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Seasonal, Diurnal and Species Variation in Forage Moisture Content in Relation to Site on Mountain Summer Range of Northern Utah

Chaudhry Mohammad Sharif
Utah State University

SEASONAL, DIURNAL AND SPECIES VARIATION IN FORAGE MOISTURE CONTENT IN RELATION TO SITE ON MOUNTAIN SUMMER RANGE OF NORTHERN UTAH

by

Chaudhry Mohammad Sharif

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INTRODUCTION

Practical assessments of range production and utilization are based on forage weight estimates. In preparing these estimates moisture content in green vegetation offers some problems. The moisture component is not likely to be constant for a given species. Diurnal, seasonal and site variability have been well illustrated for agronomic and tree species (Salisbury, 1848; Jenkins, 1879; Miller, 1917; Pearson, 1924; Watkins, 1940; Parker, 1951; Ackley, 1954; Werner, 1954; Zohary and Orshan, 1956; Slatyer, 1959; Kozlowaki, 1965 and Jameson, 1966). Since variability is also likely for range plants, computations made on green weights are apt to be fallaceous. It is a common practice, therefore, to express production on "water free" or "dry weight" basis. But the estimates of dry weight are made difficult by variations in herbage moisture. A variety of factors, relevant both to the vegetation and the site it occupies, would seem to account for variable moisture content. The prevalent methods for estimating moisture, however, seem to be more of a legacy from the past than an appreciation of ecological influences.

Earlier investigators of pastures and fodder crops were largely agronomists interested in comparing yields. They were concerned primarily with irrigated crops where soil moisture is not a limiting factor and the ecological influences, such as humidity, rain, cloudy weather, dew, shade, exposure etc. are far from dominant (Atwater, 1869; Collier, 1881; Richardson, 1884; Ladd, 1888; Richardson, 1889; Morse, 1891 and Widstoe, 1897). The variations in water content and other components were accordingly related to stage of growth. Taking a cue from these studies agencies such as the United States Forest Service and Soil Conservation Service came to use certain reducing factors to convert green weight of range forage into dry weight. In developing these factors the type of vegetation and growth phases have been considered but ecological features and context have been neglected. The methodology adopted from pasture conditions became the accepted basis for making range management decisions (Range Memo, SCS-8, Soil Conservation Service, 1963; Range Analysis, Region IV, Forest Service, 1964).

The influence of features of environment, particularly aspect, on growth differential, has long been recognized by foresters (Schlich, 1905; Champion, 1928 and Toumey, 1928). Plant physiologists have been aware of the significance of time-of-day on plant water for some time (Shreve, 1914; Miller, 1917). It is very probable that these influences express themselves in moisture content of herbage also.

The investigations reported herein were conducted to define and assess the scope and intensity of some of these ecological features in modification of the moisture component of herbage. The objective is to determine whether differences in ecological context influence range herbage moisture to a sufficient extent to warrant consideration in developing conversion factors for deriving dry weights from green weights of vegetation samples. The appraisal should reaffirm present assumptions applied or yield more accurate adjustments for estimating forage production. In either circumstance the results should enhance the scientific basis of range management decisions.

REVIEW OF LITERATURE

Moisture in Various Plant Materials

The earliest investigators of moisture in herbage were agricultural chemists concerned primarily with nutritional studies. Salisbury (1848) is credited with the first such analysis. He found that the two varieties of corn (Zea mays) he studied, differed in nutritional status and in moisture content. His results were confirmed by Atwater (1869). Atwater (1877) also ran analyses of timothy grass (Phleum pratense), cut at different periods of growth. Each harvest date yielded different percentages of water content in the forage. Jenkins (1878, 1879) studied the water component of corn at different stages of growth, observing variations in moisture content. Similar results were arrived at by Jordan (1879) and Collier (1881) with meadow grasses and legumes. Richardson (1884) analyzed fodder plants noting variations in moisture percentage at early and late periods of maturity. Jordan (1886), Ladd (1888), Woll (1889) and Cooke (1890) also observed conspicuous differences in moisture content at different stages of growth. Richardson (1889) reported the water component of 136 fodder grasses (wild and cultivated) and moisture variations in a few widespread species at various stages of development. Morse (1891) noted wide variations in moisture percentage of timothy harvested in different growth stages. Jenkins and Winton (1892) recorded the range of water content in forage species. Widtsoe (1897) studied the water content changes of alfalfa (Medicago sativa) from prebudding to late maturity. To most of the chemists, however, the herbage moisture was "a useless bulk" (USDA 1893), and its determination only incidental. Evidently care was not taken to protect samples from drying before weighing. This partially explains why moisture figures for any species, in any two publications rarely agree. One fact, however, was pretty well established by the early work; that is, water content of plants varied with growth stage.

The subject received further attention from agronomists faced with problems of yield comparisons and optimum moisture for hay or silage preparation. McKee (1913) noted that, although the moisture content of three types of alfalfa, cut at the same stage of maturity, was very comparable, their rate of loss of water, after cutting, was markedly different. Farrell (1914) did not find significant differences in moisture content of alfalfa harvested on different dates, or at different stages of maturity, when expressed as percentages of green weight. Thus he suggested yield comparisons on a green weight basis. Realizing moisture as a factor of error, with lapse of time required to weigh samples, McKee and Piper (1914) supported Farrell in basing yield on green weight immediately after cutting. This procedure eliminated the complicated moisture computation as well. Arny (1916) reported that green weight of clover yielded a closer approximation of correct weight than the air-dried weight. He based his conclusions on variations in drying rate of different clovers (Trifolium species) and initial moisture content. This work invalidated the values for moisture on a dry-weight basis. The green-weight approach was, however, rejected by Vinall and McKee (1916) on the plea that green weight, because it involved moisture content, could be influenced by species difference, condition and stage of growth, time of cutting and weather conditions. They noted that the stage of development affected even the moisture content of the air-dry material. This appears to have settled the issue, as in all later investigations, comparisons were invariably made on the basis of dry weight.

Willard (1931) rejected different times of day to be of any significance in plant-moisture assessment. Further confirmation came from Wilkins (1934) and Wilkins and Hyland (1938) who reported negligible moisture variations among different legume species and even different varieties of a species. These findings were, however, disputed by Weihing (1942) who based his conclusions on oven-dried rather than air-dried weights. He was supported by Curtis (1944) who observed higher moisture percentage in mornings and lower in afternoons. He also found that stems contained more water than leaves. The importance of diurnal moisture variation, however, continued to be questioned by some later workers. To Woodward et al. (1944) and Dexter (1945) the moisture changes during the day were insignificantly small.

Studying water rhythm in plants Galston (1962) observed that during night-time, depending on availability of soil moisture, there was a progressive flow of water from soil to plant and practically no water loss from the plant. The maximum value for water in plants is reported to be reached by about 2 a.m. (Stoddart, 1935; Wilson, 1953; and Halevy and Monselise, 1963). This relationship was exhibited by all three growth forms.

There has been some recognition, lately, of the influence of environment on dry matter and moisture components. Zaleski and Dent (1960) ascribed high moisture and low dry matter in alfalfa to a wet growing season; and high dry matter with low moisture to a dry growing season. Begg et al. (1960), Jagtenbery (1962) and Herriot et al. (1963)

related low levels of moisture in meadow plants to growth conditions that were too dry. Conversely, it is interesting to note that one agronomist is on record for interpreting plant tissues moisture in terms of need for irrigation. Hawkins (1927), working in Arizona, showed that plant moisture was correlated with soil moisture. He attempted to find critical leaf moisture levels at which water stress in the plants was to be relieved by irrigation to protect them from a serious set back.

Botanists have been exposed to the variations in dry matter and moisture of plants since the classical study of Sachs in 1892. Yapp and Mason (1932) have mentioned an earlier researcher, Von Hochnel (1878), who had studied the water content of leaves. His works, however, were ignored. Sachs well known experiment indicated a loss of 12 percent in dry weight overnight by leaves of herbaceous plants (Bonner and Galston, 1955). The daily variation in water content of foliage leaves was reported in great detail by Livingston and Brown (1912). The phenomenon was supported by Shreve (1914) in his desert plant studies and Miller (1917, 1924) working with cultivated plants. The day and night rhythm in moisture of herbaceous plants has since been reported by a number of investigators including Briggs, et al. (1920), Denny (1932), Yapp and Mason (1932), Stoddart (1935), Loomis (1935), Stanescu (1936), Kramer (1937), Reid (1942), Warne (1942), Wilson et al. (1953) and Halevy (1960). Seasonal variation in moisture was studied by Whitman (1941).

Daily moisture variation in leaves of woody plants has been reported by Meyer (1928), Portsmouth (1937), Ackley (1954), Rutter and Sands (1958), and Bliss (1964). Likewise a daily water cycle has been reported in main stems, branches, roots and reproductive structures of trees by MacDougal (1938), Kramer and Kozlowski (1960), Kramer (1962), Burstrom (1948), and Kozlowski and Peterson (1960). Seasonal moisture variation in shrubs and trees has been reported by numerous botanists including Runyon (1936), McDermott (1941), Bathurst (1944), Smith and Reuther (1950), Weatherley (1951), Wilson et al. (1953), Ackley (1954) Clark and Gibbs (1957), Reifsnyder (1961), Kozlowski and Winget (1964), Rutter (1964), Guha and Mitchell (1966), Bliss (1966), Fonda and Bliss (1966) and Miller (1966).

Foresters have conducted elaborate moisture studies to determine the water use and fire hazard status of different species (Buck,1951; Anonymous, 1955; Gibbs, 1958; Olson, 1959, 1960; Philpot, 1964; Dell and Philpot, 1965; and Jameson, 1966). In addition they have carried a great volume of research on moisture and dry matter variations as a result of environmental factors and management practices (Fielding, 1952; Chalk and Bigg, 1956; Ovington, 1956; Parker, 1957; Etheridge, 1958; Brix, 1960; Philpot, 1964; Baskerville, 1965 and Reukema, 1965). Johnston (1964) studied seasonal water variation in conifer stands for synchronizing harvest with timber floatability. Large species differences in seasonal variation of moisture have been reported by Meyer (1928), Parker (1954), Engelhard and Lommason (1960) and Jameson (1966).

Except for Stoddart (1935), Runyon (1936) and Whitman (1941) the detailed analyses of the moisture content of range species under varying conditions is lacking. A field test is, however, on record to study the time-of-day effect on grass clippings in which Jameson and Thomas (1956) cast doubts on the importance of clipping time. It is because of this dearth of knowledge and its practical importance that the present work was undertaken.

Techniques of Measurement

Literature review reveals that by the mid-1920's there was a general acceptance among researchers that dry-matter offered a better basis for estimates or comparisons of herbage. No uniformity, however, existed about the process of drying. Air drying, and oven-drying were done rather arbitrarily.

McRostie and Hamilton (1927), and Zade (1932) preferred oven-drying. Perkins (1943) pointed out that oven-drying could give erroneous results where forages involved a high content of volatile matter. In drying, at the boiling temperature of water, certain volatile materials are driven off along with water. Nevertheless Dexter (1945) and Davis et al. (1951) used oven-dry weights in their research. Common (1951) again advocated air drying. However, several workers lent support to oven-drying (Anonymous, 1952; Keshin et al., 1960 and Greenhill, 1960).

Whatever the process of drying there is a general appreciation of a definite and rapid loss of moisture and dry matter immediately after clipping of plant material. This has been attributed to enzymatic activity (Stanborn, 1893; Zade, 1932). It was claimed that delayed drying resulted in conversion of soluble carbohydrates into insoluble forms and loss of volatile oils. In addition, the enzymatic activity brought about loss of protein. First, Hanson (1950) and later Watson (1952), Hesse and Kennedy (1956), the Commonwealth Scientific and Industrial Research Organization of Australia (1960), and Forsyth (1964) ascribed the dry matter loss to respiration. But Dexter (1945) doubted whether the loss was an expression of sugars lost as carbon dioxide or used in the synthesis of other materials. Explaining the nature of the loss Greenhill (1960) indicated that respiration decreased as drying progressed until it ceased at a moisture content of 30 to 40 percent (dry weight basis). He further reported that the loss of dry matter varied inversely with the rate of drying. According to Melvin and Simpson (1963) the decrease in fructosans and the total soluble fructose residues accounted for much of the loss. The sucrose content decreased at first then increased.

The loss in moisture and dry matter occurred so fast that Odeland and Garber (1928) advised and designed an on-site drying house for quick handling of clipped material. A simpler solution was offered by Hesse and Kennedy (1956) who suggested covering samples with cut plant material.

McRostie and Hamilton (1927) maintained that "when samples are oven-dried to below moisture content of well-cured fodder and then allowed to stand in a room within a uniform temperature, until they have regained constant weight, the results are more accurate" for dry weight calculation. Odeland and Garber (1928) describe a similar procedure where samples dried in cotton bags were hung in a shed till they regained constant weight. Further support to this procedure came from Zade (1932).

The determination of the relative moisture and dry matter components of herbage, by any drying process, is by no means simple and easy. The latest refinement to freeze-dry, immediately after cutting (Burns et al., 1966), far from eases the situation. Marshall and Sagar (1965), however, point out that freeze-drying is essential for histological or cytological investigations only.

The complexities of moisture behavior and the irksome nature of weighing in the field piqued quite a few researchers to look for some less exasperating yet realistic techniques (Teare, 1963). The result was the development of a variety of electronic instrumentation (Fletcher and Robinson, 1956; Batiuk and Rybalka, 1959; Allen, 1959; Campbell et al., 1962; Hartstack, 1964; Nakayama et al., 1964; Neal and Neal, 1965; Mott et al., 1965; Johns et al., 1965). However, none of these devices has proved field worthy or accurate enough to supplant the conventional drying procedure. The land managing agencies continue to use air dry weights--a practical approach considering the extensiveness of the areas they manage.

In all moisture or dry matter studies reviewed weights of either constituent was expressed in relation to the other. Invariably, the universal procedure has been to determine one component in the context of the other. As such the weights of moisture or dry matter were, to be more precise, "relative" rather than "absolute." Since both moisture and dry matter contents are variable (Bonner and Galston, 1952) the relative weight of either of them can be troublesome. Stoddart (1935) ran into problems because of this dual variability of plant components. He noted an unaccountable decrease in water content of plant tissue after the midnight peak. Similar observations "puzzled" Stanescu (1936), Portsmouth (1937), Kramer (1937), Wilson (1953), Ackley (1954) and Halevy (1960). Meyer and Anderson (1952) surmised that this anomaly could be the result of redistribution of water within the plant in early morning hours. Kramer (1959), Vadia et al. (1961) and Halevy and Monselise (1963), however, observed that a decrease in water content after midnight was accompanied by an increase in the osmotic values of leaves. These changes were shown to be due to translocation of dry matter into leaves during early morning hours rather than any reduction in water content. A fallaceous impression of decrease in water content was created when the same quantity of water was expressed in terms of oven dry weight. A similar suggestion in explanation of this apparent water decrease has been made by Kozlowski (1964). Experimental evidence for this explanation has been provided by Williams (1964) as well as Goodall (1946).

To overcome possible anomalies from using dry matter as a base for moisture calculation Monselise et al. (1953, 1962) suggested substitution of unit-leaf-area as a standard reference. Monselise and his colleagues used 12.2 sq. cm. discs cut from leaves with a cork borer. Similar discs had been used by Miller (1917) and Weatherley (1951) in their studies. But the leaf area itself is subject to change. Diurnal changes in leaves have been reported by Goodall (1947). In addition, the practicability of punching small discs and weighing them in delicately sensitive balances in the field is open to question.

DESCRIPTION OF STUDY AREA

Location

To test the hypothesis posed, a study area was selected in the Wasatch Mountains of Northern Utah. The plots were located in the Bear River Range, about 25 miles to the northeast of the city of Logan. The experimental area is within the Logan Ranger District of the Cache National Forest. All the 24 research subplots lie in Township 13 North, Range 3 East, within a two mile radius of the Tony Grove Guard Station and within three-fourths and five-eights of a mile of the Logan River and U. S. Highway 89 respectively. The lowest subplot is about 6200 feet above sea level and the highest about 6800 feet.

Geology

The geology of the study area has been investigated by Young (1939), Williams, J. S. (1948, 1956), Williams, E. J. (1964), Holland (1952), Sadlick (1955) and Taylor (1963). An abstract of these studies is reproduced below.

During and before the Paleozoic era the Rocky Mountain region was under water: the Cordilleran Seaway. This body of water separated a string of volcanic islands along the West Coast from the main land mass of North America. Thick deposition of erosional material from mountains in the east and islands in the west occurred in the northern Utah area. These materials solidified into rocks, primarily limestone, interspersed with shale, dolomite, sandstone or quartzite.

The sea persisted in the Mesozoic era. During late Mesozoic and early Cenozoic eras tremendous earthquakes shook western North America. As a result the paleozoic rocks of the Logan canyon area were deformed, faulted and elevated. The Bear River Range began to form. Another cycle of widespread accelerated erosion set in. This time a conglomerate, the Wasatch Formation, covered extensive areas to the east of the Bear River Range. This was followed by more disturbances, uplift of the Wasatch Formation and erosion. The presently exposed Wasatch Formation consists of two members; conglomerate over-lying limestone. The limestone is stromatolitic, being light-brown to cream colored. The pebble and cobble conglomerate is cemented with a matrix of sand and iron oxide. The high content of ferric iron accounts for the red color of the deposit.

In the Pleistocene epoch there was widespread elevation of the area and heavy glaciation. The Tony Grove Canyon has been scoured by several glaciers. Ice of one glacier came within half a mile of the confluence of Tony Grove Creek with Logan River.

The uplifting process has by no means ceased. The valley bottoms and mountain peaks adjacent to the Logan Canyon continue to rise.

Topography and Soils

Southern exposures in the experimental area are convex but eastern, western and northern exposures are concave. The study plots were staggered on southern and eastern aspects from the lower one-third to the upper one-third of the slopes. On northern and western aspects the plot locations were either somewhat above or below the boundary lines separating the middle one-third from the lower one-third of the slopes. Excepting one shaded northern subplot which was in the upper middle of the slope all other western and northern study sites are on the lower middle of the slopes.

The unshaded sites slope from 8 percent (an eastern subplot) to 46 percent (a northern subplot). The highest average slope of 39 percent came from southerly exposures. The shaded sites have a steeper range between 8 percent (an eastern subplot) and 50 percent (a northern subplot). Both westerly and northerly exposures yielded the highest average slope of 38 percent.

The slope percent of various research subplots and averages are shown in Table 1. The steepest subplot at fifty percent was on northerly aspect with overhead tree cover. The gentlest slope of eight percent occurred on two eastern subplots: one with and the other without overhead tree cover. When averaged the highest (39.3 percent) and the lowest (19.3 percent) values came from unshaded subplots on southern and eastern aspects respectively.

Table 1. Slope percent of various research subplots

	Aspects							
No. of	North		South		East		West	
subplot	Unshaded	Shaded	Unshaded	Shaded	Unshaded	Shaded	Unshaded	Shaded
1	46	50	44	20	8	8	32	40
2	34	33	30	30	25	40	40	35
3	30	30	44	40	25	35	44	38
	110	113	118	90	58	83	116	113
Average	36.6	37.6	39.3	30.0	19.3	27.6	38.6	37.6

Texture of upper horizons of soils on unshaded sites vary from loam to heavy silt loam but loam dominates. The shaded subplot soils are uniformly silt loams. The soil profile studies showed two basic types of parent material: Wasatch Conglomerate and glacial till.

The soils developed on reddish colored Wasatch Conglomerate are shallow in depth and rich in silt and clay. The deeper strata are tight clays with varying proportions of very fine sand or silt. These soils have slow to very slow water permeability, poor aeration and intermediate productivity (Southard, 1958; Mortenson, 1965).

The soils developed on glacial till are deep loams with varying proportions of silt and clay. These soils have good to excellent water absorption and permeability, good soil aeration and excellent water holding capacity (Mortenson, 1966).

As a result of erosion, a desposition of finely ground material and stone took place below the glacial moraines. These sites, depending on distance from source material, are largely made up of large stones to cobbles of different sizes and gravel. Soil proper, on these sites, is limited in volume to the extent of rock component. The soils are, accordingly, limited in productivity. Both moisture and mineral nutrients are in short supply in these soils. Besides, physical obstruction to root penetration is caused by high stone content (Mortenson, 1966).

Of the twelve research plots, all three on northern aspects have soils developed from glacial till. One eastern plot is on soil with gravel and cobbles of various sizes eroded from glacial moraine. The remaining eight plots are on soils developed from the Wasatch Conglomerate.

Detailed descriptions of soil profiles at study sites can be found in Appendix I.

Climate

According to the United States Weather Bureau Precipitation Map (1965) the experimental area lies in the 25 inch annual precipitation zone. Most of the precipitation received is in the form of snow. Summers are usually dry with generally less than 6 inches of rainfall from May through September (Mortenson, 1966). Sporadic showers are expected every month during summer and widespread ones occur towards the end of July or, more often, during August.

July is the hottest month with temperatures between 85° F and 95° F common, at one foot above ground, on southern slopes. However, summer temperatures of 100° F can occur at the same height.

Vegetation

The climatic climax vegetation of the area is dominated by Douglas-fir (*Pseudosuga menziesii*).[1] However, relatively little of the area is covered by this tree since topography, soils and disturbance greatly influence the present vegetation.

Southern aspects

The southern slopes are usually treeless with abundant sagebrush (*Artemisia tridentata*) and snowberry (*Symphoricarpos vaccinioides*) in

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[1]Botanical nomenclature for plants of the study area follows Holmgren (1965).

mixture with bitterbrush (Purshia tridentata). Chokecherry (Prunus virginiana) and wild rose (Rosa woodsii) are shrubs of less frequent occurrence. Giant wildrye (Elymus cinereus) was the most plentiful of the grasses. Beardless wheatgrass (Agropyron inerme) and Kentucky blue grass (Poa pratensis) are minor associates. Goldenrod (Solidago lepida) and goldeneye (Viguiera multiflora) were common in unshaded situations. Under shade, Kentucky bluegrass was plentiful with varying proportions of bluebunch wheatgrass (Agropyron spicatum), bearded wheatgrasses (Agropyron subsecundum) and mountain brome (Bromus marginatus). Wild peas (Lathyrus leucanthus and L. pausiflorus), lupine (Lupinus caudatus), prairie mallow (Sidalcea oregana), yarrow (Achillea lanulosa) and meadow rue (Thalictrum fendleri) were the most frequently found forbs.

Western aspects

Aspens (Populus tremuloides) make almost pure canopy cover on western and eastern slopes. The western aspens, however, are shorter in height and presented a stunted appearance. Where tree cover is lacking, snowberry and sagebrush dominates. Kentucky bluegrass with geranium (Geranium fremontii), lupine, balsamroot (Balsamorhiza sagittata) and hawksbeard (Crepis occidentalis) are plentiful on slopes lacking tree shade. On shaded western aspects Kentucky bluegrass is associated with small proportions of mountain brome and bearded wheatgrass. Giant wildrye occurs on spots under gaps in the overhead cover. Of the forbs meadow rue, false Solomons seal (Smilacina stellata), wild pea, geranium and cinquefoil (Potentilla gracilis) are most common. Under low aspen cover there is a fair representation of chokecherry and serviceberry (Amelanchier alnifolia) shrubs.

Eastern aspects

The unshaded sites support bearded wheatgrass, giant wild rye and Kentucky bluegrass with wild peas, yarrow and fleabane (*Erigeron peregrinus*), snowberry and sagebrush in a rather open community. Under shade, mountain brome, Kentucky bluegrass, tall oat grass (*Arrhenatherum elatius*) and bearded wheatgrass were most abundant with a thin sprinkling of chokecherry, serviceberry and wild rose. Forbs consisted primarily of wild peas, meadow rue and geranium.

Northern aspects

The unshaded sites are characterized by the densest vegetation sampled. It is dominated by mountain brome, Kentucky bluegrass, tall larkspur (*Delphinium occidentale*) and senecio (*Senecio integerrimus*) growing in association with rather poorly developed snowberry. Under shade the percentage of Kentucky bluegrass increased conspicuously. The forbs were represented primarily by wild peas and meadow rue and shrubs by serviceberry. The overhead cover was provided by aspens with an occasional Douglas-fir and tall serviceberry shrub.

Detailed vegetation analyses data for all aspects can be found in Appendix II.

