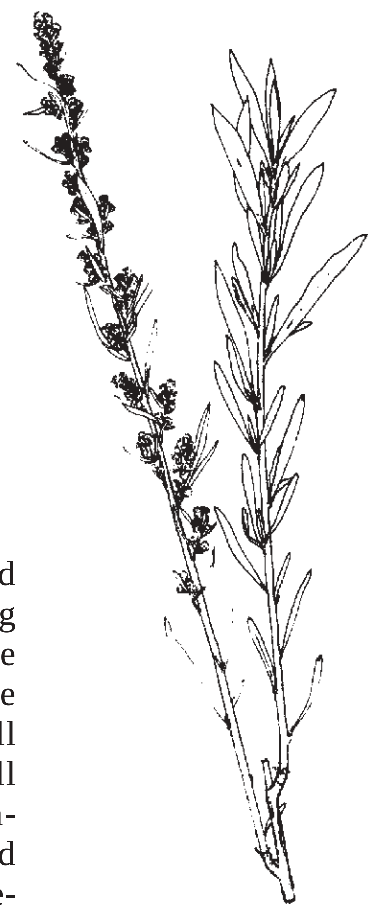
Bruce L. Welch

Chapter 14

Nutritive Principles in Restoration and Management



Most range management or revegetation programs are aimed at providing forage to support the needs of range animals. Among these needs are supplying the nutrients required to drive the physiological processes of the animal body. One major principle in this report is that there is no “perfect forage species” that will supply all the nutrients needed by any range animal for all seasons. The best approach to range management or revegetation is to supply a diversity of palatable shrubs, forbs, and grasses. Major topics to be discussed are (1) nutrient requirements of range animals, (2) judging the nutritive value of range plants, (3) factors affecting the nutritive value of range plants, and (4) seasonal nutritive value of range plants.

Nutrient Requirements of Range Animals

It is a fundamental principle that effective range management or revegetation programs rest on knowing the nutritive requirement of the target animal. The nutrient needs of range animals can be divided into five classes: dry matter intake, energy-producing compounds, protein, minerals, and vitamins.

Dry Matter

Intake of dry matter by range animals varies according to the weight and activity of the animal. Greatest consumption of dry matter, with weight held constant, occurs with lactation, followed by growth, as a percent of live range animals. This is of considerable importance to the range manager when it comes to calculating carrying capacity. Dry matter intake of selected range animals is tabulated in table 1.

Energy-Producing Compounds

From a quantitative point, energy-producing compounds make up the single largest class of nutrients needed by range animals. A lack of sufficient energy is probably the most common manifestation of nutritional deficiency in range animals (Dietz 1972). Range animals can derive energy from a variety of compounds including sugars, fats, pectins, starch, and protein. In ruminants and other range animals that can support fermentation digestion, energy can be derived indirectly from cellulose and hemicellulose.

To understand the energy requirements of range animals, the range manager or revegetation specialist needs first to understand the various terms that are used to express the energy requirement.

Energy requirements of range animals are expressed in several forms such as total digestible nutrients, digestible energy, metabolizable energy, and net energy. Total digestible nutrients, a noncaloric measurement, is the sum of all the digestible organic matter (crude protein, crude fiber, nitrogen-free extract, and crude fat) in a forage. Because fat supplies 2.25 times more energy than protein or carbohydrates, the fat content is multiplied by this 2.25 energy factor to calculate this principal measurement (table 2). The total digestible nutrients requirement of an animal is expressed as kg per animal per day or as percent of the diet. For range managers or revegetation specialists the latter expression is the most useful.

Digestible energy, a caloric measurement, is calculated by subtracting the caloric content in the feces from the caloric content of the range forage. The caloric content of a range forage is often called gross energy. In turn, metabolizable energy is calculated by subtracting the caloric content in the urine and gases lost from the body from the digestible energy of the range forage. Net energy then is calculated by subtracting the calories used to produce body heat from metabolizable energy. Net energy thus represents the amount of energy an animal has for maintenance and production. The relationship of these three caloric energy measurements was demonstrated (fig. 1). Range animal requirements for any one of these measurements is expressed as megacalories per animal per day or as

Table 1—Daily dry matter consumption by selected range animals. Data expressed as pounds of dry matter consumed on a daily basis and as a percentage of live weight (Halls 1970; National Academy of Sciences 1975, 1976, 1977, 1978, 1982, 1984).

Animal	Activity	Weight	Dry matter Per day	Dry matter Live weight
		Lbs	*Lbs*	*Percent*
Sheep (ewes)	Maintenance	110	2.2	2.0
		132	2.4	1.8
		154	2.6	1.7
		176	2.9	1.6
	Last 6 weeks of gestation	110	3.7	3.3
		132	4.2	3.2
		154	4.6	3.0
		176	4.8	2.8
	Lactation	110	5.3	4.8
		132	5.7	4.3
		154	6.2	4.0
		176	6.6	3.7
	Growth	66	2.9	4.3
		88	3.1	3.5
		110	3.3	3.0
		132	3.3	2.5
Cattle	Maintenance	881	13.4	1.5
		1,102	15.9	1.4
		1,323	18.3	1.4
	Gestation	881	16.5	1.9
		1,102	19.0	1.7
		1,323	21.4	1.6
	Lactation	881	23.8	2.7
		1,102	26.0	2.4
		1,323	28.4	2.1
	Growth	661	19.4	2.9
		881	24.3	2.8
		1,323	26.5	2.0
Horses	Maintenance		16.4	
	Gestation		16.4	
	Lactation		21.5	
	Growth		13.2	
Deer	Maintenance		2.2	
	Gestation		2.5	
	Lactation		3.0	
Elk	Maintenance (mature)		9.6	

Table 2—How the amount of digestible nutrients are calculated for a hypothetical range forage.

