35	27	22	35	38
	Headed out	44	38	—	23	40	38
	After bloom	—	—	—	—	—	41
West	Just before heading	40	24	22	23	37	32
	Headed out	45	31	23	25	40	34
	After bloom	—	—	—	—	—	40

<sup>1</sup>"Just before heading" rows refer to the "very lush" category for forbs and "lush leaf" stage for shrubs in Table 1. "Headed out" refers to "flowering" for forbs and shrubs. "After bloom" refers to "seed time" for forbs and shrubs.

<sup>2</sup>U = Unshaded; S = Shaded.

Table 6. The basis for these factors is the actual weights of forenoon clippings in the study area. Although such considerations would be expected to apply in principle to many range types, the recommendations made here are limited to mid-elevation mountain summer ranges in northern Utah.

The omissions in Table 6 result from lack of data for all phenological stages on all plots. The data were collected in a year when conditions were wetter than average. The 1965 precipitation total was 32.53 inches as compared to a long term average of 25.44 inches. Even more important, the 7.70 inches of rain between mid-June and mid-September was 37% higher than the long term average of 5.64 inches (A. Richardson, personal communication). Annual variations, although unstudied, are also likely to be important in analyses of herbage moisture.

A comparison of the factors in Table 6 with some formula values used by land managing agencies (Table 1) is made below with suggestions for improvement. Grasses and sedges: The agency formula values of 25 to 30% dry matter "just before heading" hold well for unshaded northern and eastern aspects. But for southern and western aspects a factor of 35 to 40% would give closer estimates. Likewise the agency formula values are close for shaded eastern and western grasses. On shaded northerly and southerly aspects, however, the conversion factors should be increased or decreased by 5%, respectively, to improve estimates.

The agency formula value for "headed out" grasses gives a fair dry-weight approximation for unshaded grasses on eastern, southern, and western aspects. However, for unshaded northerly grasses a reduced conversion factor of 30 to 35% would

**Table 7. Grazing capacity of one net forage acre calculated by agency and improved formulae.**

Growth form Shading Phenological stage Aspect	Derived AUMs	
	Improved formula	Agency formula
Grass		
Shaded		
Preheading:		
West and East <sup>1</sup>	2.5	2.5
South	3.0	2.5
North	2.0	2.5
Headed Out:		
East, South, and West	3.0	4.0
North	2.5	4.0
Unshaded		
Preheading:		
North and East	2.5	2.5
South and West	3.5	2.5
Headed Out:		
East, South, and West	4.0	4.0
North	3.0	4.0
Shaded and Unshaded After Bloom:		
West and South	3.5	5.5
Forbs		
Unshaded		
Very Lush Stage:		
South	1.6	1.0
Shrubs		
Shaded and Unshaded Sagebrush	0.9	1.1

<sup>1</sup>Aspects were grouped when less than 5% differences in correction factors between aspects were indicated.

yield more reliable dry weight approximations. This factor also applies to shaded grasses on easterly, southerly, and westerly aspects. For shaded northern aspects, a further reduction by 5% would improve accuracy.

The phenological stages for grasses in Table 6 refer to the most abundant species except for shaded southerly and unshaded westerly slopes where the most abundant species is Kentucky bluegrass (*Poa pratensis*). This grass presented a special problem since it was past seed maturity on these slopes before its associates headed out. A conversion factor of 35 to 45% rather than 55 to 80% would allow a more accurate estimate of its dry weight after seed maturity, irrespective of aspect and light conditions. After bluegrass, bearded wheatgrass (*Agropyron subsecundum*) was the second most abundant species. Hence the data refers to the bearded wheatgrass in the two instances.

**Forbs:** The formula values are sufficiently close to actual values except for southern aspects. The unshaded southern forbs would yield closer values with a higher conversion factor of 25 to 30%.

**Shrubs:** The values given in Table 1 for browse species are generally adequate, except for sage-

brush. The agency formula value of 40 to 60% exaggerates its dry weight estimates. Including sagebrush in the second browse category of "fibrous leaves and *Purshia*" (conversion factor, 35 to 45%) would keep sagebrush estimates closer to actual weights recorded.

Some effects of the suggested formulae modifications on grazing capacity computations are illustrated in Table 7. For simplicity, net utilizable green forage of 6,000, 4,000, and 1,300 lb/acre of grass, forb, and shrub growth, respectively, has been assumed. Actual production and composition varied with aspect, shading, and season; however, the sampling design did not adequately account for these quantitative differences. The importance of variable moisture on actual range analysis computations will exceed these assumed values because variation in production adds to the variations illustrated here. The estimated dry weights have been derived by multiplying assumed green weights by the lowest value in the conversion factor range relating to that growth form and phenological stage. For instance, in deriving dry weights of green grasses in the stage "just before heading" the agency formula conversion factor is 25 to 30%. The lowest value in the conversion range, i.e., 25% has been used in the table for agency formula derived AUMs. Likewise for AUMs calculated with improved conversion factors suggested by this research the lowest value has been used, e.g., 35% in case of unshaded grass in the "just before heading" stage on southern and western aspects ( $6,000 \text{ lb} \times 0.35 = 2,100 \text{ lb}$  air-dry forage). The lowest-factor rule has been substituted with the middle factor in case of shrubs where the range of conversion was wide. For instance, in the case of sagebrush the agency formula factors range from 40 to 60% and improved factors range from 35 to 45%. Accordingly, dry matter estimates in Table 7 have been derived by multiplying green weights by 50% and 40% to obtain agency formula and improved formula-derived AUMs, respectively.

Table 7 further shows that, in a grass sward in the stage "just before heading," for every 2.5 AUMs computed by the agency formula, the AUMs could vary from 2 to 3 AUMs computed by the improved conversion factor. Likewise in the "headed out" stage the agency formula gives 4 AUMs. However, the AUMs computed with the improved conversion factor range from 2.5 to 4. The most striking differences are presented by western aspects where the most abundant species is Kentucky bluegrass. This grass is in the stage of "seed maturity and past" when grazing capacity estimates are commonly made. For every 5.5 AUMs derived by the agency formula for this grass, (which means practically all the available herbaceous forage on the western aspects), the value should be only 3.5

AUM. These discrepancies in AUMs, when calculated to apply to extensive acreages, could mean substantial loss in AUMs or serious overgrazing.

Forbs and shrubs indicated less striking variations. Only the unshaded forbs on southern aspects resulted in a 0.6 AUM difference over and above every AUM derived by the agency formula. The agency formulae gave slightly higher values than our improved formulae for sagebrush.

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