Past Use

All of the area has been regularly grazed or browsed in the past by domestic livestock during the summer months. Western aspects had been used in recent years by sheep only; the northern and eastern aspects exclusively by cattle. As for the southern exposures, one out of the three southern slope research plots had been in a sheep allotment and the remaining two in a cattle allotment. Deer and elk have the opportunity to use all sites.

METHODS OF STUDY

Objectives of the Study

The investigations were aimed at measuring the total effect of aspect, shade, time-of-day of clipping and season on moisture in summer range plants. It should be emphasized that each of these ecological features represents a factor-complex. Aspect, for instance, includes the action and interaction of temperature, light, atmospheric humidity, soil moisture, soil temperature and wind. Likewise, shade, time-of-day of clipping and season are factor complexes. Under natural field conditions the single factor effect cannot be isolated. The effects of some factors are unavoidably confounded in the measurement of total effect. However, for practical purposes these factor-complexes are specific and constant enough to be treated as individual ecological features in the statistical analyses.

Pilot Sampling

For the purpose of pilot sampling two plots were laid out on each slope in June of 1964. Each plot consisted of two subplots of 120' x 22' = 2640 square feet each. One of the subplots was under shade of natural tree or tall shrub growth and the other had no overhead shade. Each subplot was further divided into 24 sections of 10' x 10' = 100 square feet, with a walk of two feet width separating the two rows of 12 units each. Every clipping time one of these units was sampled randomly.

The first clipping was made in the last week of June 1964 and, thereafter, once-a-week until the middle of August 1964. In the second fortnight of August and the first fortnight of September only two clippings were made a fortnight apart. As such, in all nine clippings were made over the season.

For every clipping, aspect, subplot and cutting section were randomized. Sampling of forage was done once in the forenoon and again the same afternoon. Each complete sampling required four days. The forenoon clipping was done between 9 a.m. and 11 a.m. and the afternoon between 2 p.m. and 4:30 p.m. The study area was not fenced because it was not open to grazing during the year.

Sample Size

Samples of vegetation were collected in green weights of 25, 50, 100 and 200 grams. Since moisture studies were to be made separately for shrubs, forbs and grass, samples from different growth forms were not mixed. As a result of clipping each day, on one aspect, therefore, three sets of samples in the prescribed weight increments were collected in the forenoon and three in the afternoon.

After harvesting the plant material was weighed as soon as possible in the field, on a triple-beam balance. The samples were then preserved in paper sacks. In the afternoon all the samples were taken to Logan and placed in an oven for drying at 80^{o} C. After 24 hours drying the samples were removed from the oven and stored in a room. In the spring of 1965 all the samples were reweighed. The difference between the dry weight and green weight was taken to be the moisture content in relation to the dry weight.

The moisture content data from samples of different growth forms were subjected to analysis of variance. No significant difference was noticed among percent means of the different sized samples for any of the growth forms.

For the purpose of subsequent studies, therefore a minimum green weight of 25 grams was considered statistically acceptable. Since this minimal weight was found to be available from a much smaller area, a four square foot section of the plot was used for subsequent data collection. For statistical adequacy of sample number a coefficient of variation test was applied. Three replications were found adequate to yield a mean within 10 percent of the true mean with a 5 percent probability.

Lay-out of Research Plots

In June 1965, twelve plots were selected for intensive study: three on each of the four aspects: north, east, south and west. Each plot consisted of two subplots, one shaded by natural tree or tall shrub growth and the other unshaded. The complementary subplots were not more than 400 feet apart nor more than 300 feet above or below each in elevation. Each subplot was 66 x 6 feet. The longer side of the plot followed the contours. The only exception to the above was one shaded subplot on a south slope which had to be split into three parts as no shaded area was large enough to accommodate the standard subplot size. All the subplots were fenced and divided into 66 sections of 6 x 1 feet each. To prevent against any possible edge effects a foot buffer strip was used and only alternate sections were clipped.

Clipping Schedule

Clipping (harvesting) of forage was done once a week. Aspect, subplot and section locations were randomized for every clipping. On every harvest day two sections of 4' x 1' = 4 square feet each were harvested leaving a one foot border on both sides of the section.

The objective of this study was to examine the moisture variation in forage during a normal work day (working hours). It was not intended to investigate the moisture rhythm in plants during day and night. The nocturnal moisture content of plant tissue may have significance to a plant physiologist but has little relevence in calculation of dry matter in livestock forage. The diurnal moisture content, of course, was the subject of investigation. Two clippings were designed for the purpose. The first clipping (forenoon clipping) was started at 9 a.m.: as soon as dew vanished. It was completed by 11 a.m. The second clipping commenced at 2 p.m. and was through by 4:30 p.m. This schedule conforms to pattern adopted by earlier researchers to study plant moisture differential during the day (Reid, 1942; Krotkov, 1943; Curtis, 1944; Willard, 1944; Dexter, 1945; Jameson and Thomas, 1956; Kozlowski and Peterson, 1960).

In all, twelve clipping days at each plot covered the entire grazing season, from the third week of June 1965 to the second week of September 1965. Table 2 gives the clipping schedule.

The available forage in case of herbaceous plants is nearly the entire plant above the ground. The available browse, however, is only the current year's growth. Accordingly the herbaceous plants were harvested with a paring knife leaving a stubble of one to one and a

Table 2. Clipping schedule 1965 summer (June 15 to September 11)

No. of clipping	Dates	Aspect			
		North	East	South	West
1	June 15-18	June 18	June 15	June 16	June 17
2	June 21-25	June 21	June 25	June 23	June 22
3	June 28 - July 2	June 30	July 2	June 29	June 28
4	July 6-9	July 6	July 7	July 8	July 9
5	July 12-15	July 12	July 15	July 13	July 14
6	July 19-22	July 20	July 19	July 21	July 22
7	July 26-29	July 26	July 27	July 29	July 28
8	August 2-5	Aug. 5	Aug. 3	Aug. 2	Aug. 5
9	August 9-12	Aug. 10	Aug. 9	Aug. 11	Aug. 12
10	August 17-20	Aug. 20	Aug. 18	Aug. 19	Aug. 17
11	August 23-26	Aug. 26	Aug. 24	Aug. 24	Aug. 23
12	September 10-11	Sept. 10	Sept. 11	Sept. 10	Sept. 11

half inches. In the case of woody plants only the current year's shoot growth was clipped. This procedure conforms to current practices of land management agencies.

Weather Data

At every clipping, atmospheric humidity and temperature were recorded twelve inches above ground in the center of the subplot. A record was also maintained of general weather conditions at that time. These observations included whether sunshiny, rainy or cloudy conditions existed, or whether a recent rain had occurred. Dew conditions, wind and plant phenology were also noted. The daily precipitation record at Tony Grove Station, during the study period in summer 1965, is presented in Appendix III. The annual precipitation data, from 1960 to 1965, for the station together with 25-year (1941-1965) averages for annual and summer precipitation are also given in the appendix.

Sample Preparation

The clipped forage was separated by growth-forms. Sample collection by species was not done as pilot sampling indicated. This would have required an unfeasible amount of time to collect in weights statistically acceptable. Besides this, the growth-form method is the prevalent practice in land managing agencies. It was felt that adoption of the current practice in sample collection will enhance the value of research findings from practical point of view.

The samples were weighed immediately in paper sacks. A triple beam balance was used for weighing in the field. The balance was placed in a box with transparent plastic sides, to protect it in field from wind disturbance.

The sample was then transferred to an oven located at Logan and dried at 80^{o} C for 24 hours.

Air drying, not oven drying, is the standard practice with land managing agencies. But air drying in uncertain weather conditions of 1965 summer was possible only indoors. Want of adequate indoor space for spreading out the samples made oven drying imperative. The dried forage was then stored in Logan.

In April 1966 the samples were exposed to air in a room for 15 days to absorb moisture hygroscopically in conditions of uniform humidity and temperature. The samples were then weighed and the moisture content computed.

Moisture Computation

Moisture content was expressed as percentage dry rather than green weight as recommended by Kramer (1937, p. 13):

"While Denny (1932) has shown that dry weight varied during night, it fluctuates much less than the fresh weight and is therefore a better basis for calculating moisture content."

This method has been adopted in recent studies on calculation of moisture content of plant tissue by agronomists, foresters and plant physiologists (Milthorpe, 1950; Anonymous, 1952; Wilson et al., 1953; Ackley, 1954; Kozlowski and Peterson, 1960; Reifsnyder, 1961; Clausin and Kozlowski, 1964; and Dell and Philpot, 1965). This does not, however, imply that dry matter weight is an invulnerable base. Variations in dry matter weight may occur due to respiration, photosynthesis and translocation as shown by Briggs et al. (1920), Ackley (1954) and Halevy and Monselise (1963) respectively. Stoddart's dilemma (1935) about the midnight decrease in moisture of plant tissue is a typical case how this measure can be troublesome. However, errors from this source are so small and the computation is so simple as to make the dry matter weight a more acceptable basis for expression of plant moisture. Computed as such (Appendix IV) the moisture values for data collected in 1965 were used for analysis of variance (Table 7).

Vegetation Analysis

An analysis of non-arboreal vegetation on all experimental plots was carried out to determine their floristic composition, cover value and relative species abundance. Cover as used in this study is "the proportion of ground occupied by perpendicular projection on to it of the aerial parts of individuals of the species under consideration" Greig-Smith (1964, p. 5). A wire-frame was used for the purpose. The frame was held above the vegetation in sections of subplots and ground cover by various species was estimated in square feet. Sums of cover values of the different species were expressed in percentage of absolute cover.

Relative cover was computed for each species by division of the species value by total absolute cover. Furthermore, species absolute cover values were divided by total absolute cover values for each of the three growth forms to give relative cover within a growth form. The absolute and the two relative cover values for each species and plot are recorded in Appendix II.

On subplots under natural tree cover the shade was by no means uniform. A measure of shade was developed by estimating relative portions of understory receiving sunlight. For the purpose at least three estimates were made, on each subplot, at noontime on three separate sunny days in July. The average of the three observations, expressed in percentages, gave the tree cover value. These values have been also quoted in Appendix II.

Representative botanical specimens from research plots are preserved in the Range Science herbarium at Utah State University.

RESULTS

Moisture in plants is very dynamic and variable in quantity. Nevertheless the moisture content of shrubs, grasses and forbs follows patterns amenable to some generalization. For instance, forbs always had more moisture than grasses and grasses are consistently wetter than shrubs. Significant variations within these general patterns can be attributed to differences of the plants and their environments. These variations have made the assessment of plant water a rather complex and involved study. Of the two sources of error, however, plant-induced variation is comparatively easy to handle. As a result empirical rules have been written to accommodate moisture variations associated with plant characteristics or growth phases. The environment is less amenable to any "rules of thumb." Most range workers have persuaded themselves to bypass the problem (Blaisdell, 1964).

This study provides experimental evidence concerning the significance of environmental influences on dry matter or plant water computations. Ecological features such as aspect, shade, time-of-day, and season of herbage sampling were thought important enough to merit serious consideration.

Aspect

Aspect was by far the most effective factor-complex influencing the moisture content in the plant tissue sampled. Tables 3, 4, 5 and 6 demonstrate that aspect alone can account for a variation of 100 to

Table 3. Variations in percent mean moisture of different growth forms due to aspect

Growth form	Aspects North	South	East	West
Grasses	252.1	152.5	171.1	179.2
Forbs	362.5	251.0	279.3	284.0
Shrubs	177.5	158.9	162.9	155.4

Table 4. Variations in percent mean moisture of different growth forms on various aspects due to shade

Growth form	Shaded unshaded	Aspects				Excess moisture under shade			
		North	South	East	West	North	South	East	West
Grasses	Shaded	291.3	178.8	208.8	214.8				
	Unshaded	212.9	126.3	133.5	143.5	78.4	52.5	75.3	71.3
Forbs	Shaded	406.9	295.4	304.8	314.5				
	Unshaded	318.0	206.5	253.8	253.5	88.9	88.9	51.0	61.0
Shrubs	Shaded	191.4	170.8	176.8	168.9				
	Unshaded	163.6	147.0	148.9	141.9	27.8	23.8	27.9	27.0

Table 5. Variations in percent mean moisture of different growth forms due to time-of-day of clipping

Growth form	Time-of-day	Aspects				Excess moisture in forenoon			
		North	South	East	West	North	South	East	West
Grasses	Forenoon[a]	263.7	159.4	183.0	188.5	23.2	13.8	23.7	18.6
	Afternoon[b]	240.5	145.6	159.3	169.9				
Forbs	Forenoon	376.3	262.5	291.8	297.6	27.6	23.1	25.0	27.2
	Afternoon	348.7	239.4	266.8	270.4				
Shrubs	Forenoon	183.4	163.6	169.7	160.9	11.7	9.5	13.6	11.0
	Afternoon	171.7	154.1	156.1	149.9				

[a]Forenoon: 9 a.m. to 11 a.m.

[b]Afternoon: 2 p.m. to 4:30 p.m.

Table 6. Variations in percent mean moisture of different growth forms during various clippings over the season

	Growth form											
	Grasses				Forbs				Shrubs			
	Aspects				Aspects				Aspects			
Clipping dates	North	South	East	West	North	South	East	West	North	South	East	West
June 15-18	361.4	170.3	261.8	232.9	552.6	324.3	401.5	371.8	247.3	190.6	219.7	201.4
June 21-25	344.8	159.3	243.3	240.6	537.9	305.0	356.4	348.9	233.3	195.9	207.1	193.8
June 28-July 2	307.0	176.8	212.1	220.5	455.3	287.1	353.8	332.8	203.7	173.9	186.0	184.3
July 6-9	266.8	163.4	196.9	208.4	392.8	273.3	339.2	321.9	192.2	171.0	184.9	163.3
July 12-15	273.5	170.2	173.1	182.1	407.3	276.3	278.6	283.8	183.4	158.3	154.3	160.6
July 19-22	249.4	158.3	167.7	179.3	355.2	262.3	279.0	286.1	171.4	157.4	158.8	150.5
July 26-29	239.5	157.4	146.0	165.2	315.7	258.6	242.3	274.2	164.5	147.4	140.3	144.3
Aug. 2-5	215.3	137.9	139.2	164.3	293.0	228.5	243.2	284.0	149.6	139.2	136.5	144.1
Aug. 9-12	204.9	143.8	135.7	142.0	267.9	209.5	228.8	240.8	152.0	143.5	176.6	139.3
Aug. 17-20	190.1	144.9	143.3	132.6	274.6	207.7	235.0	224.7	149.0	150.6	147.0	132.4
Aug. 23-26	197.9	128.2	122.4	151.3	262.0	199.0	218.6	239.7	144.2	135.8	138.8	138.3
Sept. 10-11	174.8	120.0	112.3	130.8	235.8	179.7	175.5	199.3	139.7	142.8	134.3	112.6
Difference between first and last clipping	186.6	50.3	149.5	102.1	316.8	144.6	226.0	172.5	107.6	47.8	85.4	88.8

111 percent in assessment of dry matter of herbaceous vegetation. For shrubs the variation could range up to 22 percent. The maximum divergence is shown by the opposite northern and southern exposures. The northern exposure always had the maximum moisture content. In contrast the southern grasses and forbs were lowest in water content most of the time. In the case of shrubs, however, the south and west changed places frequently for minimum moisture content. Although shrubs on western exposures gave minimal moisture values the difference between west and south exposures was not found to be significant.[2] Nonetheless the variations in moisture content due to aspects were found to be highly significant in grasses, forbs and shrubs (Table 7). Significant differences among aspects are shown in Table 8.

Samples from the four exposures showed different moisture content with and without shade. The southern exposure showed the minimum divergence under the two situations for grasses and shrubs (Table 4). The minimal variation for forbs came from the eastern aspect. Maximum variation for grasses was found on northern exposures, and for forbs on both northerly and southerly exposures. In the case of shrubs no significant differences existed between north, east and western aspects.

Forage samples from the four aspects reacted differently with respect to the time-of-day when they were collected. The maximum variation in moisture content of grasses, forbs and shrubs came from eastern, northern and eastern exposures, respectively. However,

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[2]Significance has been checked at two levels, "highly significant" implies statistical significance at the 0.01 level; "significant" implies statistical significance at the 0.05 level. "Not significant" denotes lack of statistical significance at the 0.05 level.

Table 7. Analyses of variance: Effect of various factors on percent mean moisture of different growth forms

		Degrees	Grasses			Forbs			Shrubs		
Factor	Notation	of freedom	Mean square	F value	Signifi-cance	Mean square	F value	Signifi-cance	Mean square	F value	Signifi-cance
Aspect	A	3	274958.3	39.9	x x	329263.1	18.4	x x	13615.9	16.1	x x
Shade	B	1	292640.4	100.5	x x	756247.6	42.4	x x	102053.6	120.8	x x
	AxB	3	4863.4	0.7	-	13580.6	0.7	-	134.4	0.15	-
	Error (a)	16	6891.0	--	-	17806.7	--	-	844.2	--	-
Time	C	1	56723.3	185.2	x x	95197.9	274.5	x x	18917.7	279.8	x x
	AxC	3	774.6	2.5	-	185.3	0.4	-	105.8	1.5	-
	BxC	1	6019.1	19.6	x x	149.0	0.4	-	582.0	8.6	x x
	AxBxC	3	119.1	0.3	-	245.0	0.7	-	295.8	4.3	x
	Error (b)	16	306.1	--	-	346.7	--	-	67.6	--	-
Clipping	D	11	77114.8	223.1	x x	218305.2	273.5	x x	35906.7	239.4	x x
	AxD	33	5490.2	15.8	x x	12009.6	15.0	-	897.8	5.9	x x
	BxD	11	2177.6	6.3	x x	374.4	0.4	-	126.3	0.8	-
	AxBxD	33	1266.9	3.6	x x	1754.9	2.1	x x	122.1	0.8	-
	CxD	11	373.8	1.0	-	328.5	0.4	-	74.5	0.4	-
	AxCxD	33	168.3	0.4	-	212.5	0.2	-	79.3	0.5	
	BxCxD	11	303.3	0.8	-	163.7	0.2	-	139.6	0.9	
	AxBxCxD	33	210.1	--	-	140.2	0.1	-	75.6	0.5	
	Error (c)	352	345.5	--	-	797.9	--	-	149.9	--	
	Total	575									

Note: One "x" indicates statistical significance at 0.05 level; two "xx" indicate statistical high significance at 0.01 level.

Table 8. The effect of aspect on percent mean moisture of different growth forms and its significance (at 5 percent level) checked by Duncan's Multiple Range test

Growth form	Aspects North	South	East	West
Grasses	1[a]	2	3[b]	4
Forbs	1	2	3	4
Shrubs	1	2	3	4

[a]Numbers 1, 2, 3 and 4 denote the northern, southern, eastern and western aspects,respectively.

[b]The items underscored do not differ significantly.

samples from the northern aspect, in case of grasses, were not significantly different from those from eastern slopes; and were very similar to southern exposure collections of forbs (Table 5). The minimal values for moisture differences during the day came invariably from southern exposures. Within the minimal values for the three growth forms the shrubs and forbs formed the extremes at 9.5 percent and 23.1 percent, respectively. Grasses contained an intermediate moisture content with an average value of 13.8 percent. The maximum diurnal moisture variation values, 13.6, 27.6 and 23.7 percent, came from eastern shrubs, northern forbs and eastern grasses, respectively. The range of moisture content variations between forenoon and afternoon clippings in grasses, forbs and shrubs was 9.9 percent, 4.5 percent and 4.1 percent, respectively (Table 5).

The initial moisture values in the three growth forms differed very significantly among themselves and on different aspects. The shrubs had moisture content values of 247.3, 190.6, 219.7 and 201.4 percent, for northern, southern, eastern and western slopes, respectively. The corresponding values for forbs were 552.6, 324.3, 401.5 and 371.8 percent. Grass values of 361.4, 170.3, 261.8 and 232.9 percent were obtained from northern, southern, eastern and western exposures, respectively. Shrubs showed the least variation. Southern slopes showed the lowest moisture-values early in the season for all three growth forms. In the final clipping, however, the minimal values occurred on eastern slopes for herbaceous plants but western slopes for shrubs. The northern aspects consistently indicated higher moisture values for grasses and forbs. Shrubs from the northern slopes generally contained more moisture but once during the season (ninth clipping), the eastern aspect had strikingly greater moisture than the north (Table 6).

In the first clipping the maximal values for shrubs (northern aspect) were 129 percent of the minimal values (southern aspect). The corresponding ratios for grasses and forbs were 212 percent (between southern and northern aspects) and 170.7 percent (again between southern and northern aspects), respectively. In the final clipping the maximal and minimal ratios were 127 percent, 156 percent and 135 percent for shrubs, grasses and forbs, respectively.

The analyses of variance among various aspects indicated that northerly slopes were significantly different, in moisture content, from the remaining slopes for all three growth forms. The moisture differential among the eastern, western and southern slopes was not statistically significant for forbs and shrubs. For grasses the eastern exposures did not differ significantly from western and southern exposures. However, the southerly aspects did differ significantly from westerly aspects (Table 8).

Shade

Table 9 indicates that for 100 units of dry matter the increase in moisture, due to the total effects of shade, could be of the order of 26.6, 79.0 and 72.4 units for shrubs, grasses and forbs, respectively. Shade is evidently more effective in modifying moisture in herbaceous rather than woody plants. Nevertheless, the variations in moisture content as a result of shade were found highly significant for all three growth forms (Table 7).

Effect of shade is in evidence even in clippings made during the forenoon and afternoon of the same day. Shaded or unshaded conditions accounted for 4.0 percent, 12.9 percent and 2.0 percent of the variation of water content of shrubs, grasses and forbs, respectively. This in-

Table 9. Variations in percent mean moisture of different growth forms due to shade

Growth form	Shaded	Unshaded	Excess moisture under shade
Grasses	233.0	154.0	79.0
Forbs	330.4	258.0	72.4
Shrubs	177.0	150.4	26.6

cludes samples harvested at two times during the same day (Table 10).

The higher moisture content under shade persisted throughout the growing season. Among shrubs the difference was 32.5 percent in the initial clipping, shrinking to 26.3 percent in the final clipping (Table 11). Grasses had a similar pattern, starting with 79.4 percent and going down to 43.4 percent at the end of the season. Forbs, however, showed a divergent trend with 73.1 percent additional moisture at the first clipping of shaded forbs increasing to 78.4 percent at the last clipping. In the final clipping the percent mean moisture of shaded shrubs, shaded grasses and unshaded forbs were comparable at 145.5 percent, 156.2 and 158.4 percent, respectively. The shaded forbs were strikingly high in moisture with a percent mean moisture value of 236.8 percent.

Time-of-Day

Variations in moisture caused by time-of-day, when the clipping was made, are indicated by Table 12. Forenoon moisture values are invariably higher than those for the afternoon. The decline in moisture by afternoon in shrubs, grasses and forbs is of the magnitude of 11.5 percent, 19.9 percent and 25.7 percent, respectively. The time-of-day effect was found highly significant among grasses, forbs and shrubs (Table 7).

The grasses and forbs indicated almost identical moisture differences between forenoon and afternoon clippings in the initial harvest, 24.1 percent and 24.5 percent, respectively (Table 13). The shrubs showed much less, 15.3 percent. In the final harvest the shrubs and grasses had very similar time-of-day differential values, 10.6 percent and 10.8 percent, respectively. Forbs, however, showed greater varia-

Table 10. Variations in percent mean moisture of different growth forms due to time-of-day of clipping under shaded and unshaded conditions

Growth form	Shaded unshaded	Clippings		Excess moisture	
		Forenoon	Afternoon	In forenoon	Under shade
Grasses	Shaded	236.6	210.3	26.3	
	Unshaded	160.8	147.4	13.4	12.9
Forbs	Shaded	343.8	317.1	26.7	
	Unshaded	270.3	245.6	24.7	2.0
Shrubs	Shaded	183.7	170.2	13.5	
	Unshaded	155.1	145.6	9.5	4.0

Table 11. Variations in percent mean moisture of different growth forms due to shade during periodic clippings over the season

	Growth form					
	Grasses		Forbs		Shrubs	
Clipping dates	Unshaded	Shaded	Unshaded	Shaded	Unshaded	Shaded
June 15-18	216.9	296.3	376.0	449.1	198.5	231.0
June 21-25	209.2	284.8	352.9	421.3	194.0	221.1
June 28-July 2	185.6	272.5	325.3	389.3	176.6	197.3
July 6-9	166.8	250.9	299.4	364.2	163.0	192.7
July 12-15	160.6	238.8	276.2	346.8	151.3	177.0
July 19-22	155.5	221.8	259.9	331.4	145.8	173.3
July 26-29	140.7	213.3	237.8	307.6	134.9	163.4
Aug. 2-5	133.6	194.7	224.0	300.4	128.3	156.4
Aug. 9-12	118.7	194.5	196.3	277.3	134.6	156.2
Aug. 17-20	125.5	179.9	199.8	271.1	131.5	158.0
Aug. 23-26	122.8	177.1	189.7	270.0	126.7	151.9
Sept. 10-11	112.8	156.2	158.4	236.8	119.2	145.5
Difference between first and last clipping	104.1	140.1	217.6	212.3	79.3	85.5
Percent first clipping	48.0	47.3	58.0	47.2	35.1	37.2

Table 12. Variation in percent mean moisture of different growth forms due to time-of-day of clipping

Growth form	Forenoon	Afternoon	Excess moisture in forenoon clipping
Grasses	198.7	178.8	19.9
Forbs	307.0	281.3	25.7
Shrubs	169.4	157.9	11.5

Table 13. Variations in percent mean moisture of different growth forms due to time-of-day of periodic clippings over the season

Clipping dates	Growth form: Grasses		Forbs		Shrubs	
	Forenoon	Afternoon	Forenoon	Afternoon	Forenoon	Afternoon
June 15-19	268.6	244.5	424.8	400.3	222.4	207.1
June 21-25	259.5	234.5	401.3	372.8	216.0	199.1
June 28-July 2	238.1	220.0	374.1	340.4	193.0	180.9
July 6-9	223.7	194.1	347.7	315.9	183.8	171.9
July 12-15	211.8	187.6	320.7	302.3	170.2	158.1
July 19-22	197.0	180.3	310.0	281.3	164.5	154.6
July 26-29	187.5	166.6	285.9	259.5	154.1	144.2
Aug. 2-5	174.4	154.0	276.7	247.7	148.1	136.6
Aug. 9-12	167.2	146.0	250.8	222.8	149.4	141.3
Aug. 17-20	160.5	144.9	246.6	224.3	149.7	139.8
Aug. 23-26	155.7	144.2	239.9	219.8	144.0	134.6
Sept. 10-11	139.9	129.1	206.3	188.9	137.6	127.0
Difference between first and last clipping	128.7	115.4	218.5	211.4	84.8	80.1

tion with a corresponding value of 17.4 percent.

The diurnal differences followed a general pattern through the season in the three growth forms. The gap between the two clippings, made the same day, was wide in the beginning, expanded to peak values during the second clipping for shrubs, third for forbs and fourth clipping for grasses. Thereafter the time-of-day effect expressed itself in fluctuating values, nevertheless, indicating a general declining trend. The progressive decrease for 100 units of dry matter was more pronounced among forbs, from 33.7 percent to 17.4 percent, than among grasses, from 25.0 percent to 10.8 percent. The shrubs showed a strikingly slow rate of decline, from 16.9 percent to 10.6 percent.

Seasonal Variation

The importance of various clippings (harvests) through the season in relation to moisture content has already been indicated in the context of aspect, shade and time-of-day. The percent mean moisture values for 12 clippings are recorded in Table 14. The variations in moisture, due to various clippings over the season are highly significant for the three growth forms (Table 7).

The moisture data for various clippings were subjected to Duncan's Multiple Range Test at the 0.05 level. The details are shown in Table 15.

Analysis of the grass data showed that the first seven clippings and the twelfth clipping differed significantly from each other. The ninth clipping indicated no significant difference from the eighth, tenth and eleventh clippings. No significant difference existed between the tenth and eleventh clippings.

Table 14. Variation in percent mean moisture of different growth forms during periodic clippings over the season

Clipping no.	Dates	Growth form		
		Grasses	Forbs	Shrubs
1	June 15-18	256.6	412.5	214.7
2	June 21-25	247.0	387.1	207.5
3	June 28-July 2	229.1	357.3	187.0
4	July 6-9	208.9	331.8	177.8
5	July 12-15	199.7	311.5	164.1
6	July 19-22	188.7	295.6	159.5
7	July 26-29	177.0	272.7	149.1
8	Aug. 2-5	164.2	262.2	142.3
9	Aug. 9-12	156.6	236.8	145.4
10	Aug. 17-20	152.7	235.5	144.8
11	Aug. 23-26	149.9	229.9	139.3
12	Sept. 10-11	134.5	197.6	132.3
1-12	Difference between first and last clipping	122.1	214.9	82.4
	Percent first clipping	47.58	52.0	38.1

Table 15. Seasonal variation in percent mean moisture of different growth forms during various clippings over the season and its significance (at 5 percent level) checked by Duncan's Multiple Range test

Growth forms	Clippings											
	1	2	3	4	5	6	7	8	9	10	11	12
Grasses	1	2	3	4	5	6	7	8[a]	9	10	11	12
Forbs	1	2	3	4	5	6	7	8	9	10	11	12
Shrubs	1	2	3	4	5	6	7	8	9	10	11	12

[a]The items underscored do not differ significantly.

For forbs the first seven clippings were found significantly different from each other. The eighth clipping was nonsignificant with the seventh but significant with the ninth clipping. The ninth, tenth and eleventh clippings were not significantly different from each other, however, the last or twelfth clipping was found significantly different.

For shrubs the first five clippings were found significantly different in moisture content. The sixth clipping, however, was not significantly different from the fifth. The eighth, ninth and tenth clippings are not significantly different from each other but they differ significantly from the sixth and the twelfth. Likewise, the seventh clipping differs significantly from the eighth but not from the ninth and the tenth. Similarly the eighth clipping differs from the twelfth but not from the ninth, tenth and eleventh. The final or twelfth clipping is significantly different from all other clippings.

In the first clipping the shrubs contained a mean moisture value of 214.7 percent. Moisture decreased with subsequent clippings and was 132.3 percent by the twelfth clipping. Therefore, a gradual decline of 82.4 percent was registered during the season. Grasses had an initial moisture content of 256.6 percent declining to 134.5 percent by the end of the sampling period. Grasses showed a steeper rate of decline with a loss of 122.1 percent over the season.

Forbs underwent the steepest decline with an initial moisture content of 412.5 percent falling off to 197.6 percent and thus losing 214.9 percent through the season.

Shrubs had the minimal moisture values in the first clipping at 214.7 percent; grasses were 20 percent and forbs 91.6 percent higher than shrubs. At the final clipping, however, shrubs and grasses were rather close in water content at 132.3 percent and 134.5 percent respectively. Forbs were still high at 197.6 percent.

Interactions

Besides the single factor effects of aspect, shade, time-of-day and season which were highly significant the following interactions were also found to be highly significant.

1. Grasses
   a. Shade x Time-of-day
   b. Aspect x Clippings
   c. Shade x Clippings
   d. Aspect x Shade x Clippings
2. Forbs
   a. Aspect x Clippings
   b. Aspect x Shade x Clippings
3. Shrubs
   a. Shade x Time-of-day
   b. Aspect x Clippings
   c. Aspect x Shade x Time-of-day

DISCUSSION

Aspect

It has been shown that the three growth forms of vegetation yielded consistently highest mean moisture values from the northern exposures. The lowest moisture values of herbaceous plants consistently came from samples taken from the southern aspects. In the case of shrubs the western aspect was found to have the least moisture content. However, the difference was so small between the two aspects that the southern and the western exposures did not differ significantly. This pattern of extremes in moisture content is understandable considering the orientation of the two aspects with respect to solar insolation. The duration, amount and intensity of solar insolation is a major influence on plant-moisture behavior (Briggs and Shantz, 1916; Vaadia et al., 1961; Aikman, 1941; Kozlowski, 1964). The southern aspect being directly exposed to the sun (in the northern hemisphere) is subject to maximum radiation (Alter, 1913; Byram and Jemison, 1933; Wang, 1963; Spurr, 1964; Frank and Lee, 1966). The resultant high temperatures and low humidities cause rapid loss of water from soil and plants (Shreve, 1922 and 1927; MacDougal, 1925; Wolfe et al., 1949). The northern aspects, on the other hand, are protected from direct solar radiation. The steepness of the slopes further helps increase the topographic shade. Thus less moisture is likely to be lost from northerly sites. The plants on northern slopes are,therefore, suspected to be relatively well supplied with water. Comparatively better soil moisture, higher air humidities and lower soil and air temperatures have been reported from northern exposures by a number of investigators including Shreve (1922-27), Cottle (1932), Potzger (1939) and Parker (1952). Studying the influence of aspects on vegetation in Saskatchewan, Ayyad and Dix (1964) observed highly significant differences between soil moisture on northern and southern aspects.

The marked difference in the two aspects is indicated by 99.6 percent, 111.5 percent and 18.6 percent more moisture on northern than southern slopes for grasses, forbs and shrubs, respectively. The two slopes obviously represent two vastly different microenvironments as suggested by Cantlon (1953) and Shanks and Norris (1950).

Nevertheless the strikingly high moisture values from northerly slopes may not be all due to insolation differential and its allied effects. The wide variations in moisture between north and other aspects are matched only by disparity in soils on northern exposures and elsewhere. The soils in Tony Grove area, where all the northerly plots are located, have been developed from glacial till (Williams 1964 and 1966). These glacial soils being deep, loamy and relatively low in gravel and stone are considered good reservoirs for water (Salter and Williams, 1965). The soils on other aspects have developed from Wasatch Conglomerate (Williams, 1964). The Wasatch Formation derived soils are shallow with various proportions of gravel, cobbles and stone. Rather high clay content is very likely to exercise an adverse effect on the rate of infiltration of these soils (Mortenson, 1966). Close relationship has been reported between physical edaphology and moisture availability by a number of workers including Russell (1961), Messines (1952) and Taylor (1964). Parker (1952) explained the natural occurrence of different tree species in northern Idaho on the basis of physical features and their capacity to make water available for plant use. It is therefore suspected that constant maintenance of high moisture values, particularly during intervals between rains, may, in part, be due to deep loamy soils on that aspect.

Part of the additional northerly moisture could be an expression of plant phenology. The southern exposures were observed to be seven to ten days ahead of the northern exposures in any phenological event. This was probably a result of an earlier warming of southern slopes. This time lag between aspects is in agreement with a report by MacHattie and McCormack (1961). These researchers noted that earliest flowering occurred on the ridge tops and latest on the northern exposures, and that of the southern exposures being intermediate. Since higher moisture content is associated with early gorwth stages (Wilson, 1953), hence the phenological contribution to moisture differential of aspects at any particular clipping.

Overemphasis on any particular factor as being the primary cause for mositure content variation on different aspects could be highly fallaceous. This holds good for phenology as well: an area in which plant differences between aspects are most prominent. Appendix V records the dry matter factors (for conversion from green weight) for grasses, forbs and shrubs in the boot stage. These factors have been calculated from actual moisture and green weights. It will be seen that, under unshaded condition, the dry matter in mountain brome on northern exposure was 24 percent of green weight against 27 percent from eastern exposures. Likewise, under shaded conditions, the dry matter factors ranged from 19 percent to 28 percent depending on aspects. Similar comparisons could be made for wildpea and snowberry from data in the appendix.

The ranking of the four aspects, by herbage moisture content at various cuttings (Table 3) did not follow the pattern which could have been expected from consideration, purely, of atmospheric events. The eastern exposures receive direct solar radiation in the morning only. They are shaded in the afternoons. The reverse, however, is true of the western exposures. The eastern exposures are considered relatively cooler than western exposures. The south receiving the maximum radiation is considered the warmest (Geiger, 1965; Daubenmire, 1962; Humphrey, 1962; Spurr, 1964). The moisture values, however, did not conform to this model. The western slopes either yielded higher or comparable moisture values with eastern slopes for herbaceous plants. The variations in side shade and overhead cover; individual species differences in resisting moisture loss; and soil factors, particularly, stone content probably modified the tissue-moisture behavior.

Table 6 indicates that the southern moisture figures are surprisingly close to the eastern and western exposures. These values seem to be unusually high for the shallow soil and intense radiation characterizing that aspect. Most likely these southerly values are a relfection of well distributed and plentiful rainfall during the summer of 1965. The rainfall record in Appendix III shows that the year 1965 was wetter than average with 32.53 inches of precipitation against the long time average of 25.44 inches (United States Geological Survey, 1965). The precipitation at 7.70 inches during the three summer months (mid-June to mid-September 1965) was about 37 percent higher than the long-time average at 5.64 inches for the same period (Richardson, 1966).

The annual precipitation total for 1964 at 32.23 inches is comparable with the total for 1965 at 32.53 inches. Despite this superficial similarity there is a striking difference in the timing of precipitation during the two years. June and July 1964: a critical period for forage growth, had no precipitation. August 1965 with meagre 0.30 inch of precipitation was also practically dry. During the same period in 1965 the amount and timing of precipitation were most favorable for plant growth (Appendix III).

The frequent rains seem to have kept the moisture supply of southern slopes well replenished. The effect of the shallow soil and southern aspect are, therefore, suspected to have been considerably modified by a very favorable rainfall pattern. In a year of average or below summer rainfall the southern values are very likely to be much less. This hypothesis, however, needs testing.

In the case of shaded subplots, on the southern aspects, it is very likely that surface wash or a perched water table also contributed to high moisture content of shrubs and herbaceous plants.

Unlike the herbaceous plants the shrubs had high moisture content on eastern exposures. Their lowest moisture values came from samples clipped from western rather than southern slopes. Although the overall excess moisture from the southern shrubs was small, 3.5 percent (Table 3) the ranking between the two aspects was altered only after the ninth clipping. The mean moisture value of the western slopes, for the first nine clippings, exceeded the corresponding value from the southern slopes. But the tenth and the twelfth clipping reversed the position. These clippings, however, were made towards the end of the growing season. The deciduous snowberry on westerly exposure was yellowing at that time but the evergreen bitterbrush on southerly exposures was still lush and green. The difference in water content of the two species was significant (Table 6).

Because of a variety of modifying influences operative on different slopes no slope gave consistently lowest moisture values in all the twelve clippings individually. The frequent reshuffling of ranks rounded off the variations in moisture between the eastern, western and southern aspects and made differences between them nonsignificant (Table 8). The northern slope, however, marked by invariably highest moisture values, presented a highly significant difference from the other slopes.

Shade

The forage growth under shade was taller, denser and more robust than that in adjoining unshaded areas. The latter areas supported comparatively lesser numbers of mesic species. All the three growth forms under shade had invariably higher moisture content than their unshaded counterparts (Figure 1). Even the same species: bromes, Kentucky bluegrass, cinquefoil, meadow rue and snowberry; growing in shaded and unshaded conditions, had different moisture content in identical phenological stages. Moisture differences of up to 25 percent were shown by the common forbs growing under shaded and unshaded conditions in similar phenological stages. Corresponding differences in grasses and shrubs were 11 percent and 8 percent respectively. The above figures hold good for a forenoon moisture content of 100 units of dry matter.

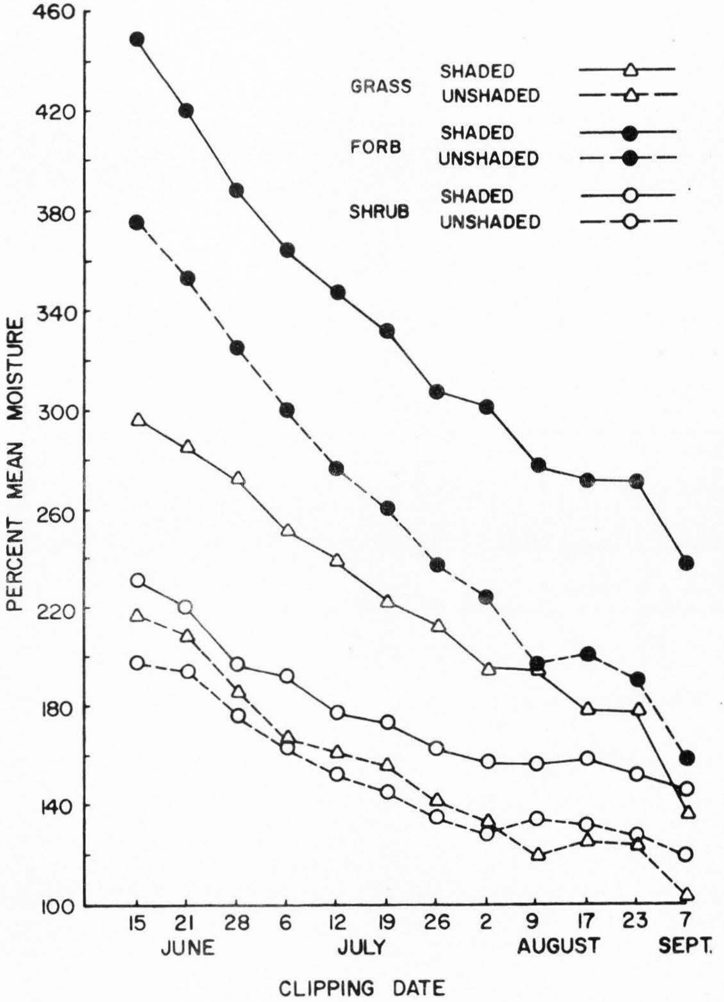

Figure 1. Moisture variation in different growth forms in shaded and unshaded conditions.

The luxuriant growth and higher moisture values, under shade, appear to be anomalous considering the root competition offered to ground flora by aspen (Ellison and Houston, 1958). The striking difference in shaded and unshaded situations could have been induced by differential grazing pressures. The weaker growth and higher percentage of zeric species may be at least partially the result of a heavier incidence of grazing on unshaded sites. This surmise is supported by studies of Ellison and Houston (1958) made in central Utah. They reported two to four times as heavy forage utilization in the openings as under aspen. Plice (1952) ascribed this grazing behavior to higher quantities of sugar manufactured by plants in the open than plants in the shade of trees. In addition, and probably as a consequence of heavy use, the soils in unshaded areas are shallower, harder and poorer in organic matter (Appendix II).

Watkins (1940) and Pritchet and Nelson (1951) established a close correlation between light and dry matter of plants. They demonstrated that relatively less intense light or shade prevented the formation of woody tissue inside the cambium of basal internodes of alfalfa and bromegrass. As a result the basal internodes of shaded plants remained succulent like their apical internodes.

Shade, or protection from solar radiation, is also associated with higher humidities and lower temperatures. This is evident from field records of atmospheric conditions for shaded and unshaded situations. The response of moisture in plants to these atmospheric conditions has been reported by several workers including Vaadia et al. (1961), Fogg (1963), and Bonner and Galston (1955). Zahner (1956) attempted to calibrate high atmospheric temperatures and humidities (he called it "atmospheric demand" for water) with water loss by plants.

Despite the fact that shaded plants underwent greater diurnal and seasonal variations in moisture content their water component (because of higher initial values) remained consistently higher than that of unshaded plants. Many of the same factors responsible for higher forage moisture values on northerly exposures are very much suspected to have been operative on shaded sites.

The low moisture content of various unshaded species, irrespective of growth form and growth stage, could be the result of low soil-moisture availabilities under unshaded conditions. Hawkins (1927) working with field crops in Arizona and Runyon (1936) in desert plant studies established close correlation between tissue moisture and soil moisture. This relationship does not seem to exist under the conditions of the Tony Grove area. Nor does there seem to be any justification for considering soil moisture as a limiting factor, at least in 1965, when the summer happened to be unusually wet. At no time during the summer of 1965 did the moisture values from unshaded situations match those from shaded situations. The strikingly low water content of unshaded plants, particularly herbs, at all times and under all weather conditions, seem to stem more from species differences or intraspecific variations than any other factor.

The species differences also help to explain another anomaly in relative moisture variations between shaded and unshaded situations. Notwithstanding the lower atmospheric temperatures and higher humidities, all the growth forms under shade lost greater quantities of moisture diurnally and seasonally (Tables 10 and 11). This is very probably the result of higher initial moisture in shaded plants. Since the shaded plants had more moisture to start with, they lost more in the course of the day. The same argument could be advanced about comparatively greater water loss from shaded plants during the season. But species differences are likely to have been more important in this context. The shaded sites had an abundance of mountain brome, bearded wheatgrass and tall oatgrass (Appendix II). These mesic grasses are relatively susceptible to dehydration. On the other hand the truly unshaded sites supported drought-resistant giant wild rye and bluebunch wheatgrass as major species with columbia needlegrass, letterman needlegrass and onion grass as minor associates. These grasses are known to have adaptations to conserve moisture. The rolling of leaves alone, a common trait of these species, is reported by Oppenheimer (1960) to reduce water loss to the atmosphere by two-thirds. A possible explanation, therefore, for water loss differential between shaded and unshaded grasses and herbs could be that mesic plants, growing under shade, were capable of absorbing larger quantities of water, when available; but not equally efficient in holding it. In contrast, the plants in unshaded situations were capable of absorbing and storing lesser quantities of moisture only, even when moisture was plentiful; but exceeded their shaded counterparts in efficiency to withstand water loss.

The moisture behavior, under shade, was by no means marked by any rigid conformity to a discernible pattern. Species differences, plant health, growth stages and shade characteristics, as reported in the site description, could be cited as the probable causes. But even with the common species occupying shaded sites, on southern and northern exposures there seems to be some intraspecific variation in water holding capacity. This is suggested by the differences in percent mean moisture of the common species, snowberry and meadow rue, in the beginning of the season, when the species were in the same phenological stage and soil moisture was probably not a critical factor (Appendix VI). Similar intraspecific differences in moisture content have been reported by Countryman (1963). Soil moisture was probably not a critical factor.

The maximum variations in moisture values between shaded and unshaded situations were yielded by grasses and the minimum by shrubs (Table 9). The higher moisture content of grasses, the species differences and possibly intraspecific variations in absorbing moisture or restricting water loss and growth stage differential in the two situations possibly contributed to give maximum variations in moisture content of grasses. The minimal variation was exhibited by shrubs. The shrub behavior could possibly be the expression of its rooting pattern. The bulk of the absorbing roots of shrubs are in deeper subsoil. As such the shrubs depend more on subsoil rather than surface soil moisture for their water balance. The subsoil moisture is less likely to show rapid fluctuations like the surface moisture. Most of the herbaceous plant roots are restricted to the surface soil and draw heavily upon its water reservoir (Lane and McComb, 1948). But because of exposure at the top, the surface soil and its water content is likely to be more effectively influenced by surface conditions such as shade or want of it. The bulk of moisture added to soil by rains is generally absorbed by massive root systems of grasses and forbs before it has a chance to percolate deeper to the zone of absorption of shrubs. Apparently small additions of moisture to the shrub root zone were inadequate to cause striking fluctuations in moisture content of the zone. Lack of drastic fluctuations in daily moisture content of shrubs may, therefore, be partly a reflection of the relatively stable water regime deep in the soil profile.

Shrubs also differ from the herbaceous plants studied. Unlike the latter which undergo dormancy or, at least, have dead aerial parts by the approach of dry period, shrubs have living aerial parts during the period of water stress. This behavior and hardiness of shrubs is suspected to be the result of deeper roots and adaptations to withstand water loss even under adverse conditions of exposure to solar insolation. This adaptive characteristic, conducive to water retention, could have contributed to reduction of wide variations in moisture contents of shrubs.

The ranking of aspects in relation to shade effects on moisture values did not follow an identical pattern for herbaceous plants and shrubs. The plant, soil and site factors intervened to mitigate or exaggerate the atmospheric effects and reactions. The consequent ranking of aspects, under shaded and unshaded conditions (Table 4), therefore, is the result of interaction of biotic and abiotic factors of environment.

Time-of-Day

The moisture values for forenoon clippings were consistently higher than corresponding afternoon values.

During the day, as the sun's radiation increases, plants respond by water loss (Kramer, 1949; Bonner and Galston, 1964). Minimum water content of plant tissue has been found to occur by about noon or late afternoon depending on atmospheric and soil moisture conditions (Kramer, 1937; Wang, 1963; Knight, 1965). That time coincides with the afternoon clipping of this experiment.

The magnitude of diurnal variation fluctuated in accordance with the variation in moisture content of the growth form in forenoon clippings. Forbs invariably had the highest moisture content of the three growth forms of vegetation observed. They showed maximum variation in water content between the two particular times of clipping. Shrubs which, at all times, contained the minimal moisture in the forenoon yielded minimum variation because of low afternoon values. Grasses showed intermediate differences. A rigid conformity to this pattern was shown at every clipping.

The time-of-day effect persisted throughout the season (Table 13). However, the absolute data do not follow any apparent pattern. They do not even show a consistent trend in any growth form.

Within a growth form the forenoon and afternoon moisture values vary reflecting probable effects of soil moisture conditions of the previous day (Rehman and Batanouny, 1965) and reaction of plant (moisture) to atmospheric conditions that day (Zahner, 1956). The variations in moisture content, during the day fluctuate accordingly. Four days before the first clipping were sunny and without rains. But two rains fell between the first and second clippings. This explains why the first clippings did not yield the maximum value for time-of-day effect. For the same reason the minimal values did not come consistently from the last clippings in the three growth forms. The variations in diurnal moisture, however, show a strong pattern when graphed as in Figure 2.

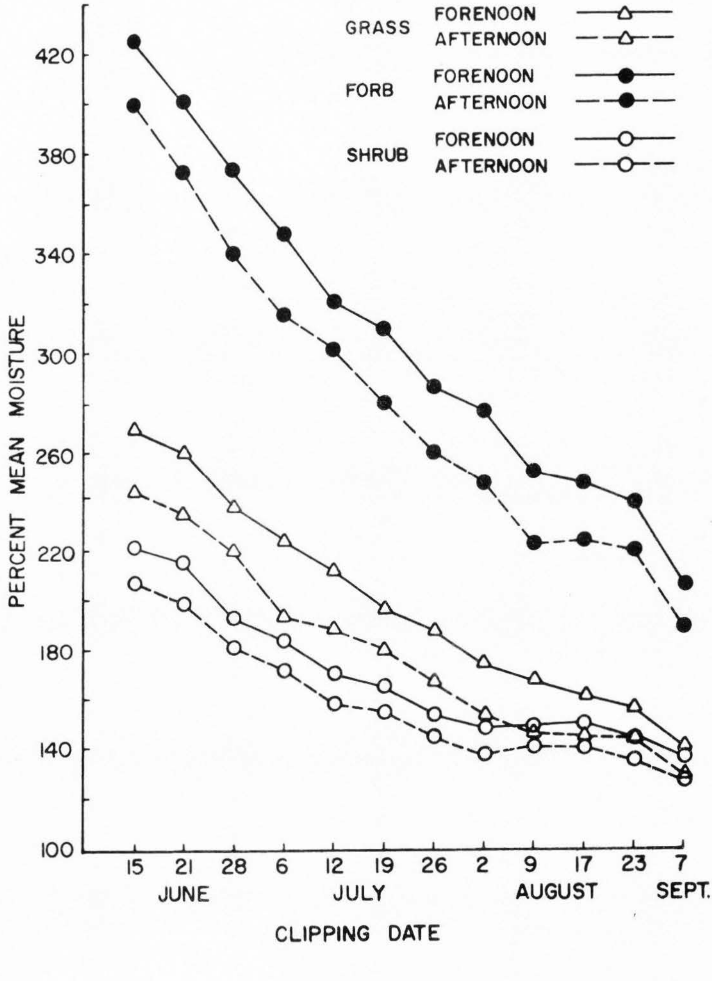

Figure 2. Moisture variation in different growth forms due to time-of-day effect on clippings.

The lines indicating forenoon and afternoon moisture contents show a near parallelism which continues for the entire period of the experiment. This parallelism is more marked in the case of shrubs indicating a relative stability at which the shrub values probably stay during the daylight hours. Conspicuous variations in forb values are probably suggestive of susceptibility of forbs to react promptly to minor changes in the environment. The time-of-day effect tended to shrink rather rapidly towards the end of the season when plants were yellowing. This again seems to be a reflection of a steep drop in mean moisture content of the plants between the eleventh and the twelfth clippings.

The relative differences between diurnal moisture variation of the three growth forms on different aspects are recorded in Table 5. The widest variation among grasses, exhibited by the eastern exposures, may have been the result of greater wind activity because of minimal shrub growth on those aspects. The differences are likely to have been exaggerated for want of effective protection against solar insolation in shaded situations as detailed in site descriptions. The relative differences among aspects for time-of-day effect on forb moisture content are rather narrow: the four values lie between 23.1 and 27.6 percent. Among the three growth forms, forbs seem to have shown least resistance to desiccation on any aspect. The minimal variation value of 9.5 percent is given by southerly shrubs and the maximal value of 27.6 percent came from forbs on northern aspects.

The above situation, however, merits reconsideration. Acceptance of moisture variation values as absolute quantitative expressions of diurnal moisture variation phenomenon could be fallaceous. Since moisture changes during the day are primarily correlated with initial (forenoon) moisture values the figures for moisture variations are meaningful when considered in the context of corresponding forenoon moisture values. Expressed in terms of forenoon values the moisture variation figures present more realistic and less drastic values. According to these converted values the minimal moisture variation value continues to be the same, represented by 9.5 percent from the shrubs on southern aspects. The new value, however, is 6.1 percent of the forenoon moisture value. The maximal value is no longer the value yielded by forbs from northern aspects which shrank from 27.6 percent to 7.4 percent of the relevant forenoon moisture value. The maximal variation in moisture is now exhibited by eastern grasses at 13 percent of the corresponding forenoon moisture value.

A similar conversion of moisture variation values in Table 10 further illustrates the moisture behavior of the three life forms under time-of-day effect. The diurnal changes under unshaded conditions, between grasses and forbs, are rather close, forbs losing slightly more at 9.3 percent against 8.3 percent of initial water content by grasses. But forb loss is strikingly lower than grasses under shade, 7.8 percent against 11.1 percent of their forenoon moisture value. In shaded situations forb loss is surprisingly close to a corresponding loss by shrubs (7.6 percent of forenoon moisture values) but quite different from the change for grasses. These figures bring out the relatively higher susceptibility of shaded grasses to the time-of-day effect if moisture variation is studied in the context of moisture values in forenoon clippings.

Seasonal Variation

In all, twelve clippings were made to study the plant moisture behavior over the season. The first eleven clippings were made at weekly intervals but the twelfth was made after a two-week interval.

The first two clippings, especially the first one, showed high water content in all three growth forms. When these clippings were made the plants were growing actively. Except for the Kentucky bluegrass, which matured seed by the third week of June or before the time of first clipping, no other major species in the study area had approached heading stage. The young leaves, with a high protoplasmic content relative to thin cell wall material, had high water content. This helps explain the high moisture value in the clippings made earlier in the season. But as the season advanced the later clippings indicated a progressive decline in moisture content. The final clipping showed minimal moisture values of the season for grasses, forbs and shrubs. This gradual decline in water component of new growth over the season is in keeping with the findings of numerous researchers including Yapp and Mason (1932), Wilson (1953) and Kozlowski (1964). Thickening of cell walls, deposition of starch, lignin and minerals, in the course of time, are suspected to have reduced values for water content of plant tissue. Parry and Smithson (1957, 1958) and Arimura and Kanno (1965) detected opaline silica in mature grass leaves. Wilson (1953) identified thickness of cell walls with seasonal decrease in moisture. He further surmised that the translocation of assimilates also probably contributed to this phenomenon. Ackley (1953), on the other hand, reported that the decrease in moisture was "relative" rather than "true." He observed that a 25 percent seasonal reduction in moisture of tree leaves was actually the result of an increase in dry matter.

The seasonal variation in moisture is, therefore, a physiological response of plant. The advancement in growth accompanied by changes in cell walls and cell content determined the potential for water content in plant tissue. How far this potential is satisfied depends on moisture availability from the soil and the capacity of the plant to absorb it. Under favorable water absorption condition, high moisture and low dry matter are associated with wet growing seasons. Conversely high dry matter with low moisture are ascribed to a dry growing season (Zaleski and Dent, 1960). The seasonal variation in moisture is, therefore, expected to be mild in a year with more than normal rainfall. A dry year, on the other hand, would probably induce drastic variations in moisture during the growing season.

The rate of water decline over the season was by no means identical for grasses, forbs and shrubs. This is likely to be due to highly variable moisture content in the three growth forms early in the season. The forbs which contained maximum moisture initially had the steepest rate of change and, by the end of clipping season, had lost 52 percent of its water content in the first clipping. Accordingly shrubs possessing minimal moisture to start with, lost 38.1 percent through the season. Grasses having intermediate values in the first clipping maintained the pattern until the end of the season (Figure 3).

The various aspects, however, modified plant moisture behavior (Table 6). The quantitative differences in moisture during the season, from different exposures, do not lend themselves to an understandable pattern. For example, the eastern slope shrubs lost 85.4 percent

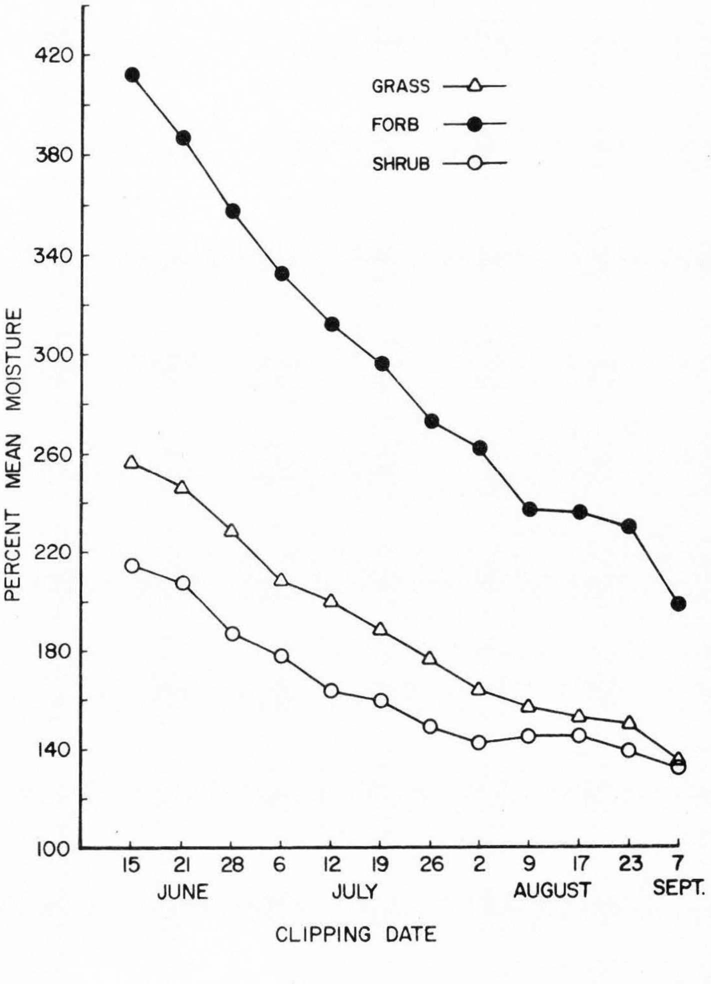

Figure 3. Moisture variation in different growth forms over the season.

moisture against a 88.8 percent lost by shrubs on western aspects. Considering the crop physiognomy of the vegetation and soil differences already discussed, these relative losses do not seem to fit. But an understandable pattern emerges when the seasonal variation in moisture content is expressed as a fraction of the water content values yielded by the initial clippings. Converted as such, the variations among shrub values, on eastern and western aspects, become 38.6 and 44.2 percent of initial values. The variations from north, south, east and west are now represented by 43.7, 25.1, 38.6 and 44.2 percent, respectively. The corresponding variations for forbs are 57.3, 44.7, 56.2 and 46.5 percent, respectively. The grasses yielded intermediate values of 51.6, 29.5, 57.1 and 43.8 percent. These values represent a more intelligible and comparable picture of reaction of plant moisture to various exposures over the season.

The grasses lost 104.1 and 140.1 percent moisture from unshaded and shaded situations during the season (Table 11). These variations are 48.0 and 47.3 percent of the corresponding initial moisture values. This means that in spite of quantitative differences, which appear striking, the rate of variation in both situations was almost identical. Likewise close values are yielded by shrubs; 35.1 and 37.2 percent of initial values for unshaded and shaded conditions, respectively. Conversely, forbs give the moisture differences between the first and final clipping at 217.6 and 212.3 percent from unshaded and shaded situations. Quantitatively these values are comparable. But, expressed as fractions of initial moisture values, these figures represent 58.0 and 47.2 percent of corresponding values from unshaded and shaded sites. These values improve understanding of moisture behavior under the two conditions by bringing into focus this variation.

A comparison of the converted values shows that the rate of seasonal variation in moisture for shaded forbs is comparable with that of shaded grasses. It was shown previously that grasses exhibited greater moisture variation than forbs in response to the time-of-day effect. However, when the average moisture content values for both the first and the final clippings are compared the rate of seasonal moisture reduction masks the sharp diurnal variation. Under the unshaded conditions the conformity to diurnal fluctuation patterns was conspicuous. The forbs tended to lose at a relatively higher rate, possibly for want of adaptive characteristics of unshaded grasses.

Interactions

Aspect x clippings (grasses, forbs and shrubs)

All the three growth forms showed highly significant differences in moisture content on four aspects. This was primarily due to dissimilarity of atmospheric conditions prevailing on the different exposures. The interaspect micro-climatological diversity was reflected in species differences and phenological disparity on various slopes. As the season advanced the effect of aspect on moisture contents was modified by characteristics of different species and their phenological stages. The soil heterogeneity on different aspects is suspected to have influenced the phenomenon by regulating soil water availability, particularly, between rains. The combined effect of slope and season, therefore, produced a dissimilar pattern of moisture variation on different aspects during the season. These differences turned out to be highly significant.

Aspect x shade x clipping (grasses and forbs)

For much the same reasons the aspect x shade x clipping interaction indicated highly significant moisture variations. Shade, as explained earlier, was responsible for creating microenvironments analogous to northern aspects. This site modification accounted for species, intra-specific and phenological differences. Shade also influenced the temperature and moisture of surface soils--the root zone of herbaceous plants. In the case of grasses and forbs, therefore, the shade factor was effective enough to further modify the combined influence of aspect and clippings.

Shade x time-of-day (grasses and shrubs)

Shade or want of it accounted for striking species differences among grasses. The unshaded grasses exhibited zeromorphic characteristics not noted in their shaded counterparts. The grass species with these adaptive characteristics responded differently to atmospheric conditions during the day than those without water-retaining mechanisms. Thus the effect of shade was modified by plant characteristics in diurnal variation of moisture among grasses. Among shrubs the time-of-day effect on shade was probably the result of differences in species, phenology and soils. Shade influenced later phenological development, better soil moisture conditions whereas unshaded sites had accelerated phenology and low availability of soil moisture. Under shade the plants invariably had higher initial (forenoon) moisture. Diurnal variation in moisture, as such, under the two conditions differed in response to atmospheric conditions.

Aspect x shade x time-of-day (shrubs)

The shade x time-of-day interaction was further modified by aspect among shrubs. Because of striking micro-environmental differences the various aspects accounted for different species within the same growth-form. The height of other species, particularly grasses, associated with shrubs on a particular aspect determined whether shrubs shaded the grass (western and northern aspects) or benefitted from side shade of grass (southern aspect). The different aspects were also distinguished by the relative presence of species noted for significantly different behavior patterns and moisture characteristics. For instance, there was more evergreen bitterbrush on southern aspects and more deciduous snowberry on eastern aspects. These factors accounted for highly significant variations in moisture as a result of the aspect x shade x time-of-day interaction among shrubs.

Shade x clipping (grass)

Of the three growth forms, shade or want of it was most effectively distinguished with species differences among grasses. As the season advanced the unshaded grasses either remained low under partial overhead shade of shrubs throughout the season, e.g. Kentucky bluegrass, or grew in moderately dense, uniformly high, communities receiving side shade from each other, e.g. wheatgrasses and bromes. The third pattern noted was of one grass species outgrowing its associates and forming tall, isolated, open clumps, e.g. giant wild rye. The exposure of the grass species to atmospheric conditions, thus, was highly variable. Since the initial moisture contents, under shade or without shade, were also different, the disparity in exposure over the season resulted in highly significant variations in moisture component of grasses.

CONCLUSIONS

The conventional method used by Federal agencies for computation of dry matter for range decisions is based on certain assumptions. One of these assumptions is that the moisture-dry matter relationship is specific to various growth forms. For this purpose three growth forms: grasses and grasslike plants; forbs; and shrubs (implying all browse) are recognized (Range Memo, SCS-8, Soil Conservation Service, 1963; Range Analysis, Region IV, Forest Service U. S. Dept. Agr., 1964). Within a growth form certain fixed moisture-dry matter ratios are associated with plant phenology. In the case of browse, leaf texture is substituted for phenology. When growth form and phenology are known the dry matter computation is reduced to a slide-rule calculation.

This oversimplification has its hazards. To demonstrate this the first clipping has been considered, for making comparisons between the actual and the computed dry matter weights. This clipping was made during the third week of June 1965. The Tony Grove area where the study was conducted is opened to cattle about July 21, and to sheep about July 1 each year (Roberts, 1966). Thus the third week of June is about the time when the dry matter computations are made in the field. The details of computation of dry matter by conventional conversion factors are shown in Tables 16, 17 and 18. The actual weight of dry matter, in all cases (called the base value), is 100 units. As such all deviations of computed weight from 100, or, divergences from the base value, are indicative of the magnitude of percent error. These tables show the variations in weight on the same aspect

Table 16. Computation of dry matter from green grasses, clipped from all aspects, by conventional conversion factors

	North		South		East		West		Average		Average for day
	Forenoon	Afternoon	Forenoon	Afternoon	Forenoon	Afternoon	Forenoon	Afternoon	Forenoon	Afternoon	
A. UNSHADED											
Moisture	309.7	291.0	159.7	144.0	239.7	214.0	195.3	181.7	226.1	207.7	216.9
Dry matter	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Green weight	409.7	391.0	259.7	244.0	339.7	314.0	295.3	281.7	326.1	307.7	316.9
Conversion factors for dry matter	1/3:0.25	2/3:0.25	2/3:0.25	2/3:0.25				1/3:0.25			
	1/3:0.35	1/3:0.35	1/3:0.35	1/3:0.35	1/3:0.35	1/3:0.35					
	1/3:0.55				2/3:0.55	2/3:0.55	1:0.55	2/3:0.55			
DM (computed)	102.5	149.5	73.6	69.2	163.9	153.3	162.3	126.9	125.6	124.7	125.2
B. SHADED											
Moisture	430.1	414.7	198.3	179.0	319.3	274.0	296.7	258.0	311.2	281.4	296.3
Dry matter	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Green weight	530.1	514.7	298.3	279.0	419.3	374.0	396.7	358.0	411.2	381.4	396.3
Conversion factors for dry matter		1:0.25	1:0.25	2/3:0.25							
	1/3:0.35					1/3:0.35					
	2/3:0.55				1:0.55	2/3:0.55	1:0.55	1:0.55			
DM (computed)	256.7	128.8	74.5	79.0	230.5	180.7	218.4	196.9	195.0	146.4	170.7

C. MEAN VALUES

1. Time-of-day average for shaded and unshaded

Forenoon	Afternoon
160.3	135.5

2. Mean value for clipping.

147.9

Table 17. Computation of dry matter from green forbs, clipped from all aspects, by conventional conversion factors

	North		South		East		West		Average		Average for day
	Forenoon	Afternoon	Forenoon	Afternoon	Forenoon	Afternoon	Forenoon	Afternoon	Forenoon	Afternoon	
A. UNSHADED											
Moisture	510.7	468.7	308.7	295.7	381.3	341.7	353.3	347.7	388.5	363.4	376.0
Dry matter	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Green weight	610.7	568.7	408.7	395.7	481.3	441.7	453.3	447.7	488.5	463.4	476.0
Conversion factor	1:0.15	1:0.15	1:0.15	1:0.15	1:0.15	1:0.15	1:0.15	1:0.15			
DM (computed)	91.6	85.3	61.3	59.4	72.1	66.3	68.0	67.2	73.4	69.5	71.4
B. SHADED											
Moisture	629.7	601.3	352.3	340.7	451.0	432.0	411.3	374.7	461.1	437.2	449.1
Dry matter	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Green weight	729.7	701.3	452.3	440.7	551.0	532.0	511.3	474.7	561.1	537.2	549.1
Conversion factor	1:0.15	1:0.15	1:0.15	1:0.15	1:0.15	1:0.15	1:0.15	1:0.15			
DM (computed)	109.5	105.2	67.8	66.2	82.7	79.8	76.7	71.3	84.2	80.6	82.4

C. MEAN VALUES

1. Time-of-day average for shaded and unshaded

Forenoon	Afternoon
78.8	75.0

2. Mean value for clipping

77.0

Table 18. Computation of dry matter from green shrubs, clipped from all aspects, by conventional conversion factors

	North		South		East		West		Average		Average
	Forenoon	Afternoon	Forenoon	Afternoon	Forenoon	Afternoon	Forenoon	Afternoon	Forenoon	Afternoon	for day
A. UNSHADED											
Moisture	231.7	221.3	185.0	179.0	205.3	199.3	189.0	177.0	202.8	194.2	198.5
Dry matter	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Green weight	331.7	321.3	285.0	279.0	305.3	299.3	289.0	277.0	302.8	294.2	298.5
Conversion factor	1:0.30	2/3:0.30 1/3:0.55	2/3:0.30 1/3:0.55	2/3:0.30 1/3:0.55	4/5:0.30 1/5:0.55	1:0.30	4/5:0.30 1/5:0.55	4/5:0.30 1/5:0.55			
DM (computed)	99.5	122.9	109.0	106.7	103.8	89.8	98.3	94.2	106.65	103.4	105.0
B. SHADED											
Moisture	281.7	254.3	203.0	195.3	251.0	223.0	232.3	207.3	242.0	220.0	231.0
Dry matter	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Green weight	381.7	354.3	303.0	295.3	351.0	323.0	332.3	307.3	342.0	320.0	331.0
Conversion factor	1:0.30	2/3:0.30 1/3:0.55	1:0.30	1:0.30	1:0.30	1:0.30	1:0.30	1:0.30			
DM (computed)	114.5	135.5	90.9	88.6	105.3	96.9	99.7	92.2	102.6	103.3	102.9

C. MEAN VALUES

1. Time-of-day average for shaded and unshaded

Forenoon	Afternoon
322.4	307.1

2. Mean value for clipping

314.7

between two clippings made at different times of the day. In addition they show the differences in weights between aspects. The summaries of these computed values are presented in Tables 19, 20 and 21.

According to Table 19, the grass weight could be 175 percent above or 31 percent below the true value. This means the actual value of 100 units could fluctuate in a range of (157 + 31=) 188 percent. Likewise the forbs vary from +10 to -41: a divergence range of 51 percent. The minimal values are yielded by shrubs at +36 to -11 which gives them a latitude of 47 percent.

The wide range of variation in grass values is suspected to have been contributed to in large measure by *Poa pratensis*. This early grass matured and shattered seed by the third week of June 1965 but helped, probably, by its rhizomatous root system and a wet summer, managed to retain a high moisture content. The application of the high conversion factor of .55, for grasses after seed matures, gave unrealistically high dry matter values. The forbs, on the other hand, are usually underrated. The conventional method seems to be relatively close in the case of shrubs except where the high conversion factor for big sagebrush (northern aspect, afternoon clipping) accentuates error. The lower deflection of true shrub values may, in part, be a reflection of the deep root system of shrubs which is relatively unaffected by light showers moistening only the surface soil. The frequent moistening of surface soils, however, is very likely to be important for herbaceous plants which draw the bulk of their moisture from the upper soil strata (Bahrani and Taylor, 1961; Denmead and Shaw, 1962; Gardner, 1963).

Evidently the conversion factor approach, through its failure to appreciate differences in plant behavior and environmental factors,

Table 19. Variations in computed weights of dry matter of grasses clipped from all aspects for base value of "100" units (based on Table 16).

	Forenoon clipping			Afternoon clipping			
	Dry matter values		Divergence (range) from base value	Dry matter values		Divergence (range) from base value	Divergence (range) within day from base value
	Maximum	Minimum		Maximum	Minimum		
Shaded	257	75	+157 to -25	197	79	+97 to -21	+157 to -21
Unshaded	164	74	+ 64 to -26	153	69	+53 to -31	+ 64 to -31
Divergence between shaded and unshaded from base value	+64 to +157	-25 to -26	+157 to -26	+53 to +97	-21 to -31	+97 to -31	+157 to -31

Table 20. Variations in computed weights of dry matter of forbs clipped from all aspects for base value of "100" units (based on Table 17)

	Forenoon clipping			Afternoon clipping			
	Dry matter values			Dry matter values			
	Maximum	Minimum	Divergence (range) from base value	Maximum	Minimum	Divergence (range) from base value	Divergence (range) within day from base value
Shaded	110	68	+10 to -32	105	66	+ 5 to -34	+10 to -34
Unshaded	92	61	- 8 to -39	85	59	-15 to -41	- 8 to -41
Divergence between shaded and unshaded from base value	+10 to - 8	-32 to -39	+10 to -39	+ 5 to -15	-34 to -41	+ 5 to -41	+10 to -41

Table 21. Variations in computed weights of dry matter of shrubs clipped from all aspects for base value of "100" units (based on Table 18)

	Forenoon clipping			Afternoon clipping			
	Dry matter values			Dry matter values			
	Maximum	Minimum	Divergence (range) from base value	Maximum	Minimum	Divergence (range) from base value	Divergence (range) within day from base value
Shaded	115	91	+15 to -9	136	89	+36 to -11	+36 to -11
Unshaded	109	98	+ 9 to -2	123	90	+23 to -10	+23 to -10
Divergence between shaded and unshaded from base value	+ 9 to +15	-9 to -2	+15 to -9	+23 to +36	-10 to -11	+36 to -11	+36 to -11

is apt to yield erroneous values. Add to this the field sampling error and the computed values can indeed be skewed from the true mean. Acceptance of conventional procedures as a basis for any research purpose or intensive management planning is, therefore, open to question.

Tables 22, 23 and 24 illustrate how far conventionally computed AUM's could deviate from true AUM's available for use. In the case of grass, for every computed AUM the actually available herbage could range between equivalents of 0.69 and 2.57 AUM's. Table 22 details the ranges of divergence of true AUM's from computed values as a result of disregard of ecological factors influencing herbage moisture. Likewise in the case of forbs, the true AUM's could be up to 10 percent above or 41 percent below the computed values. The corresponding values for shrubs are up to 36 percent above or 11 percent below.

Practical Application of Results

The results show that the moisture component of plants is influenced both by plant and environmental factors. The variations resulting from plant phenology and species differences, especially in herbaceous plants, are substantial enough to be considered in practical assessment of moisture or dry weights of green plants. The species differences are, however, related to aspect differences. In addition, where the same species appear on different aspects intraspecific variation in moisture content is suggested as well (Appendix V). Aspect considerations appear to be an easier field basis for improving formulae for deriving dry weights. However it should be realized that slope differences include a complex of ecological differences. The other site feature

Table 22. Comparisons of carrying capacities of one net grass acre calculated on actual and computed dry matter weights

Grass, green weight: 6000 lbs (utilizable herbage)

Growth stage: Just before heading.

i. Carrying capacity calculated on

A: Computed weight (lbs)
Conversion factor: 0.30
Dry matter (computed): 2000 x 0.30 = 600
Carrying capacity : 600 ÷ (20 x 30) = 1 AUM

B: Actual weight (lbs)

Light condition / AUM	Dry matter values: Forenoon Maximum	Forenoon Minimum	Afternoon Maximum	Afternoon Minimum	Divergence from computed weight of actual weights from clippings made in: Forenoon	Afternoon
1. Shaded	1542	450	1182	474	+942 to -150	+582 to -126
AUM	2.57	0.75	1.97	0.79	+1.75 to -0.25	+0.97 to -0.21
2. Unshaded	984	444	918	414	+384 to -156	+318 to -186
AUM	1.64	0.74	1.53	0.69	+0.64 to -0.26	+0.53 to -0.31

ii. Comparisons of carrying capacities calculated on computed and actual weights

Carrying capacity based on weights	Light condition	AUMs based on actual weights from: Forenoon clippings Maximum	Forenoon clippings Minimum	Afternoon clippings Maximum	Afternoon clippings Minimum	Divergence in AUMs based on: Forenoon values	Afternoon values	AUM divergence range within day
a. Actual	Shaded	2.57	0.75	1.97	0.79	+1.57 to -0.25	+0.97 to -0.21	+1.57 to -0.21
b. Computed		1.00	1.00	1.00	1.00			
a. Actual	Unshaded	1.64	0.74	1.53	0.69	+0.64 to -0.26	+0.53 to -0.31	+0.64 to -0.31
b. Computed		1.00	1.00	1.00	1.00			
Divergence due to shade effect		+0.64 to +1.57	-0.25 to -0.26	+0.53 to +0.97	-0.21 to -0.31	+1.57 to -0.26	+0.97 to -0.31	+1.57 to -0.31

Table 23. Comparisons of carrying capacities of one net forb acre calculated on actual and computed dry matter weights

Forbs, green weight: 4000 lbs (utilizable herbage)

Condition: Lush

i. Carrying capacity calculated on

A: Computed weight (lbs)
Conversion factor: 0.15
Dry matter (computed): 4000 x 0.15 = 600
Carrying capacity: 600 ÷ (20 x 30) = 1 AUM

B: Actual weight (lbs)

Light condition / AUM	Dry matter values: Forenoon Maximum	Forenoon Minimum	Afternoon Maximum	Afternoon Minimum	Divergence from computed weight of actual weights from clippings made in: Forenoon	Afternoon
1. Shaded	660	408	630	396	+60 to -192	+30 to -204
AUM	1.1	0.68	1.05	0.66	+0.1 to -0.32	+0.05 to -0.34
2. Unshaded	552	366	510	354	-48 to -234	-90 to -246
AUM	0.92	0.61	0.85	0.59	-0.08 to -0.39	-0.15 to -0.41

ii. Comparisons of carrying capacities calculated on computed and actual weights

Carrying capacity based on weights	Light condition	AUMs based on actual weights from Forenoon clippings: Maximum	Forenoon clippings: Minimum	Afternoon clippings: Maximum	Afternoon clippings: Minimum	Divergence in AUMs based on: Forenoon values	Afternoon values	AUM divergence range within day
a. Actual	Shaded	1.1	0.68	1.05	0.66	+0.1 to -0.32	+0.05 to -0.34	+0.10 to -0.34
b. Computed		1.00	1.00	1.00	1.00			
a. Actual	Unshaded	0.92	0.61	0.85	0.59	+0.08 to -0.39	-0.15 to -0.41	-0.08 to -0.41
b. Computed		1.00	1.00	1.00	1.00			
Divergence due to shade effect		+0.10 to -0.39	+0.32 to -0.39	-0.05 to -0.15	-0.34 to -0.41	+0.1 to -0.39	+0.05 to -0.41	+0.10 to -0.41

Table 24. Comparisons of carrying capacities of one net shrubs acre calculated on actual and computed dry matter weights

Shrubs, green weight: 1300 lbs (utilizable browse)

Composition: Snowberry and sagebrush (50% each)

i. Carrying capacity calculated on

A: Computed weight (lbs)
Conversion factor: 0.46
Dry matter (computed): 1300 x 0.46 = 608
Carrying capacity: 608 ÷ (20 x 30) = 1 AUM

B: Actual weight (lbs)

Light condition / AUM	Dry matter values: Forenoon Maximum	Forenoon Minimum	Afternoon Maximum	Afternoon Minimum	Divergence from computed weight of actual weights from clippings made in: Forenoon	Afternoon
1. Shaded	690	546	816	534	+90 to -54	+216 to -66
AUM	1.15	0.91	1.36	0.89	+0.15 to -0.09	+0.36 to -0.11
2. Unshaded	654	588	738	540	+54 to -12	+138 to -60
AUM	1.09	0.98	1.23	0.90	+0.09 to -0.02	+0.23 to -0.10

ii. Comparisons of carrying capacities calculated on computed and actual weights

Carrying capacity based on weights	Light condition	AUMs based on actual weights from Forenoon clippings: Maximum	Forenoon clippings: Minimum	Afternoon clippings: Maximum	Afternoon clippings: Minimum	Divergence in AUMs based on: Forenoon values	Afternoon values	AUM divergence range within day
a. Actual	Shaded	1.15	0.91	1.36	0.89	+0.15 to -0.09	+0.36 to -0.11	+0.36 to -0.11
b. Computed		1.00	1.00	1.00	1.00			
a. Actual	Unshaded	1.09	0.98	1.23	0.90	+0.09 to -0.02	+0.23 to -0.10	+0.23 to -0.10
b. Computed		1.00	1.00	1.00	1.00			
Divergence due to shade effect		+0.09 to +0.15	-0.09 to -0.02	+0.23 to +0.36	-0.1 to -0.11	+0.15 to -0.09	+0.36 to -0.1	+0.36 to -0.11

highly effective in modifying plant moisture is shade or lack of it. Although time-of-day is statistically significant in moisture variations, it is relatively less important than slope or shade. The time-of-day effect, therefore, could be ignored in developing factors for estimating dry weight of green plant material in non-research situations.

Simplified as such the conversion factors for deriving dry weights are set out in Table 25. The basis of these factors are 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 until further research can be performed elsewhere.

A comparison of the factors in Table 25 with formula values used by land managing agencies (Appendix VI) is made below with suggestions for improvement.

A. Grasses and sedges: The formula values of 25 to 30 percent dry matter in the boot stage hold well for unshaded northern and eastern aspects. But for southern and western aspects a factor of 35 to 40 percent would give closer estimates. Likewise the 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 percent, respectively, to improve estimates.

The two phenological stages the agency formula recognizes are "the headed out" and the "after bloom." The air dry factors given for these stages are 35 to 40 percent and 45 to 50 percent respectively. The intermediary stage of flowering or blooming could be interpolated at 40 to 45 percent. This formula value is a fair dry weight approximation

Table 25. Conversion factors: percent air-dry weights

Aspect	Phenological stage	Grass[a] Unshaded	Grass[a] Shaded	Forbs Unshaded	Forbs Shaded	Shrubs Unshaded	Shrubs Shaded
North	Boot/Pre bloom, leafy	24	20	18	16	31	--
	Bloom	31	25	25	19	33	31
	Past bloom	--	--	--	--	--	36
East	Boot/Pre bloom, leafy	32	28	22	20	34	--
	Bloom	40	33	24	22	36	36
	Past bloom	--	--	--	--	--	41
South	Boot/Pre bloom, leafy	39	35	27	22	35	38
	Bloom	44	38	--	23	40	38
	Past bloom	--	--	--	--	--	41
West	Boot/Pre bloom, leafy	40	24	22	23	37	32
	Bloom	45	31	23	25	40	34
	Past bloom	--	--	--	--	--	40

[a]The above phenological stages refer to the most abundant species except for shaded grass on southerly and unshaded on westerly slopes where the most abundant species is Kentucky bluegrass. Kentucky bluegrass was past seed maturity before its associates reached boot stage. After the bluegrass, bearded wheatgrass was second most abundant species. Hence the phenological stage refers to the bearded wheatgrass, i.e. the second most abundant rather than the first most abundant species.

for unshaded grasses in bloom on eastern, southern and western aspects. However, for unshaded northerly grasses a reduced conversion factor of 30 to 35 percent would yield more realistic dry weights. This factor also applies to shaded grasses on easterly, southerly and westerly aspects. But for shaded northern aspects a further reduction by 5 percent would improve accuracy.

Agency formula values of 55 to 80 percent in the stage of "seed maturity" and after are high for Kentucky bluegrass. This early grass matured seed in the study area before any other major forage species developed inflorescences. A conversion factor of 35 to 45 percent would allow truer computation of its dry weight after seed maturity, irrespective of aspect and light conditions.

B. Forbs: The formula values are adequately 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 percent.

C. Shrubs: The 10 percent moisture variation categories for browse species accommodate well the effects of aspect and shade, except for sagebrush. The formula value of 40 to 60 percent exaggerates its dry weight estimates. Bracketing sagebrush with the second browse category of "fibrous leaves and the Purshia" (conversion factor 35 to 45 percent) would keep sagebrush estimates more close to true weights.

A diagrammatic sketch of the prevalent formula values and the suggested modifications, based on values in Table 25, are presented in Figure 4.

Impact of Modifications on Grazing Management

The effect of suggested modifications on utilization of range forage are illustrated in Table 26. In this table the net utilizable forage of 6000, 4000 and 1300 pounds from a net grass, forb and shrub acre respectively, have been assumed as in Tables 22, 23 and 24. The estimated dry weights have been derived by multiplying green weights with the lowest value in the conversion factor range relating to that growth form and

A. Grasses

A(i) Boot Stage
25 to 30 percent

- Shaded
  East & West
  - +5
    South
  - -5
    North
- Unshaded
  North & East
  - +10
    South & West

A(ii) Flowering
40 to 45 percent

- Shaded
  -10
  East, South & West
  - -5
    North
- Unshaded
  East, South & West
  - -10
    North

A(iii) Seed Maturity and After
55 to 80 percent

- Shaded & Unshaded (Kentucky Bluegrass)
  -20 to -35
  West & South

B. Forbs

Very Lush
15 to 20 percent

- Shaded
  East, West, South & North
- Unshaded
  East, West & North
  - +10
    South

C. Shrubs

i. Lush leaves (Snowberry) " " 30 to 40 percent
ii. Fibrous leaves and sagebrush " 35 to 45 percent

Figure 4. Suggested conversion factors for air-dry weights.

Table 26. Grazing capacity of one net forage acre

Shaded			Formula derived	Unshaded			Formula derived
Aspect	Estimated dry weight	AUMs	AUMs	Aspect	Estimated dry weight	AUMs	AUMs
A. Grass: Utilizable forage from one net grass acre = 6000 lbs							
i. Phenological stage: Boot stage.							
West, East	6000 x .25 = 1500	2.5	2.5	North, East	6000 x .25 = 1500	2.5	2.5
South	6000 x .30 = 1800	3.0	2.5	South, West	6000 x .35 = 2100	3.5	2.5
North	6000 x .20 = 1200	2.0	2.5				
ii. Phenological stage: In bloom.							
East, South, West	6000 x .30 = 1800	3.0	4.0	East, South, West	6000 x .40 = 2400	4.0	4.0
North	6000 x .25 = 1500	2.5	4.0	North	6000 x .30 = 1800	3.0	4.0
iii. Phenological stage: Seed maturity and after.							
Shaded and unshaded							
West, South	6000 x .35 = 2100	3.5	5.5				
B. Forbs: Utilizable forage from one net forb acre = 4000 lbs							
Unshaded							
South	4000 x .25 = 1000	1.6	1.0				
C. Shrubs: Utilizable forage from one net browse acre = 1300 lbs							
Shaded and unshaded							
Sagebrush	1300 x .40 = 520	0.87	1.1				

phenological stage. For instance, in deriving dry weights of green grasses in boot stage the formula conversion factor is 25 to 30 percent. The lowest value in the conversion range, i.e. 25 percent, has been used in the table for formula derived AUMs. Likewise for AUMs calculated with suggested conversion factors the lowest value in allowable factors has been used: 35 percent in case of unshaded grass in the boot stage on southern and western aspects. The-lowest-allowable-factor rule has been substituted with the middle-allowable-factor in case of shrubs where the range of conversion factors was very wide. For instance, in the case of sagebrush the formula factors range from 40 to 60 percent and suggested factors range from 35 to 45 percent. The dry matter estimates in Table 26 have been derived by multiplying green weights by 50 percent and 40 percent for formula and suggested AUMs respectively.

The table indicates that, in a grass sward in the boot stage, for every 2.5 AUMs computed by the formula, the true AUMs may vary from 2 to 3 AUMs. Likewise in the bloom stage for every formula derived 4 AUMs. The true AUMs may 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" when grazing estimates are made. For every 5.5 AUMs derived by the formula for this grass, which means practically all the available herbaceous forage on the western aspect, the true values are only 3.5 AUMs. These discrepancies in AUMs, when calculations apply to extensive range areas, 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 formula. The agency formula gave slightly higher than true values for sagebrush.

Plant Moisture Indication of Other Attributes

Apart from deriving dry matter weights the accurate information of plant moisture is rewarding in other ways also. Researchers have established its indicator value in grazing preference and palatability; forage nutrition and range fires.

Grazing preference and palatability

Cully (1937) suggested that moisture content had indicator value for grazing preference. He observed that cattle concentrated on areas where local showers had started new growth and sustained it. Local areas such as washes, where growth remained green longer at the end of growing season received the most use. Springfield and Reynolds (1951) found the moisture component of herbage was a reliable index to grazing preference by cattle. They noted that succulence of forage, as described by moisture content, strongly influenced preference during late summer and early fall grazing. The species with highest moisture content were most highly preferred. They surmised that higher moisture content contributed to high preference of new growth on semidesert Arizona ranges.

The changes in palatability ratings of different range species with advance in season or change in seasons probably needs a second look from this angle.

Nutrition

Of late (Anonymous, 1961) moisture in plant tissue has been studied for predicting crude protein in herbage. According to this report crude protein decreased as moisture content decreased in forages of the Blackhills of South Dakota. A correlation coefficient of 0.78 for *Poa pratensis* and 0.87 for other grasses and sedges was found. In *Poa pratensis* crude protein decreased rapidly as moisture content declined from 80 percent to 60 percent of the dry weight but it decreased relatively little when moisture fell below 60 percent. A similar decline in crude protein at the higher moisture levels was determined for *Phleum pratense*, *Elymus innovatus* and sedges. However, in contrast to *Poa pratensis*, the protein content of those species continued to decrease rather rapidly when moisture content was less than 60 percent. It has been suggested that closeness of the moisture-crude protein relationship warrants use of field moisture as a general index of crude protein. The report further points out that this method is advantageous since moisture content is easier and less expensive to determine. If this is done, ecological influences reported here should be considered.

Fire hazard

With progression of the summer season and advancement of growth, fire hazard increases on forest and rangelands. So long as the water content in plant tissue is high the vegetation resists burning. However, there is a critical moisture level below which this resistance wears off rather rapidly (Lane and McComb, 1948). In any fire prevention planning and management it would be a great advantage to know the critical level at which fire-retarding vegetation tends to become fire-carrying fuel. These levels can be expected to vary with ecological context. Therefore, the results of studies such as this could have application also in fire control planning.

SUMMARY

Evaluation of dry matter in range forage is a basic requirement in determining range productivity, condition and utilization. The assessment of dry matter is, however, complicated by extremely variable behavior of water in green plants. The existing, widely-used formula for deriving dry weight consider only growth form and growth stage. In this study the possible importance of site and species influences on moisture content was examined. Investigations were made on mountain summer range in the Douglas-fir climatic climax zone of the Cache National Forest, northern Utah.

A pilot study was made in 1964 to determine sample size and number. Accordingly, 12 experimental plots were laid out early in 1965: 3 on each of the 4 exposures: north, south, east and west. Each plot had 2 subplots: one shaded by natural tree growth and the other unshaded. Each subplot contained 66 sections of 6 x 1 feet each with alternate sections available for clipping. On every harvesting day 2 cutting sections of 4' x 1' = 4 square feet each were randomly selected and clipped leaving a one-foot border on either side. One clipping was made in the forenoon and the other the same afternoon. In all, 12 clipping days at each plot covered the grazing season from the third week of June 1965 to the second week of September 1965.

The clipped material was separated by growth forms, weighed immediately and then oven dried at 80 C for 24 hours. In May 1966 the dry forage was reweighed and moisture content of green

forage computed. Analysis of variance of moisture data showed that aspect, clipping time, shade and season and interaction between aspect and clippings (season) were highly significant in the three growth forms. The interaction between aspect, shade and clippings was highly significant in grasses and forbs. Significance of aspect x shade x clipping time interaction was restricted to shrubs. The shade x clipping time interaction was highly significant in grasses only.

The moisture data showed that forbs always had more moisture than grasses and grasses were invariably wetter than shrubs. Within this general pattern, however, considerable moisture differences were noted. Aspect alone accounted for 100, 110 and 20 percent moisture variation among grasses, forbs and shrubs respectively. Within the same growth form, shade could induce higher mean moisture values by 78.4, 88.9 and 27.9 percent for grasses, forbs and shrubs. The aspect difference expressed itself even in diurnal moisture variations accounting for up to 23.7, 27.6 and 13.6 percent variations in grasses, forbs and shrubs, respectively. Likewise, the seasonal moisture variations ranged from 50.3 to 186.6 percent in grasses, 144.6 to 316.8 percent in forbs and 47.8 to 107.6 percent in shrubs.

The shade-induced excess moisture in grasses and shrubs was greater early in the season: 79.4 percent in grasses and 32.5 percent in shrubs. By the end of the growing season the differences had shrunk to 43.4 and 26.3 percent. Forbs showed a divergent pattern with a 73.1 percent initial differential value increasing to 78.4 percent by the season's end. This was probably due to striking differences in phenological development. Over the season therefore the mean moisture excess under shade evened out to 79.0, 72.4

and 26.6 percent for grasses, forbs and shrubs, respectively. The effect of shade on mean moisture variation during day was less: 12.9 percent for grasses, 2 percent for forbs and 4 percent for shrubs.

Diurnal variation was similar for herbage in the first clipping: 24.1 and 24.5 percent for grasses and forbs. Shrubs had a lower mean value of 15.3 percent. Over the season the diurnal variation averaged 19.9, 25.7 and 11.5 percent for grasses, forbs and shrubs, respectively. In the final clipping, however, grasses and shrubs yielded comparable variation of 10.8 and 10.6 percent but forbs gave a strikingly high average value at 17.4 percent.

Initially the shrubs contained 214.7 percent moisture: grasses had 20 percent and forbs 91.6 percent higher than shrubs. But at the end of the season shrubs and grasses showed comparable values of 132.3 and 134.5 percent respectively whereas forbs were conspicuously higher at 197.6 percent. The seasonal decline in moisture, however, was steepest for forbs which lost 214.9 percent and minimal for shrubs at 82.4 percent. Grasses had an intermediate average value of 122.1 percent.

The moisture data show that higher moisture values came invariably from northern slopes. This could have been anticipated from the orientation of the slope and its consequent protection from solar insolation. However, the significantly divergent moisture values from northern and other slopes reflect the possible influence of site and species differences. The northern slopes possess deep loamy soils relatively free from stone. These soils are likely to store considerable quantities of water for plant use. Other slopes have comparatively shallow soils, high in clay with varying proportions of stone. Such soils are limited in water holding capacity and offer resistance to root development. Efficient mutual side shade in dense low-statured plant growth and dense Douglas fir-aspen overhead cover very likely reduced water loss. Cool and humid northerly microenvironments had the plant moisture consistently well replenished. The mesic species and later phenologic development, characteristic on northern exposures, are also associated with high moisture content. The eastern, western and southern slopes had comparable soils. The insolation differential on these slopes was masked by an inordinately wet summer. The moisture differences on these aspects were not divergent enough to be significant.

Shaded samples were always higher in moisture than their unshaded counterparts. Lower temperatures, higher humidity, later phenology and possibly better soil moisture effect this relationship. Furthermore, the shaded sites carried mesic species and the unshaded ones supported xerophytic species. This difference was particularly marked in grasses where bromes and tall oat grass abounded under shade but drought resistant giant wild rye, blue bunch wheatgrass and needlegrass, which roll their leaves to resist water loss, grew on unshaded sites. The minimal diurnal moisture variation among herbs is possibly indicative of their high susceptibility to desiccation even under shade. The low diurnal and seasonal moisture variation among shrubs could be an expression of their relatively stable and deep moisture-absorption zone to which surface shade or light showers are of little importance. The adaptive characteristics enabling shrubs to resist water-loss during stress also possibly suppressed drastic moisture variation. The increase in moisture variation in forbs toward the end of the season is the result of differences in growth stage under shaded and unshaded conditions.

The magnitude of clipping-time (diurnal) moisture variation corresponded to variation in mean moisture content of the different growth forms. Accordingly, forbs and shrubs gave the maximal and minimal variations with grass yielding intermediate values.

The diurnal moisture variations persisted at every clipping through the season but the absolute values indicate no pattern or trend. However, graphed forenoon and afternoon values at different clippings show a near parallelism indicating a close correlation. Expression of diurnal and shade-induced moisture variation values as fractions of corresponding forenoon moisture values gave clear evidence of moisture trends.

Grasses, forbs and shrubs declined in moisture over the season by 122.1, 214.9 and 82.4 percent, respectively. Expressed in relation to initial moisture content these values denote losses of 47.6, 52.0 and 38.1 percent of average forenoon values.

Comparison of true dry matter values with empirically derived values shows that the latter, in case of grass, could be 157 percent above or 31 percent below the true value. In the case of forbs, the formula values could be 10 percent above or 41 percent below. For shrubs the range would be from 36 percent higher to 11 percent lower than true means. In terms of utilization every formula-based AUM in grass-dominated range could actually vary from 0.69 to 2.57 AUM. Likewise the true values could be from 1.1 to 0.59 AUM in forbs and from 1.4 to 0.89 AUM in browse.

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APPENDIXES

Appendix I

Aspect : East

Light Conditions: Unshaded

Elevation : 6300 feet

Slope : 8 percent

Location : R. 3 E. T. 13 N. Section 11, N. E. ¼ of S. W. ¼. Three-fourths mile to the west of U. S. Highway 89, to the south of old Tony Grove Lake road. Half way down the slope.

Parent Material : Morainal wash

Horizon	Depth	Description
A_1	0-24 inches	Dark grayish brown (10 YR.4/2) dry, very dark brown (10 YR.2/2) moist; loam; weak medium granular; slightly hard dry, very friable moist, slightly sticky and slightly plastic wet; noncalcareous; smooth wavy boundary; 35% gravel, moderate permeability; abundant fine roots, few medium roots.
A_2	24-35 inches	Grayish brown (10 YR.5/3) dry, brown (10 YR.4/3) moist; loam; weak medium subangular blocky; soft dry, very friable moist, slightly sticky and slightly plastic wet; noncalcareous; smooth wavy boundary; 50% cobbles, moderate permeability; few fine and medium roots.
B_2	35 + inches	Yellowish brown (7.5 YR.5/4) dry, reddish brown (7.5 YR.4/4) moist; silty clay loam; moderate

medium subangular blocky; hard dry, friable moist, sticky and slightly plastic wet; noncalcareous.

Aspect : East

Light Conditions: Shaded by aspen

Elevation : 6,300 feet

Slope : 8 percent

Location : R. 3 E. T. 13 N. Section 11, N. E. ¼ of S. W. ¼. Three-fourths mile to the west of U. S. Highway 89, to the south of old Tony Grove Lake road. Half way down the slope.

Parent Material : Morainal wash

Horizon	Depth	Description
A_1	0-24 inches	Dark grayish brown (10 YR.4/2) dry, very dark brown (10 YR.2/2) moist; silt loam; moderate, medium granular; slightly hard dry, very friable moist, slightly sticky and slightly plastic wet; non-calcareous, wavy boundary, moderate permeability.
A_2	24-60+ inches	Grayish brown (10 YR.5/3) dry, brown (10 YR.4/3) moist; silt loam; weak moderate subangular blocky, slightly hard dry, very friable moist, slightly sticky and slightly plastic wet; non-calcareous, cobbles 40% at 29 inch; moderate permeability.

Aspect	:	East
Light Conditions:		Unshaded
Elevation	:	6400 feet
Slope	:	25 percent
Location	:	R. 3 E. T. 13 N. Section 11, N. W. ¼ of N. E. ¼. Three-fourths mile to the west of U. S. Highway 89, one-fourth mile to the north of Tony Grove Canyon. Near top of slope.
Parent Material :		Wasatch conglomerate

Horizon	Depth	Description
A_1	0-20 inches	Five percent organic matter (estimated); very dark grayish brown (10 YR.3/2) dry, very dark brown (10 YR.2/2) moist; silt loam; weak fine and medium granular; slightly hard dry, very friable moist, slightly sticky and nonplastic wet; non-calcareous; some indications of salinity; gradual and wavy boundary, 40% cobbles and gravel; moderate permeability; plentiful fine and medium roots.
A_2	20-33 inches	Grayish brown (10 YR.5/3) dry, reddish brown (7.5 YR.4/4) moist; light silty clay loam; weak fine and medium subangular blocky; slightly hard dry, friable moist, slightly sticky and slightly plastic; noncalcareous; gradual and wavy boundary; 50% cobbles and gravel; moderate permeability; common fine and medium roots.

B_2	33 + inches	Yellowish brown (7.5 YR.5/4) dry, reddish brown (7.5 YR.3/4) moist; clay loam; moderate medium subangular blocky; hard dry, firm moist, sticky and very plastic wet; noncalcareous, 30% gravel; moderately slow permeability; few fine and medium roots.

Aspect :	East
Light Conditions:	Shaded by aspen
Elevation :	6380 feet
Slope :	40 percent
Location :	R. 3 E. T. 13 N. Section 11, N. W. ¼ of N. E. ¼. Three-fourths mile to the west of U. S. Highway 89, one-fourth mile to the north of Tony Grove Canyon. Upper one-third of slope.
Parent Material :	Wasatch conglomerate

Horizon	Depth	Description
A_1	0-11 inches	Seven percent organic matter (estimated); dark brown (10 YR.3/3) dry, very dark brown (10 YR.2/2) moist; silt loam; moderate fine granular; slightly hard dry, friable moist, slightly sticky and slightly plastic wet; noncalcareous; clear and wavy boundary; 40% cobbles; moderately rapid permeability; abundant fine and medium roots, few large roots.
A_2	11-20 inches	Light yellowish brown (7.5 YR.6/4) dry, reddish brown (7.5 YR.4/4) moist; heavy sandy loam; moderate medium subangular blocky; slightly hard dry, friable moist, slightly sticky and slightly plastic wet; noncalcareous; gradual and wavy boundary; 30% cobbles and gravel; moderately rapid permeability; common fine and medium roots.
A_2B_2	20-31 inches	Light yellowish brown to light reddish brown (7.5 YR.6/4 to 5 YR.4/6) dry, reddish brown to

		dark reddish brown (7.5 YR.4/4 to 2.5 YR.3/6) moist; heavy sandy loam and clay; moderate medium subangular blocky; slightly hard to very hard dry, firm moist, sticky and plastic wet; noncalcareous; clear and wavy boundary; slow permeability; few fine and medium roots.
B_2	32 + inches	Dark brown (5 YR.3/3) dry, dark reddish brown (5 YR.4/8) moist; sandy clay; strong coarse subangular blocky; very hard dry, very firm moist, very sticky and very plastic wet; noncalcareous; slow to very slow permeability; very few fine roots.

Aspect : East

Light Conditions: Unshaded

Elevation : 6300 feet

Slope : 25 percent

Location : R. 3 E. T. 13 N. Section 2, N. E. ¼ of S. W. ¼. Three-fourths mile to the west of U. S. Highway 89, one-half mile to the north of Tony Grove Canyon, lower one-third of slope.

Parent Material : Wasatch conglomerate

Horizon	Depth	Description
A_1	0-10 inches	Three percent organic matter (estimated); dark grayish brown (10 YR.4/2) dry, very dark brown (10 YR.2/2) moist; silt loam; moderate medium and coarse granular; hard dry, firm moist, slightly sticky and slightly plastic wet; noncalcareous; some indications of salinity, clear and smooth boundary; 20% cobbles; moderate permeability; plentiful fine and medium roots.
B_2	10 + inches	Yellowish brown (7.5 YR.5/4) dry, reddish brown (5 YR.4/4) moist; clay; strong medium prismatic; extremely hard dry, very firm moist, very sticky and very plastic wet; noncalcareous; 45% gravel; slow to very slow permeability; few fine roots.

Aspect : East

Light Conditions: Shaded by aspen

Elevation : 6380 feet

Slope : 35 percent

Location : R. 3 E. T. 13 N. Section 2, N. E. ¼ of S. W. ¼. Three-fourths mile to the west of U. S. Highway 89, one-half mile to the north of Tony Grove Canyon, lower one-third of slope.

Parent Material : Wasatch conglomerate

Horizon	Depth	Description
A_1	0-7 inches	Eight percent organic matter (estimated); very dark grayish brown (10 YR.3/2) dry, very dark brown (10 YR.2/1) moist; silt loam; moderate medium granular; slightly hard dry, friable moist, slightly sticky and slightly plastic wet; noncalcareous; clear and smooth boundary; 40% cobbles and gravel; moderate permeability; abundant fine and medium, few large roots.
B_2	7 + inches	Reddish yellow (5 YR.5/6) dry, dark brown (5 YR.4/6) moist; clay; strong coarse angular blocky; extremely hard dry, very firm moist, very sticky and plastic wet; noncalcareous; 50% cobbles and gravel; slow permeability; few fine and medium roots.

Aspect	:	West
Light Conditions:		Unshaded
Elevation	:	6200 feet
Slope	:	32 percent
Location	:	R. 3 E. T. 13 N. Section 12, N. E. ¼ of S. W. ¼. Below the bench mark hill, to north of Little Bear Creek, 0.2 mile to the east of U. S. Highway 89. Lower one-third of slope.
Parent Material	:	Sandstone over glacial moraine. Rounded sandstone suggesting local movement, glacial boulders dispersed below 12 inches.

Horizon	Depth	Description
A_1	0-17 inches	Organic matter 3% (estimated); dark grey (10 YR.4/1) dry, very dark grey (10 YR.3/1) moist; loam; fine to coarse strong granular; slightly hard dry, friable moist, slightly sticky and nonplastic wet; noncalcareous; clear and smooth boundary; gravel 10%; moderate permeability; abundant fine and medium roots.
A & B	17-43 inches	Yellowish brown (5 YR.5/4) dry, reddish brown (5 YR.4/4) moist; clay loam; fine angular blocky; hard dry, firm moist, sticky and plastic wet; noncalcareous; clear and wavy boundary; cobbles and gravel 25%; slow permeability; few to common fine roots above 24 inches, very few fine roots below 24 inches.

B_2	43+ (60) inches	Dark brown (5 YR.3/3) dry, dark reddish brown (5 YR.4/8) moist; sandy clay; strong coarse subangular blocky; very hard dry, very firm moist, very sticky and very plastic wet; non-calcareous; cobbles and gravel 45%; slow to very slow permeability; very few fine roots.

Aspect : West

Light Conditions: Shaded by a stunted pole crop of aspen and chokecherry (*Prunus virginiana*) shrubs

Elevation : 6200 feet

Slope : 40 percent

Location : R. 3 E. T. 13 N. Section 12, N. E. ¼ of S. W. ¼. Below the bench mark hill, to north of Little Bear Creek, 0.2 mile to the east of U. S. Highway 89. Lower one-third of slope.

Parent Material : Sandstone overlying glacial moraine. Rounded sandstone suggesting local movement, glacial boulders dispersed below 12 inches.

Horizon	Depth	Description
A_1	0-14 inches	Organic matter 4% (estimated); dark grayish brown (10 YR.4/2) dry, very dark brown (10 YR.2/2) moist; silt loam; moderate fine granular; soft dry, friable moist, nonsticky and nonplastic wet; noncalcareous; clear and wavy boundary; gravel 10%; moderate permeability; plentiful fine and medium roots, few large roots.
A_2	14-30 inches	Grayish brown (10 YR.5/3) dry, brown (10 YR.4/3) moist; silt loam; moderate medium subangular blocky; slightly hard dry, friable moist, slightly sticky and slightly plastic wet; clear and wavy boundary; cobbles and gravel 10%, moderately permeable; common fine and medium roots a few large ones.

B_2	30+ (60) inches	Brown (7.5 YR.5/3) dry, dark brown (7.5 YR.3/3) moist; clay loam; medium subangular blocky; hard dry, firm moist, sticky and very plastic wet; noncalcareous; cobbles and gravel 20%, slow permeability, few fine and medium roots.

Aspect : West

Light Conditions: Unshaded

Elevation : 6200 feet

Slope : 40 percent

Location : R. 3 E. T. 13 N. Section 13, N. E. ¼ of N. W. ¼. Two-thirds mile to the south of Forestry Summer Camp. Lower one-third of slope.

Parent Material : Wasatch conglomerate

Horizon	Depth	Description
A_1	0-11 inches	Four percent organic matter (estimated); dark grayish brown (10 YR.4/2) dry, very dark brown (10 YR.2/2) moist; heavy silt loam; moderate fine and medium granular; slightly hard dry, friable moist, slightly sticky and slightly plastic wet; noncalcareous; clear and smooth boundary; 10% gravel, moderate permeability; plentiful fine and medium roots.
B_1	11-28 inches	Brown (7.5 YR.5/4) dry, dark brown (7.5 YR.3/2) moist; clay loam; moderate medium subangular blocky; hard dry, firm moist, slightly sticky and plastic wet; noncalcareous; clear and smooth boundary; 20% gravel; moderate permeability; common fine and medium roots.
B_2	28 + inches	Yellowish brown (5 YR.5/4) dry, reddish brown (5 YR.4/4) moist; clay; strong medium angular blocky; extremely hard dry, extremely firm moist,

sticky and plastic wet; noncalcareous; 25% cobbles and gravel; very slow permeability; very few fine roots.

Aspect	:	West
Light Conditions:		Shaded by (stunted) aspen and chokecherry
Elevation	:	6200 feet
Slope	:	35 percent
Location	:	R. 3 E. T. 13 N. Section 13, N. E. ¼ of N. W. ¼. Two-thirds mile to the south of the Forestry Summer Camp. Lower one-third of slope.
Parent Material	:	Wasatch conglomerate

Horizon	Depth	Description
A_1	0-20 inches	Organic matter 6% (estimated), dark grayish brown (10 YR.4/2) dry, very dark brown (10 YR.2/2) moist; silt loam; weak fine granular; soft dry, very friable moist, nonsticky and nonplastic wet; noncalcareous; clear and gradual boundary; 10% gravel; moderate permeability; plentiful fine and medium roots.
A_2	20-31 inches	Grayish brown (10 YR.5/3) dry, dark brown (7.5 YR.4/4) moist; silty clay loam; moderate medium subangular blocky; slightly hard dry, firm moist, sticky and plastic wet; noncalcareous; clear smooth boundary; 10% cobbles and gravel; moderately permeable; few fine roots.
B_2	31 + inches	Brown (7.5 YR.5/4) dry, dark brown (7.5 YR.4/4) moist; clay; strong medium subangular blocky; hard dry, firm moist, sticky and plastic wet; noncalcareous; 25% cobbles and gravel; slow permeability; few fine roots.

Aspect :	West
Light Conditions:	Unshaded
Elevation :	6200 feet
Slope :	44 percent
Location :	R. 3 E. T. 13 N. Section 13, S. W. ¼ of N. W. ¼. Three-fourths mile to the south of Forestry Summer Camp. Lower one-third of slope.
Parent Material :	Wasatch conglomerate

Horizon	Depth	Description
A_1	0-10 inches	Organic matter 3% (estimated); grayish brown (10 YR.5/2) dry, very dark brown (10 YR.2/2) moist; heavy silt loam; medium fine and medium granular; slightly hard dry, friable moist, slightly sticky and slightly plastic; noncalcareous; clear and smooth boundary, cobbles and gravel 15%; moderate permeability; abundant fine and medium roots.
B_1	10-31 inches	Brown (7.5 YR.5/3) dry, dark brown (7.5 YR.3/2) moist; silt loam; medium subangular blocky; hard dry, firm moist, slightly sticky and plastic wet; noncalcareous; clear and smooth boundary, cobbles and gravel 20%; moderate permeability; common fine and medium roots.
B_2	31+ (58) inches	Yellowish brown (5 YR.5/4) dry, reddish brown (5 YR.4/4) moist; clay; strong medium subangular blocky; extremely hard dry, extremely firm moist,

sticky and plastic wet; noncalcareous; cobbles and gravel 30%; very slow permeability; very few fine roots.

Aspect : West

Light Conditions: Shaded by low (stunted) aspen and tall chokecherry shrubs

Elevation : 6200 feet

Slope : 38 percent

Location : R. 3 E. T. 13 N. Section 13, S. E. ¼ of N. W. ¼. Three-fourths mile to the south of Forestry Summer Camp. Lower one-third of slope.

Parent Material : Wasatch conglomerate

Horizon	Depth	Description
A_1	0-18 inches	Organic matter 6%; grayish brown (10 YR.5/2) dry, dark grayish brown (10 YR.3/2) moist; silt loam; weak fine granular; soft dry, friable moist; nonsticky and nonplastic wet; noncalcareous; clear and smooth boundary; gravel 15%; moderate permeability; plentiful fine and medium roots, common medium ones.
A_2	18-32 inches	Brown (10 YR.5/3) dry, dark brown (7.5 YR.4/4) moist; silty clay loam; moderate subangular blocky; slightly hard dry, firm moist, sticky and slightly plastic wet; noncalcareous; clear and smooth boundary; cobbles and gravel 15%; moderate permeability; common fine and medium roots.
B_2	32+ (58) inches	Yellowish brown (7.5 YR.5/4) dry, dark brown (7.5 YR.4/4) moist; clay; strong medium subangular blocky; hard dry, very firm moist, very sticky

and plastic wet; noncalcareous; cobbles and gravel 30%; slow permeability; few fine roots.

Aspect : North

Light Conditions: Unshaded

Elevation : 6400 feet

Slope : 46 percent

Location : R. 3 E. T. 13 N. Section 11, S. W. ¼ of N. W. ¼. 1.2 miles to the west of U. S. Highway 89 in the watershed of North Fork: a feeder of Tony Grove Canyon. Lower one-third of slope.

Parent Material : Glacial wash possibly with some erosional deposition from upper slope.

Horizon	Depth	Description
A_1	0-15 inches	Organic matter 6% (estimated); very dark grayish brown (10 YR.3/2) dry, very dark brown (10 YR.2/2) moist; silt loam, slightly hard dry, friable moist, slightly sticky and slightly plastic wet; noncalcareous; clear and smooth boundary; gravel 5%; permeability moderately rapid; abundant fine and medium roots, a few large ones.
A_2	15-27 inches	Grayish brown (10 YR.5/3) dry, dark brown (7.5 YR.4/3) moist; silt loam; moderate medium subangular blocky; slightly hard dry, friable moist; slightly sticky and slightly plastic wet; noncalcareous; gradual and wavy boundary; 10% gravel; moderately rapid permeability; common fine and medium roots.

B_2	27+ (60) inches	Yellowish brown (7.5 YR.5/4) dry, reddish brown (7.5 YR.4/4) moist; silty clay loam; moderate medium subangular blocky; hard dry, firm moist, sticky and slightly plastic wet; noncalcareous; 10 to 15% gravel, slow permeability; few fine roots.

Aspect : North

Light Conditions: Shaded by mature and tall (over 25 feet) aspen and Douglas-fir trees; a few service berry (Amelanchier alnifolia) shrubs

Elevation : 6400 feet

Slope : 50 percent

Location : R. 3 E. T. 13 N. Section 11, S. W. ¼ of N. W. ¼. 1.2 miles to the west of U. S. Highway 89, in the watershed of North Fork; a feeder of Tony Grove Canyon. Lower one-third of slope.

Parent Material : Glacial wash with overwash from slope

Horizon	Depth	Description
0_1	1-0 inches	Matted leaves, twigs and coniferous needles.
A_1	0-12 inches	Organic matter 5% (estimated); dark grayish brown (10 YR.4/2) dry, very dark brown (10 YR.2/2) moist; silt loam; weak fine granular; soft dry, very friable moist, nonsticky and nonplastic; noncalcareous; clear and wavy boundary; gravel 5%; moderately rapid permeability; plentiful fine, medium and large roots.
A_2	12+ (60) inches	Light brown (10 YR.6/4) dry, dark brown (7.5 YR.4/4) moist; silt loam; weak, fine and moderate subangular blocky; slightly hard dry, friable moist, slightly sticky and slightly plastic wet; noncalcareous; gravel 5% above 35 inches, below 35 inches

large rounded quartzite stones (13-18 inches long) and gravel 60%; moderately rapid permeability; common fine and medium roots.

Aspect : North

Light Conditions: Unshaded. Tall forbs, however, provide side shade to grasses.

Elevation : 6600 feet

Slope : 34 percent

Location : R. 3 E. T. 13 N. Section 10, S. W. ¼ of N. E. ¼. 1.3 miles to the west of Tony Grove guard station, to the south of old Tony Grove Lake road. Lower one-third of slope.

Parent Material : Glacial wash possibly with some wash from upper slope. Below 35 inch quartzite stones (unweathered) 12 inches to 18 inches long.

Horizon	Depth	Description
A_1	0-15 inches	Organic matter 4% (estimated); dark brown (10 YR.4/3) dry, very dark brown (10 YR.2/2) moist; loam; weak fine granular; soft dry, very friable moist, slightly sticky and nonplastic wet; noncalcareous; clear and wavy boundary; 13% gravel; moderately rapid permeability; plentiful fine and medium roots. Intense rodent activity.
A_2	15-51 inches	Pale brown (10 YR.6/3) dry, dark brown (7.5 YR.4/4) moist; heavy silt loam; moderate medium subangular blocky; slightly hard dry, friable moist, slightly sticky and slightly plastic wet; noncalcareous; clear and wavy boundary; top 5 inches 14% gravel, below 35 inch stones and cobbles

		60%, small pockets of clay dark brown dry (7.5 YR.4/4) less than 5%; moderately rapid permeability; few fine and medium roots in top 5 inches.
C_1	51 + inches	Light brown (7.5 YR.6/3) dry, yellowish brown (10 YR.5/4) moist; loamy sand; single grain; loose dry, loose moist; nonsticky and nonplastic; noncalcareous; large quartzite stones and gravel 60%; rapid permeability; no roots.

Aspect : North

Light Conditions: Shaded by an open crop of mature to overmature aspen, over 45 feet tall. A mixed crop of aspen and Douglas fir surround the plot.

Elevation : 6600 feet

Slope : 33 percent

Location : R. 13 E. T. 13 N. Section 10, S. W. ¼ of N. E. ¼. 1.3 mile to the west of Tony Grove guard station, one-eighth mile to the south of old Tony Grove Lake road. Upper middle of slope.

Parent Material : Glacial wash possibly with some wash from upper slope, large quartzite stones (18 inches long) unweathered and weathered sandstone in surface foot depth.

Horizon	Depth	Description
A_1	0-12 inches	Organic matter 6% (estimated); very dark grayish brown (10 YR.3/2) dry, very dark brown (10 YR.2/2) moist; silt loam; weak fine granular; soft dry, very friable moist, slightly sticky and nonplastic wet; noncalcareous; clear and wavy boundary; quartzite stones about 18 inches long edges rounded, cobbles and gravel 20%; moderately rapid permeability; common fine and medium, few large roots.
A_2	12+ (58) inches	Pale brown (10 YR.6/3) dry, dark brown (10 YR.4/3) moist; very fine sandy loam; moderate medium subangular blocky; slightly hard dry, friable moist,

nonsticky and nonplastic wet; noncalcareous; cobbles and pebbles 35%; moderately rapid permeability; few fine and medium roots.

Aspect : North

Light Conditions: Unshaded

Elevation : 6350 feet

Slope : 30 percent

Location : R. 3 E. T. 13 N. Section 10, N. W. ¼ of N. E. ¼. Seven-eighths mile to the west of U. S. Highway 89, to the south of old Tony Grove Lake road. Half way down the slope.

Parent Material : Wasatch conglomerate possibly with some erosional deposition at top.

Horizon	Depth	Description
A_1	0-22 inches	Organic matter 3% (estimated), dark grayish brown (10 YR.4/2) dry, very dark brown (10 YR.2/2) moist; silt loam; weak fine granular; soft dry, very friable moist, slightly sticky and nonplastic wet; noncalcareous; clear and wavy boundary; 60% stones, cobbles and gravel; moderately rapid permeability; plentiful fine and medium roots.
B_2	22 + inches	Reddish brown (10 YR.4/4) dry, dark brown (10 YR.3/3) moist; heavy sandy loam; moderate medium subangular blocky hard dry, friable moist, slightly sticky and slightly plastic wet; noncalcareous; 75% cobbles and gravel, moderate permeability; common fine and medium roots.

Aspect : North

Light Conditions: Shaded by aspen over 20 feet high and 3 Douglas fir saplings less than 12 feet tall.

Elevation : 6350 feet

Slope : 30 percent

Location : R. 3 E. T. 13 N. Section 10, N. W. ¼ of N. E. ¼. Seven-eighths mile to the west of U. S. Highway 89, to the south of old Tony Grove Lake, middle of the slope.

Parent Material : Wasatch conglomerate possibly with some erosional deposition on top.

Horizon	Depth	Description
A_1	0-16 inches	Organic matter 5% (estimated); dark grayish brown (10 YR.4/2) dry, very dark brown (10 YR.2/2) moist; silt loam; moderate medium granular; slightly hard dry, friable moist, slightly sticky and slightly plastic wet; noncalcareous; clear and wavy boundary; 4% gravel; moderately rapid permeability; common fine and medium, few large roots.
A_2	16-36 inches	Grayish brown (10 YR.5/3) dry, dark brown (7.5 YR.4/4) moist; heavy silt loam; moderate medium subangular blocky; slightly hard dry, friable moist, slightly sticky and slightly plastic wet; noncalcareous; clear and wavy boundary; 5% gravel; moderately rapid permeability; common fine and medium, few large roots.

B_2	36 + inches	Yellowish brown (7.5 YR.5/4) dry, dark brown (7.5 YR.4/4) moist; heavy clay loam; moderate medium subangular blocky; hard dry, firm moist, sticky and plastic wet; noncalcareous; 20% fine gravel; slow permeability; few fine roots.

Aspect : South

Light Conditions: Unshaded

Elevation : 6400 feet

Slope : 44 percent

Location : R. 3 E. T. 13 N. Section 11, N. W. ¼ of N. W. ¼. The southern slope facing the camp ground, 0.3 mile to the west of Tony Grove guard station. Middle of the slope.

Parent Material : Wasatch conglomerate

Horizon	Depth	Description
A_1	0-11 inches	Dark grayish brown (10 YR.4/2) dry, very cobbly very fine sandy loam (60 percent angular cobble and gravel), very dark grayish brown (10 YR.3/2) moist; weak medium granular structure; slightly hard, very friable, nonsticky nonplastic, plentiful fine roots; noncalcareous, mildly alkaline; well drained, moderate to moderately rapid permeability; clear wavy boundary.
B_2	11-29 inches	Brown (10 YR.5/3) dry, very cobbly, very fine sandy loam (65 percent angular cobble and gravel), brown (10 YR.4/3) moist; very weak fine subangular blocky structure; slightly hard, friable, slightly sticky and slightly plastic; few fine roots; noncalcareous; mildly alkaline; moderately rapid permeability, clear irregular boundary.

C_1	29-38 inches	Brown (10 YR.5/3) dry, very cobbly loam (70 percent angular cobble and gravel), brown (10 YR.4/3) moist; massive; slightly hard, friable slightly sticky and slightly plastic; few fine roots, moderately rapid permeability.
C_2	38-60+ inches	Cobbly loam; brown (10 YR.5/3) dry, brown (10 YR.4/3) moist; 80 percent angular cobble and gravel; slightly hard; friable; nonsticky nonplastic; few fine roots; moderately rapid permeability.

Aspect	:	South
Light Conditions	:	Shaded by compact overlapping crowns of chokecherry and serviceberry.
Elevation	:	6500 feet
Slope	:	20 percent
Location	:	R. 3 E. T. 13 N. Section 11, N. W. ¼ of N. W. ¼. The southern slope facing the camp ground, 0.3 mile to the west of Tony Grove guard station. Slightly below the upper one-third of the slope.
Parent Material	:	Wasatch conglomerate with substantial deposition of erosional material from upper slope. The eroded material filled the concavity of the slope to form a gently sloping terrace, 12% slope. The aspect, otherwise, has a general slope of 44%.

Horizon	Depth	Description
A_1	0-16 inches	Gravelly loam, brown to dark brown (7.5 YR.4/3) dry, very dark brown (7.5 YR.2/2) moist; weak fine granular structure, soft, very friable, non-sticky and slightly plastic; abundant fine, medium and large roots; 20 percent gravel and cobble; slightly acid, well drained, moderate permeability; gradual wavy boundary.
B_2	16-32 inches	Gravelly light clay loam; brown (7.5 YR.5/4) dry, dark brown (7.5 YR.3/2) moist; weak coarse sub-angular blocky structure breaking to weak fine subangular blocky; slightly hard, firm, slightly

sticky and plastic; plentiful fine and medium roots; many fine random, interstitial pores; common thin clay films; 30 percent gravel and cobble; neutral; moderate permeability; gradual wavy boundary.

C	32-60+ inches	Gravelly heavy loam, reddish yellow (5 YR.6/6) dry, yellowish red (5 YR.4/6) moist; slightly hard; firm, nonsticky and slightly plastic, few fine and medium roots; many fine pores; 40 percent gravel and cobble; moderately permeable.

Aspect : South

Light Conditions: Unshaded. However grasses and forbs received side shade from tall horsemint (<u>Agastache</u> <u>urticifolia</u>) shrubs

Elevation : 6500 feet

Slope : 30 percent

Location : R. 3 E. T. 13 N. Section 11, S. E. ¼ of S. W. ¼. 1.4 miles to the west of Tony Grove guard station on new Tony Grove Lake road. Lower half of the slope.

Parent Material : Wasatch conglomerate

Horizon	Depth	Description
A_1	0-20 inches	Organic matter 3 percent; dark gray (10 YR.4/1) dry, very dark gray (10 YR.3/1) moist; loam; weak to moderate medium angular blocky; no rodent activity but material porous probably due to root channels; soft dry, very friable moist, slightly sticky but nonplastic wet; noncalcareous; clear smooth boundary; gravel 10 percent; moderate permeability; abundant fine and medium roots.
A & B	20-24 inches	Yellowish brown (7.5 YR.5/4) dry, dark brown (7.5 YR.3/2) moist; moderate medium subangular blocky, hard dry, firm moist, slightly sticky and plastic wet; noncalcareous; diffused boundary; gravel 15 percent; indication of lateral flow of water and mottling, slow permeability; common fine roots.

B_2 24-55+ inches Yellowish brown (5 YR.5/4) dry, reddish brown (5 YR.4/4) moist; heavy clay loam; strong medium to fine angular and subangular blocky; very hard dry, very firm moist, very sticky and very plastic wet; calcite; gravel and quartzite boulders increase rapidly from 20% at 39 inch to 60% at 55 inch depth; extremely slow permeability; very few fine roots above 39 inch rare below.

Aspect :	South
Light Conditions:	Shaded by middle-aged aspen crop and chokecherry shrubs
Elevation :	6500 feet
Slope :	30 percent
Location :	R. 3 E. T. 13 N. Section 11, S. E. ¼ of S. W. ¼. 1.4 miles to the west of Tony Grove guard station on new Tony Grove Lake road. Lower half of the slope.
Parent Material :	Wasatch conglomerate

Horizon	Depth	Description
A_1	0-22 inches	Organic matter 4.5% (estimated); dark grayish brown (10 YR.4/2) dry, very dark brown (10 YR.2/2) moist; silty loam; weak fine angular to moderate medium angular blocky; soft to slightly hard dry, very firm moist, nonsticky and nonplastic wet; noncalcareous; clear smooth boundary; gravel 10%; moderate permeability; abundant fine, medium and large roots.
A & B	22-26 inches	Brown (7.5 YR.5/2) dry, dark brown (7.5 YR.3/2) moist; clay loam; medium subangular blocky; hard dry, firm moist, sticky and very plastic wet; clear wavy boundary; cobbles and gravel 15%; dark red mottling, slow permeability; common fine roots and a few medium roots.

B_2	26-55 inches	Dark brown (7.5 YR.3/2) dry, reddish brown (5 YR. 4/4) moist; gravelly heavy clay loam; strong medium prismatic; moderate continuous clay films; very hard dry, very firm moist, very sticky and plastic wet; calcite; gravel and quartzite cobbles vary from 30% at top to 50% at bottom; very slow permeability.

Aspect : South

Light Conditions: Unshaded

Elevation : 6400 feet

Slope : 44 percent

Location : R. 3 E. T. 13 N. Section 12, S. W. ¼ of S. E. ¼. Southern exposure of bench mark hill, to the north of Little Bear Creek, three-fourths mile to the east of the U. S. Highway 89. Middle of the slope.

Parent Material : Wasatch conglomerate with some overwash from slope

Horizon	Depth	Description
A_1	0-16 inches	Organic matter 4% (estimated); dark gray brown (10 YR.4/2) dry, very dark brown (10 YR.2/2) moist; loam; fine to coarse strong granular; slightly hard dry, friable moist, slightly sticky and nonplastic wet; noncalcareous; clear wavy boundary; gravel 10%, moderate permeability; abundant fine and medium roots.
A & B	16-37 inches	Light reddish brown (5 YR.6/4) dry, reddish brown (5 YR.4/4) moist; clay loam; medium moderate angular blocky; hard dry, firm moist; sticky and slightly to very plastic (below 24 inches) wet, noncalcareous; clear wavy boundary; cobbles and gravel 65%, slow permeability, common fine roots above 30 inches but very few below.
B_2	37-60+ inches	Dark brown (5 YR.3/3) dry, reddish brown (5 YR.5/4) moist; sandy clay; moderate to coarse subangular

blocky; very hard dry, very firm moist, very plastic wet; noncalcareous; cobbles and gravel 60%, slow permeability; very few fine roots.

Aspect	:	South
Light Conditions	:	Shaded by service berry, wild rose (Rosa woodsii) and chokecherry shrubs
Elevation	:	6400 feet
Slope	:	40 percent
Location	:	R. 3 E. T. 13 N. Section 12, S. W. ¼ of S. E. ¼. Southern exposure of the bench mark hill, to the north of the Little Bear Creek. Seven-eighths mile to the east of U. S. Highway 89. Middle of the slope. The plot received wash from above.
Parent Material	:	Wasatch conglomerate with some overwash from slope

Horizon	Depth	Description
A_1	0-22 inches	Organic matter 4.5% (estimated); dark gray (10 YR. 4/1) dry, very dark brown (10 YR.2/2) moist; silt loam increasing in clay with depth; moderate fine and medium granular, slightly hard dry, firm moist, slightly sticky and slightly plastic wet; noncalcareous; clear wavy boundary; gravel 15%; moderate permeability; plentiful fine and medium roots, a few large ones.
A_2	22-30 inches	Grayish brown (10 YR.5/2) dry, dark brown (7.5 YR. 3/3) moist; clay loam; moderate medium prismatic, noncalcareous with gravel and rock increasing with depth to 40%; hard dry, firm moist, sticky and very plastic wet; clear wavy boundary; slow permeability; few fine and medium roots.

B_2	30-55+ inches	Reddish brown (5 YR.5/4) dry, dark brown (5 YR. 4/4) moist; clay loam; moderate medium subangular blocky, hard dry, firm moist, sticky and plastic wet; noncalcareous; gravel and rock increase with depth from 40% to 50%, slow permeability; a few fine roots.

Appendix II

Vebetation of southern unshaded subplots

Shrubs, forbs and grasses constituted about 45, 32 and 23 percent, respectively, of the vegetation cover on these subplots.

Giant wild rye and shrubs side-shaded each other in the beginning of the season. Both giant wild rye and the shrubs provided side shade to low herbaceous plants. As the season advanced the giant wild rye outgrew the shrub associates and other herbaceous plants. The shrubs and other plants then received the benefit of side shade and possibly of hedge effect of giant wild rye. The tops of this tall grass, on the other hand, were exposed on all sides to the sun and wind activity.

Plants on these subplots were earlier than those on other aspects and in shade, in phenological development.

The composition of the vegetal cover is detailed below under three growth forms.

A. Shrubs	Absolute cover	Relative cover within growth form
1. *Symphoricarpos vaccinioides* Rydb.	22.1	67 percent
2. *Artemisia tridentata* Nutt.	7.6	23
3. *Purshia tridentata* (Pursh) DC.	2.0	6
4. *Prunus virginiana* L.	0.7	2
5. *Eriogonum heracleoides* Nutt.	0.3	1
6. *Chrysothamnus viscidiflorus* (Hook.) Nutt.	0.3	1
Total shrubs	33.0	100

B. Forbs	Absolute cover	Relative cover within growth form
1. *Solidago lepida* DC.	4.2	18 percent
2. *Viguiera multiflora* (Nutt.) Blake	3.4	14
3. *Agastache urticifolia* (Benth.) Kuntze	1.9	8
4. *Erigeron peregrinus* (Pursh) Greene	1.9	8
5. *Madia glomerata* Hook.	1.7	7
6. *Aster chilensis* Nees.	1.4	6
7. *Sidalcea oregana* (Nutt.) A. Gray	1.4	6
8. *Linum Lewisii* Pursh	1.1	5
9. *Potentilla gracilis* Doug.	1.1	5
10. *Cirsium eatoni* (A. Gray) Rob.	0.9	4
11. *Lupinus caudatus* Kell.	0.9	4
12. *Achillea lanulosa* Nutt.	0.7	3
13. *Crepis acuminata* Nutt.	0.4	2
14. *Eriogonum umbellatum* Toll.	0.4	2
15. *Calochortus nuttallii* Torr.	0.2	1
16. *Polygonum douglasii* Greene	0.2	1
17. *Hieracium scouleri* Hook.	0.2	1
18. *Lactuca serriola* L.	0.2	1
19. *Tragopogon dubius* Scop.	0.2	1
20. *Collomia linearis* Nutt. 21. *Collomia grandiflora* Doug.	0.2	1
22. *Balsamorhiza sagittata* (Pursh) Nutt.	0.2	1
23. *Epilobium paniculatum* Nutt.	0.2	1
Total forbs	23.0	100

C. Grasses	Absolute cover	Relative cover within growth form
1. *Elymus cinereus* Scribn. & Merr.	12.1	72 percent
2. *Poa pratensis* L.	3.0	17
3. *Agropyron inerme* (Scribn. & Smith) Rydb.	0.9	5
4. *Agropyron spicatum* (Pursh) Scribn. & Smith	0.7	4
5. *Stipa lettermani* Vasey		
6. *Stipa columbiana* Macoun	0.3	2
Total, grasses	17.0	100
Total absolute cover	73.0	

Vegetation of southern shaded subplots

Overhead shade in one subplot was provided primarily by chokecherry with some serviceberry. The second plot was covered by aspen and serviceberry. In the third plot chokecherry was the only shrub cover. Cover in all plots was surprisingly dense, particularly in the first subplot, where shade was continuous and without interruptions. The average cover value was estimated at 85 percent.

The cover contributed by shrubs, forbs and grasses was estimated at 20, 20 and 60 percent respectively. Details of the species components are as follows:

A. Shrubs	Absolute cover	Relative cover within growth form
1. Prunus virginiana L.	12.6	70 percent
2. Rosa woodsii Lindl.	2.4	13
3. Symphoricarpos vaccinioides Rydb.	1.4	8
4. Amelanchier alnifolia Nutt.	1.4	8
5. Artemisia tridentata Nutt.	0.2	1
Total, shrubs	18.0	100
B. Forbs		
1. Lathyrus leucanthus Rydb. 2. Lathyrus pausiflorus Fern.	4.1	23
3. Lupinus caudatus Kell.	3.1	17
4. Sidalcea oregana (Nutt.) A. Gray	1.9	10
5. Achillea lanulosa Nutt.	1.4	8
6. Thalictrum fendleri Engelm.	1.4	8
7. Agastache urticifolia (Benth.) Kuntze	1.2	7
8. Geranium fremontii Torr.	1.1	6

		Absolute cover	Relative cover within growth form
9.	*Potentilla glandulosa* Lindl.	0.7	4 percent
10.	*Viguiera multiflora* (Nutt.) Blake	0.7	4
11.	*Penstemon cyananthus* Hook.	0.7	4
12.	*Tragopogon dubius* Scop.	0.5	3
13.	*Erigeron peregrinus* (Pursh) Greene	0.4	2
14.	*Ereogonum umbellatum* Toll.	0.4	2
15.	*Lactuca serriola* L.	0.2	1
16.	*Polygonum douglasii* Greene	0.2	1
	Total, forbs	18.0	100
C.	Grasses		
1.	*Poa pratensis* L.	35.1	65
2.	*Agropyron subsecundum* (Link) Hitchc.	6.5	12
3.	*Bromus marginatus* Nees	5.9	11
4.	*Agropyron spicatum* (Pursh) Scribn. & Merr.	3.8	7
5.	*Elymus cinereus* Scribn. & Merr.	2.2	4
6.	*Melica bulbosa* Geyer	0.5	1
	Total, grasses	54.0	100
	Total absolute cover	90.0	

Vegetation of western unshaded subplots

These subplots had maximum shrub cover and almost a pure understory of Kentucky bluegrass. According to the vegetation analysis, shrubs, forbs and grasses made up 60, 15 and 25 percent respectively of the vegetation cover. The herbaceous species, especially the Kentucky bluegrass, were sideshaded and partially covered overhead by low spreading snowberry and rabbitbrush. During clippings, the branches of shrubs almost invariably had to be pushed aside to reach to grasses and forbs for sampling. The overhead shade on herbaceous plants was estimated at 40 percent.

The components of the three growth forms and their absolute cover and relative cover within the growth form are listed below:

A. Shrubs	Absolute cover	Relative cover within growth form
1. *Symphoricarpos vaccinioides* Rydb.	31.5	70 percent
2. *Artemisia tridentata* Nutt.	4.0	9
3. *Chrysothamnus viscidiflorus* (Hook.) Nutt.	3.6	8
4. *Prunus virginiana* L.	1.8	4
5. *Rosa woodsii* Lindl.	1.3	3
6. *Eriogonum heracleoides* Nutt.	0.9	2
7. *Purshia tridentata* (Pursh) DC.	0.9	2
8. *Amelanchier alnifolia* Nutt.	0.5	1
9. *Mahonia repens* (Lindl.) G. Don.	0.5	1
Total, shrubs	45.0	100

B. Forbs	Absolute cover	Relative cover within growth form
1. Geranium fremontii Torr.	2.0	18 percent
2. Lupinus caudatus Kell.	1.4	13
3. Balsamorhiza sagittata (Pursh) Nutt.	1.3	12
4. Crepis occidentalis Nutt.	1.1	10
5. Achillea lanulosa Nutt.	0.8	7
6. Solidago lepida DC.	0.7	6
7. Lathyrus pauciflorus Fern.	0.6	5
8. Aster chilensis Nees	0.6	5
9. Sidalcea oregana (Nutt.) A. Gray	0.6	5
10. Viguiera multiflora (Nutt.) Blake	0.4	4
11. Epilobium paniculatum Nutt.	0.4	4
12. Thalictrum fendleri Engelm.	0.4	4
13. Wyethia amplexicaulis Nutt.	0.3	3
14. Gilia aggregata (Pursh) Spreng.	0.2	2
15. Senecio serra Hook.	0.2	2
Total, forbs	11.0	100
C. Grasses		
1. Poa pratensis L.	17.0	90
2. Festuca Idahoensis Elmer	0.6	3
3. Melica bulbosa Geyer	0.4	2
4. Koeleria cristata (L.) Pers.	0.4	2
5. Stipa columbiana Macoun	0.2	1
6. Elymus cinereus Scribn. & Merr.	0.2	1
7. Bromus tectorum L. 8. Agropyron subsecundum (Link) Hitchc.	0.2	1

	Absolute cover	Relative cover within growth form
Total, grasses	19.0	100
Total, absolute cover	75.0	

Vegetation of western shaded subplots

The overhead cover was provided by aspen which appeared rather stunted. The average height of the aspen canopy was 12 feet. The shade was, however, accentuated by the presence of tall chokecherry and serviceberry. The shrubs, forbs and grasses composed 35, 30 and 35 percent of the vegetation. The overhead cover was estimated at 65 percent. Details of the undergrowth are given below:

A. Shrubs	Absolute cover	Relative cover within growth form
1. *Prunus virginiana* L.	17.0	59 percent
2. *Amelanchier alnifolia* Nutt.	9.0	31
3. *Symphoricarpos vaccinioides* Rydb.	2.5	8
4. *Rosa woodsii* Lindl.	0.5	2
Total, shrubs	45.0	100
B. Forbs		
1. *Thalictrum fendleri* Engelm.	8.5	35
2. *Smilacina stellata* (L.) Desf.	3.5	15
3. *Lathyrus pauciflorus* Fern.	2.0	8
4. *Geranium fremontii* Torr.	2.0	8
5. *Potentilla gracilis* Doug.	1.4	6
6. *Agastache urticifolia* (Benth.) Kuntze	1.1	5
7. *Achillea lanulosa* Nutt.	1.1	5
8. *Sidalcea oregana* (Nutt.) A. Gray	1.0	4
9. *Osmorhiza chilensis* T.& A.	0.7	3
10. *Balsamorhiza sagittata* (Pursh) Nutt.	0.7	3
11. *Lupinus caudatus* Kell.	0.5	2

	Absolute cover	Relative cover within growth form
12. *Madia glomerata* Hook.	0.5	2 percent
13. *Viola adunca* J. E. Smith	0.5	2
14. *Stellaria jamesiana* Torr.	0.5	2
Total, forbs	24.0	100
C. Grasses		
1. *Poa pratensis* L.	20.2	70
2. *Bromus marginatus* Nees	5.0	17
3. *Agropyron subsecundum* (Link) Hitchc.	1.7	6
4. *Carex* species	1.2	4
5. *Elymus cinereus* Scribn. & Merr.	0.6	2
6. *Poa idahoensis* Elmer	0.3	1
Total, grasses	29.0	100
Total, absolute cover	82.0	

Vegetation of northern unshaded subplots

These subplots supported the densest vegetation studied. The number of species involved was of the greatest diversity analyzed. The vegetation appeared comparatively vigorous as suggested by leaf size and plant height. The tallest forbs, tall larkspur and senecio (Senecio integerrimus), were observed on these subplots. The plant cover of these subplots consisted of shrubs, forbs and grasses at 30, 28 and 42 percent respectively. The species making different growth forms are enumerated below:

A. Shrubs	Absolute cover	Relative cover within growth form
1. Symphoricarpos vaccinioides Rydb.	18.0	60 percent
2. Amelanchier alnifolia Nutt.	3.6	12
3. Prunus virginiana L.	3.6	12
4. Chrysothamnus nauseosum (Pall.) Britt.	1.8	6
5. Populus tremuloides Michx.	1.2	4
6. Rosa woodsii Lindl.	0.9	3
7. Eriogonum heracleoides Nutt.	0.9	3
Total, shrubs	30.0	100
B. Forbs		
1. Delphinium occidentale S. Wats.	9.2	33
2. Senecio integerrimus Nutt.	4.1	15
3. Lathyrus leucanthus Rydb.	2.2	8
4. Lupinus caudatus Kell.	1.4	5
5. Thalictrum fendleri Engelm.	1.4	5
6. Geranium fremontii Torr.	1.1	4
7. Sidalcea oregana (Nutt.) A. Gray	0.8	3

		Absolute cover	Relative cover within growth form
8.	Potentilla glandulosa Lindl.	0.8	3 percent
9.	Achillea lanulosa Nutt.	0.8	3
10.	Agastache urticifolia (Benth.) Kuntze	0.8	3
11.	Castilleja chromosa A. Nels.	0.6	2
12.	Vicia americana Muhl.	0.6	2
13.	Polemonium albiflorum Eastw.	0.6	2
14.	Rudbeckia occidentalis Nutt.	0.6	2
15.	Heracleum lanatum Michx.	0.3	1
16.	Helianthella uniflora (Nutt.) T. & G.	0.3	1
17.	Arnica species	0.3	1
18.	Commandra umbella (L.) Nutt.	0.3	1
19.	Phacelia linearis (Pursh) Holz.	0.3	1
20.	Allium acuminatum Hook.	0.3	1
21.	Polygonum douglasii Greene	0.3	1
22.	Galium boreale L.	0.3	1
23.	Apocynum androsaemifolium L.	0.3	1
24.	Penstemon cyananthus Hook.	0.3	1
	Total, forbs	28.0	100
C.	Grasses		
1.	Bromus marginatus Nees	22.3	53
2.	Poa pratensis L.	9.2	22
3.	Agropyron subsecundum (Link.) Hitchc.	5.5	13
4.	Arrhenatherum elatius (L.) Mest & Koch	1.7	4
5.	Poa fendleriana (Steud) Vasey	1.3	3

		Absolute cover	Relative cover within growth form
6.	Melica spectabilis Scribn.	0.8	2 percent
7.	Dactylis glomerata L.	0.8	2
8.	Koeleria cristata (L.) Pers.	0.4	1
	Total Grasses	42.0	100
	Total absolute cover	100.0	

Vegetation of northern shaded subplots

These subplots supported an overstory of tall (45 feet) aspen with an occasional large-size Douglas fir. The portions of subplots under Douglas fir received dense shade but the portions under aspen received sunlight to the extent of 30 percent. The average cover was estimated at 80 percent. Shrub growth was rather poor except for serviceberry. Grasses included abundant mountain brome.

The vegetation cover comprised shrubs 22 percent, forbs 30 percent and grasses 48 percent.

Phenologically this aspect was the latest to develop.

The various species represented on these subplots are listed below.

A. Shrubs	Absolute cover	Relative cover within growth form
1. *Amelanchier alnifolia* Nutt.	15.3	90 percent
2. *Symphoricarpos vacciniodes* Rydb.	1.0	6
3. *Rosa woodsii* Lindl.	0.7	4
Total, shrubs	17.0	100
B. Forbs		
1. *Lathyrus leucanthus* Rydb. 2. *Lathyrus pausiflorus* Fern.	6.4	28
3. *Thalictrum fendleri* Engelm.	5.0	21
4. *Valeriana occidentalis* Heller	1.1	5
5. *Potentilla glandulosa* Lindl.	1.1	5
6. *Rudbeckia occidentalis* Nutt.	1.1	5
7. *Viola adunca* J. E. Smith	1.1	5
8. *Agastache urticifolia* (Benth.) Kuntze	0.7	3

		Absolute cover	Relative cover within growth form
9.	*Vicia americana* Muhl.	0.7	3 percent
10.	*Achillea lanulosa* Nutt.	0.7	3
11.	*Trifolium repens* L.	0.7	3
12.	*Galium boreale* L.	0.7	3
13.	*Osmorhiza chilensis* T. & A.	0.7	3
14.	*Balsamorhiza macrophylla* Nutt.	0.7	3
15.	*Aster engelmannii* (D. C. Bat) A. Gray	0.7	3
16.	*Heracleum lanatum* Michx.	0.5	2
17.	*Cynoglossum officinale* L.	0.5	2
18.	*Clematis columbiana* (Nutt.) T. & G.	0.2	1
19.	*Allium acuminatum* Hook.	0.2	1
20.	*Melilotus officinalis* (L.) Lam.	0.2	1
	Total, forbs	23.0	100
C.	Grasses		
1.	*Bromus marginatus* Nees	23.4	63
2.	*Poa pratensis* L.	7.4	20
3.	*Agropyron trachycaulum* (Link) Malte	1.8	5
4.	*Agropyron subsecundum* (Link) Hitchc.	1.8	5
5.	*Phleum pratense* L.	0.7	2
6.	*Arrhenatherum elatius* (L.) Mert & Koch	0.7	2
7.	*Melica spectabilis* Scribn.	0.4	1
8.	*Dactylis glomerata* L.	0.4	1
9.	*Carex* species	0.4	1
	Total, grasses	37.0	100
	Total absolute cover	77.0	

Vegetation of eastern unshaded subplots

Sagebrush (10%) and snowberry (12%) were almost evenly divided on these subplots. Wheatgrasses were the most representative grasses. Kentucky bluegrass was restricted to spots receiving partial shade from shrubs. Wild peas were the commonest forb. Detailed vegetation analysis showed that shrubs, forbs and grasses contributed 40, 25, and 35 percent respectively. The components of each growth form and their individual contribution are shown below.

A. Shrubs	Absolute cover	Relative cover within growth form
1. *Symphoricarpos vacciniodes* Rydb.	11.7	45 percent
2. *Artemisia tridentata* Nutt.	10.3	40
3. *Chrysothamnus viscidiflorus* (Hook.) Nutt.	2.3	9
4. *Rosa woodsii* Lindl.	0.8	3
5. *Eriogonum heracleoides* Nutt.	0.3	1
6. *Purshia tridentata* (Pursh) DC.	0.3	1
7. *Populus tremuloides* Michx.	0.3	1
Total, shrubs	26.0	100
B. Forbs		
1. *Lathyrus pauciflorus* Fern. 2. *Lathyrus leucanthus* Rydb.	2.7	17
3. *Achillea lanulosa* Nutt.	2.0	12
4. *Erigeron peregrinus* (Pursh) Greene	1.6	10
5. *Geranium fremontii* Torr.	1.1	7
6. *Tragopogon dubius* Scop.	1.1	7
7. *Sidalcea oregana* (Nutt.) A. Gray	1.1	7
8. *Lactuca serriola* L.	1.1	7

	Absolute cover	Relative cover within growth form
9. *Vicia americana* Muhl.	0.8	5 percent
10. *Wyethia amplexicaulus* Nutt.	0.8	5
11. *Viguiera multiflora* (Nutt.) Blake	0.7	4
12. *Epilobium paniculatum* Nutt.	0.5	3
13. *Madia glomerata* Hook.	0.5	3
14. *Helianthella uniflora* (Nutt.) T. & G.	0.5	3
15. *Lithophragma parviflora* (Hook.) Nutt.	0.3	2
16. *Thlaspi arvense* L.	0.3	2
17. *Phacelia linearis* (Pursh) Holz.	0.3	2
18. *Polygonum douglasii* Greene	0.3	2
19. *Solidago lepida* DC.	0.3	2
Total, forbs	16.0	100
C. Grasses		
1. *Agropyron subsecundum* (Link) Hitchc.	7.4	32
2. *Elymus cinereus* Scribn. & Merr.	5.0	22
3. *Poa pratensis* L.	4.6	20
4. *Agropyron cristatum* (L.) Beauv.	1.8	8
5. *Bromus marginatus* Nees	1.6	7
6. *Stipa columbiana* Macoun 7. *Stipa lettermani* Vasey	1.2	5
8. *Melica bulbosa* Geyer	0.5	2
9. *Festuca Idahoensis* Elmer	0.5	2
10. *Koeleria cristata* (L.) Pers.	0.2	1
11. *Dactylis glomerata* L.	0.2	1

	Absolute cover	Relative cover within growth form
12. Bromus tectorum L.	___	trace
Total, grasses	23.0	100
Total absolute cover	65.0	

Vegetation of eastern shaded subplots

These plots had overhead shade of almost pure aspen. The cover, however, was not very dense. The average height of the tree crowns was estimated at 20 feet and the cover value at 50 percent. The thin overhead shade permitted considerable sunlight on the ground, particularly during afternoons, when wind usually kept the aspen leaves constantly quivering. The undergrowth included 26 percent shrubs, 40 percent forbs and 34 percent grasses. Since shrub growth is less the side-shade benefit of shrubs to harbaceous plants is reduced accordingly. The herbaceous plants were also suspected to be more exposed to wind activity for want of adequate hedge affect by shrubs. The fact that 47 percent of grasses were tall and mesic, e.g., tall oatgrass and mountain brome, is suggestive of their possible susceptibility to sunlight and wind affects.

The species making up various growth forms were:

A. Shrubs	Absolute cover	Relative cover within growth form
1. Prunus virginiana L.	7.7	35 percent
2. Amelanchier alnifolia Nutt.	4.8	22
3. Rosa woodsii Lindl.	4.8	22
4. Symphoricarpos vaccinioides Rydb.	3.8	17
5. Artemisia tridentata Nutt.	0.9	4
Total, shrubs	22.0	100
B. Forbs		
1. Lathyrus leucanthus Rydb. 2. Lathyrus pausiflorus Fern.	14.2	42
3. Thalictrum fendleri Engelm.	6.1	18

	Absolute cover	Relative cover within growth form
4. *Geranium fremontii* Torr.	3.4	10 percent
5. *Agastache urticifolia* (Benth.) Kuntze	1.7	5
6. *Vicia americana* Muhl.	1.4	4
7. *Lupinus caudatus* Kell.	1.4	4
8. *Polemonium albiflorum* Eastw.	1.0	3
9. *Achillea lanulosa* Nutt.	1.0	3
10. *Epilobium paniculatum* Nutt.	1.0	3
11. *Viguiera multiflora* (Nutt.) Blake	0.7	2
12. *Castilleja chromosa* A. Nels.	0.7	2
13. *Heracleum lanatum* Michx.	0.7	2
14. *Delphinium occidentale* S. Wats.	0.7	2
Total, forbs	34.0	100
C. Grasses		
1. *Bromus marginatus* Nees	10.7	37
2. *Poa pratensis* L.	5.8	20
3. *Arrhenatherum elatius* (L.) Mert & Koch	4.4	15
4. *Agropyron subsecundum* (Link) Hitchc.	2.9	10
5. *Carex* species	2.0	7
6. *Poa fendleriana* (Steud.) Vasey	1.4	5
7. *Agropyron trachycaulum* (Link) Malte	1.2	4
8. *Melica spectabilis* Scribn.	0.6	2
Total, grasses	29.0	100
Total absolute cover	85.0	

Appendix III

III-1: Daily precipitation data for 1965 of Tony Grove Station, June 19, 1965 to September 11, 1965 (in inches)

Month	Date	Time-of-day	Amount	Cumulative amount of precipitation
June 1965	19	Afternoon	0.42	
	20	Evening	0.48	0.90
	26	Before daybreak	0.75	1.65
July 1965	3	Evening	0.85	2.50
	12	Evening	0.55	3.05
	18	Forenoon	0.07	3.12
	20	Evening	0.08	3.20
	21	Evening	0.10	3.30
	30	Whole day	0.70	4.00
	31	Whole day	0.75	4.75
August 1965	1	Forenoon	0.20	4.95
	3	Evening	0.36	5.31
	4	Night (Previous)	0.50	5.81
	10	Evening (Till midnight)	0.48	6.29
	13	Forenoon	0.22	6.51
	16	Whole day	0.34	6.85
	19	Evening	0.12	6.97
	21	Daybreak	0.03	7.00
	25	Forenoon	0.11	7.11
	28	Evening	0.20	7.31
Sept. 1965	3	Afternoon	0.07	7.38
	4	Afternoon	0.20	7.58
	8	Evening	0.12	7.70

III-2: Yearly precipitation data of Tony Grove Station[a]
(in inches)

A. Annual

Year	Amount
1960	25.92
1961	23.45
1962	23.92
1963	24.82
1964	32.23
1965	32.53

B. Average for 25 years (1941-1965)

a. Annual	25.44
b. Three months (Mid-June to Mid-Sept.)	5.64

[a]Data supplied by Mr. A. Richardson, State Climatologist, Utah State.

III-3: Periodic precipitation data of Tony Grove Station in 1964 and 1965 (in inches).[a]

1964		1965	
January 1 to February 2	: 4.38	December 13, 1964 to January 10, 1965	: 8.80
February 2 to March 7	: 1.80	January 10 to January 17	: 1.00
March 7 to March 29	: 2.60	January 17 to January 31	: 6.55
March 29 to May 17	: 3.90	January 31 to March 7	: 2.10
May 17 to June 27	: 4.40	March 7 to April 4	: 1.75
June 27 to July 25	: 0	April 4 to April 23	: 2.65
July 25 to August 30	: 0.30	April 23 to May 24	: Not available
August 30 to September 27	: 0.10	May 24 to July 4	: 2.50
September 27 to November 1	: 0.15	July 4 to July 26	: 0.80
November 1 to December 13	: 6.90	July 26 to September 12	: 4.40
December 13 to January 10, 1965	: 8.80	September 12 to September 26	: 1.30
		September 26 to November 28	: 5.15
Yearly total	32.23	November 28 to January 1, 1966	: 2.90
		Yearly total	32.53

[a]Data supplied by Mr. A. Richardson, State Climatologist, Utah State.

Appendix IV

Table 27. Percent mean moisture for grasses in shaded and unshaded conditions, on four aspects, in forenoon and afternoon during 12 clippings over the season

	Unshaded									Shaded								
	Aspect									Aspect								
	North		South		East		West		Aver-	North		South		East		West		Aver-
Clipping	FN	AN	FN	AN	FN	AN	FN	AN	age	FN	AN	FN	AN	FN	AN	FN	AN	age
June 15	309.7	291.0	159.7	144.0	239.7	214.0	195.3	181.7	216.9	403.3	414.7	198.3	179.0	319.3	274.0	296.7	258.0	296.3
June 21	318.3	280.3	158.3	144.7	226.3	191.0	184.0	170.3	209.2	399.3	381.3	166.7	167.7	306.0	249.7	316.7	291.3	284.8
June 28	274.3	249.0	137.0	158.7	173.7	163.0	168.7	160.7	185.6	362.7	342.0	229.3	182.0	273.3	238.3	286.0	266.7	272.5
July 6	214.0	195.7	139.3	132.7	169.0	161.0	169.3	153.7	166.8	369.0	288.3	201.3	180.3	258.0	199.7	269.3	241.3	250.9
July 12	250.7	219.3	144.7	131.3	127.3	116.7	158.0	137.0	160.6	323.0	301.0	213.7	191.0	245.7	202.7	231.7	201.7	238.8
July 19	222.0	200.7	125.3	131.3	139.7	125.7	155.0	144.3	155.5	304.7	270.3	199.0	177.7	318.0	187.3	212.7	205.0	221.8
July 26	206.0	195.0	135.0	120.7	105.0	100.3	142.0	121.7	140.7	299.0	258.0	194.0	180.0	206.0	172.7	212.7	184.3	213.3
Aug. 2	194.0	184.0	109.0	95.0	109.3	100.7	145.0	132.0	133.6	249.7	233.3	194.7	153.0	186.3	160.3	207.0	173.3	194.7
Aug. 9	175.3	155.7	113.0	89.0	106.0	85.3	115.3	109.7	118.7	260.3	228.3	196.3	176.7	185.0	166.3	186.3	156.7	194.5
Aug. 17	167.0	156.3	121.7	116.0	115.3	107.3	115.7	105.0	125.5	228.3	208.7	180.7	161.3	186.3	164.3	169.3	140.3	179.9
Aug. 23	172.0	163.3	115.7	105.3	91.0	76.7	135.0	123.3	122.8	237.7	218.7	152.7	139.0	164.7	157.3	177.0	169.7	177.1
Sept. 10	161.3	154.7	102.0	101.7	88.0	72.0	117.0	105.3	112.8	200.3	182.7	139.3	137.0	153.7	135.7	157.3	143.7	156.2
Average	222.1	203.8	130.1	122.5	140.9	126.1	150.0	137.1	154.1	305.4	277.3	188.8	168.7	225.2	192.4	226.9	202.7	223.4

Table 28. Percent mean moisture for forbs in shaded and unshaded conditions, four aspects, in forenoon and afternoon during 12 clippings over the season

	Unshaded									Shaded								
	Aspect									Aspect								
	North		South		East		West		Aver-age	North		South		East		West		Aver-age
Clipping	FN	AN	FN	AN	FN	AN	FN	AN		FN	AN	FN	AN	FN	AN	FN	AN	
June 15	510.7	468.7	308.7	295.7	381.3	341.7	353.3	347.7	37[illegible]	629.7	601.3	352.3	340.7	451.0	432.0	411.3	374.7	449.1
June 21	501.7	445.0	286.0	265.7	351.0	326.7	332.7	314.3	35[illegible]	620.0	585.0	337.3	331.0	386.7	361.3	395.0	353.7	421.3
June 28	428.7	387.3	267.7	239.7	344.3	325.7	318.3	290.3	32[illegible]	524.7	480.3	338.3	302.7	386.3	359.0	384.3	338.3	389.3
July 6	358.7	339.0	248.3	219.3	335.3	308.3	305.7	280.3	29[illegible]	450.3	423.0	339.3	286.3	366.0	347.0	377.7	324.0	364.2
July 12	367.7	339.0	230.3	214.7	274.0	260.7	275.7	247.3	27[illegible]	467.3	455.0	341.7	318.7	292.7	287.0	316.3	296.0	346.8
July 19	313.0	283.0	232.3	215.7	270.7	253.0	271.7	239.7	2[illegible]	432.3	392.3	313.3	287.7	312.7	278.7	332.7	300.3	331.4
July 26	285.0	276.0	235.3	203.7	233.7	206.7	237.0	225.0	23[illegible]	368.7	333.0	306.0	289.3	282.0	247.0	339.7	295.0	307.6
Aug. 2	272.7	254.0	173.0	167.3	231.3	180.0	273.0	240.3	22[illegible]	333.0	312.3	299.0	274.7	300.7	260.7	330.7	292.0	300.4
Aug. 9	244.7	219.7	172.7	138.0	209.3	189.0	222.0	175.0	19[illegible]	314.0	293.3	276.3	251.0	273.0	244.0	294.0	272.3	277.3
Aug. 17	256.3	224.7	172.3	143.3	213.3	197.7	202.0	189.0	19[illegible]	320.0	297.3	268.3	246.7	277.0	252.0	263.7	244.0	271.1
Aug. 23	240.3	212.7	142.3	125.3	209.0	181.7	210.0	196.3	18[illegible]	303.0	291.7	276.3	252.7	252.7	231.0	285.0	267.3	270.0
Sept. 10	211.0	193.7	141.3	117.0	144.0	123.0	175.3	162.0	15[illegible]	278.0	260.7	241.0	219.3	225.0	210.0	234.3	225.7	236.8
Average	332.5	303.6	217.5	195.4	266.4	241.2	264.7	242.3	25[illegible]	420.1	393.8	307.4	283.4	317.2	292.5	330.4	298.6	330.4

Table 29. Percent mean moisture for browse in shaded and unshaded conditions on four aspects in forenoon and afternoon during 12 clippings over the season

	Unshaded									Shaded								
	Aspect									Aspect								
	North		South		East		West		Aver-	North		South		East		West		Aver-
Clipping	FN	AN	FN	AN	FN	AN	FN	AN	age	FN	AN	FN	AN	FN	AN	FN	AN	age
June 15	231.7	221.3	185.0	179.0	205.3	199.3	189.0	177.0	198.5	281.7	254.3	203.0	195.3	251.0	223.0	232.3	207.3	231.0
June 21	224.3	219.7	192.3	178.0	196.7	183.7	187.7	169.3	194.0	249.0	240.3	213.7	199.7	244.0	204.0	220.0	198.3	221.1
June 28	198.7	190.0	169.0	165.3	173.3	167.7	182.7	166.3	176.6	215.7	210.3	191.0	170.3	218.0	185.0	195.7	192.3	197.3
July 6	189.0	172.7	154.7	161.3	168.7	167.0	151.7	138.7	163.0	206.3	200.7	194.3	173.7	217.3	186.7	188.3	174.3	192.7
July 12	176.0	167.3	145.0	140.7	146.7	141.0	152.0	142.0	151.3	200.0	190.3	182.3	165.0	174.0	155.7	185.7	162.7	177.0
July 19	165.0	149.3	146.7	143.3	150.7	131.7	143.7	135.7	145.8	190.3	181.0	168.0	171.7	183.3	169.3	168.0	154.7	173.3
July 26	156.3	139.0	137.7	130.7	131.7	120.7	135.0	128.3	134.9	188.0	174.7	166.3	155.0	160.3	148.7	157.7	156.3	163.4
Aug. 2	143.3	123.7	131.3	126.0	124.7	111.7	133.7	131.7	128.3	173.3	158.0	151.3	148.0	164.7	145.0	162.3	148.7	156.4
Aug. 9	149.0	131.0	138.7	123.7	143.7	140.0	130.3	120.3	134.6	165.7	162.3	157.7	154.0	154.0	149.0	156.3	150.3	156.2
Aug. 17	142.0	129.0	143.3	131.0	140.3	132.0	120.7	113.7	131.5	166.0	159.0	170.0	158.0	163.0	152.7	152.3	143.0	158.0
Aug. 23	139.3	123.0	121.0	128.7	126.7	124.3	129.0	121.7	126.7	160.7	153.7	159.3	134.3	157.0	147.3	158.7	144.0	151.9
Sept. 10	128.0	118.3	140.0	115.0	127.7	119.0	105.0	100.3	119.2	161.7	150.7	164.7	151.3	149.3	141.0	124.7	120.3	145.5
Average	170.2	157.0	150.4	143.6	153.0	144.8	146.7	137.1	150.4	196.5	186.3	176.8	164.7	186.3	167.3	175.2	162.7	177.0

Appendix V

Dry matter factor (for conversion from green weight)

Phenological stage: Boot stage.

1. Grass

Aspect and spp.	Unshaded Percent	Unshaded Clipping date	Number of subplots occurrence	Shaded Percent	Shaded Clipping date	Number of subplots occurrence
North						
Bromus marginatus	23	June 15	1	19	June 28	2
	24	June 21	3	21	July 6	3
East						
Bromus marginatus	26	June 15	1	24	June 28	1
	28	June 21	2	25	July 6	1
				25	July 12	1
Agropyron subsecundum	32	July 6	2	29	July 12	2
Arrhenatherum elatius	--			33	Aug. 2	1
Carex spp.	--			30	July 12	1
Melica spectabilis	--			28	July 6	1
South						
Elymus cinereus	38	June 21	1	33	July 6	1
	39	June 28	2	35	July 12	1
	40	July 6	2			
Agropyron inerme	38	June 21	1			
	39	June 28	2			
Agropyron spicatum	39	June 21	1			
Bromus marginatus	--	--		26	June 28	2
				28	July 6	1
Agropyron subsecundum	--	--		31	June 28	1
				32	July 6	1

Aspect and spp.	Unshaded Percent	Unshaded Clipping date	Number of subplots occurrence	Shaded Percent	Shaded Clipping date	Number of subplots occurrence
West						
Stipa columbiana	36	June 21	1			
Melica bulbosa	30	June 21	1			
Agropyron subsecundum	35	July 6	1	31	July 6	1
Bromus marginatus	--	--		24	July 12	2
Elymus cinereus				33	July 6	2

Dry matter factor (for conversion from green weight)

Phenological stage: Boot stage.

2. Forb

Aspect and spp.	Unshaded Percent	Unshaded Clipping date	Number of subplots occurrence	Shaded Percent	Shaded Clipping date	Number of subplots occurrence
North						
Lathyrus spp.	16	June 21	2	15	July 12	2
	18	June 28	2	--		
Thalictrum fendleri	23	June 28	1	17	July 6	1
	25	July 6	1	18	July 12	1
East						
Lathyrus spp.	22	June 28	2	20	June 21	1
				20	June 28	1
Erigeron peregrinus	21	June 28	2	--	--	
	23	July 6	1	--	--	
Thalictrum fendleri	--	--		20	June 28	1
				21	July 6	3
South						
Erigeron peregrinus	23	June 21	2			
Viguiera multiflora	25	June 21	1			
	27	June 28	1			
Linum Lewisii	27	June 28	2			
Solidago lepida	29	July 6	2			
Lathyrus spp.	--	--		23	June 21	3
	--	--		22	June 28	1
Lupinus caudatus				20	June 28	1
				21	July 6	2

Aspect and spp.	Unshaded		Number of subplots occurrence	Shaded		Number of subplots occurrence
	Percent	Clipping date		Percent	Clipping date	
West						
Solidago lepida	27	July 12	2			
Lupinus caudatus	24	July 6	2			
Viguiera multiflora	24	June 28	2			
	25	July 6	1			
Geranium fremontii	20	June 28	1			
Lathyrus spp.	--	--		20	June 28	1
				22	July 6	2
Thalictrum fendleri	--	--		24	June 28	2

Dry matter factor (for conversion from green weight)

Phenological stage: Boot stage.

3. Shrub

	Unshaded			Shaded		
Aspect and spp.	Percent	Clipping date	Number of subplots occurrence	Percent	Clipping date	Number of subplots occurrence
North						
Symphoricarpos vaccinioides	31	June 21	2	25	June 21	2
	32	June 21	1	27	June 28	2
East						
Symphoricarpos vaccinioides	32	June 15	1	30	June 28	2
	33	June 21	1			
	33	June 28	1			
South						
Symphoricarpos vaccinioides	34	June 15	1	32	June 21	3
	35	June 21	1			
West						
Symphoricarpos vaccinioides	36	June 15	1	30	June 15	2
	37	June 21	2			
	38	June 28	1			

Appendix VI

Conversion Factors[a]

Air-dry content of green forage

A. Grasses and sedges.

Just before heading	25-30 percent
Headed out	35-40 percent
After bloom	45-50 percent
Seed maturity and past	55-80 percent

B. Forbs

Very lush	15-20 percent
Flowering	20-25 percent
Seed time	30-35 percent

C. Browse

Lush leaves (snowberry)	30-40 percent
Fibrous leaves (oak) and *Purshia*	35-45 percent
Rabbitbrush and sagebrush	40-60 percent

[a]An extract from Exhibit 93·3-B, R-4 Range Analysis Handbook, Forest Service, United States Department of Agriculture, 1966.