Nutrient	Total nutrients in 100 kg	Digestion coefficients	Digestible nutrients
	kg	*- - - - - - Percent - - - - - -*	
Crude protein	9.0	50.0	4.5
Crude fiber	30.0	40.0	12.0
Nitrogen-free extract	50.0	50.0	25.0
Crude fat	11.0	50.0 (2.25)	12.4
Total digestible nutrients			53.9

megacalories per kg of dry matter. The latter expression is the most useful for range managers or revegetation specialists.

Energy needs of range animals vary according to weight and activity (lactating, fattening, growing, gestation). Larger animals require more kilograms of total digestible nutrients per day for a given activity than smaller animals, yet when total digestible nutrients is expressed as a percent of the diet the percentage is the same. This is due to differences in dry matter intake. Thus a large animal extracts more kilograms per day of total digestible nutrients than a smaller animal eating the same forages. Similarly, a lactating female requires more energy than a nonlactating female of similar weight. On a constant weight basis, lactation requires the greatest amount of energy followed by fattening, growing, gestation, and maintenance. Table 3 lists the energy requirements of selected range animals. Unfortunately, the total digestible nutrients content or amount of metabolizable energy is unknown for many range forages. More information is expressed as *in vitro* digestibility. I have attempted to express the energy requirements of range animals in terms of *in vitro* digestibility (table 4). Maintenance was set at 50 percent *in vitro* digestibility with all other activities adjusted accordingly (Ammann and others 1973).

Gross Energy
Energy loss in feces
Digestible Energy
Energy loss in gases
Energy lost in urine
Metabolizable Energy
Energy lost as body heat
Net Energy
Energy for production
Energy for maintenance

Figure 1—Relationship of gross, digestible, metabolizable, and net energy.

Protein

Protein in animal bodies makes up a large chemically related, but physiologically diverse, group of compounds. Protein is the major organic compound of the organs and soft tissues of the animal body. All proteins are made from a common set of building blocks known as amino acids. It is the sequence of these amino acids along the protein molecule that gives a particular protein its character which, in turn, determines its function. Proteins are the chief component in nearly all body parts including skeletal muscle for external movement; smooth and cardiac muscle for internal movement; tendons and ligaments for tying together body parts; organs and glands such as the stomach, eyes, pituitary, and skin with its covering of hair; and other structures including hemoglobin, cytochromes, and membranes. Enzymes are also an important group of proteinaceous compounds that provide the framework in which the chemical reactions of the body take place.

Because of the involvement of protein in so many bodily functions, the animal body needs a liberal and continuous supply of protein. Like energy, the protein requirement of range animals varies according to the weight and activity of the animal. From a qualitative point, the protein requirement varies according to the type of digestive system operating in the range animal. For ruminants and other range animals that can support fermentation digestion, including horses, rabbits, burros, and sage-grouse, the quality of the protein—that is the actual amino acid makeup—is not important, only the quantity. The microorganisms responsible for the fermentation also manufacture needed amino acids from plant protein and organic nitrogen compounds.

Protein requirement of range animals is expressed either in terms of digestible protein, or as crude (sometimes called total) protein. The requirement values in the diet are expressed as grams per day or as a percentage. For range managers or revegetation specialists, the term crude protein as a percent in the diet is the most useful. As with energy, the greater the weight of the animal, the higher the protein requirement, assuming similar body activity. Because larger range animals consume more dry matter, their higher protein requirement can be met by consuming diets with the same percentage of protein as smaller animals. The difference is in the amount of dry matter eaten. Protein requirement varies also according to animal's activities. Lactation has the highest demand

Table 3—The energy requirements of selected range animals. Data expressed on a dry matter basis as a percent of total digestible nutrients in the diet, as a percent of *in vitro* digestibility[a], or as megacalories of metabolizable energy/kg of dry matter (Halls 1970, National Academy of Sciences 1975, 1976, 1977, 1978, 1982, 1984).

Animal Activity Weight (lbs)	Total digestible nutrients (dry)	*In vitro* digestibility[a]	Metabolizable energy
	- - - - - - - - - *Percent*	- - - - - - - - -	*mcal/kg*
Sheep			
Maintenance 110-176	55	50	2.0
Last 6 weeks of gestation 110-176	65	60	2.4
Lactation 110-176	62	56	2.4
Growth			
66	62	56	2.2
88	60	56	2.1
Cattle			
Maintenance and gestation 882-1,323	52	50	1.9
Lactation 882-1,323	55	53	2.0
Growth			
661-882	64	57	2.3
1,323	61	56	2.2
Horses			
Maintenance	47	50	1.8
Gestation	58	53	2.1
Lactation	62	56	2.2
Growth	66	58	2.5
Work			
Light	58	53	2.1
Moderate	65	57	2.4
Intense	66	58	2.5
Small range animals (rabbits, squirrels, foxes)			
Maintenance	—[b]	—	3.6
Gestation	—	—	3.9
Lactation	—	—	4.5
Growth	—	—	3.9
Range birds (grouse, pheasant, quail, turkey)			
Maintenance	—	—	2.9
Breeding	—	—	2.9
Growth	—	—	3.1

[a]Unfortunately, the total digestible nutrients content or amount of metabolizable energy is unknown for many range forages. More information is expressed as *in vitro* digestibility. In this table, energy requirements are expressed in terms of *in vitro* digestibility. Maintenance was set at 50 percent *in vitro* digestibility with other activities adjusted accordingly (Ammann and others 1973).
[b]A dash ("—") means no information available.

followed by fattening, growth, gestation, and maintenance. The protein requirements of selected range animals demonstrates this hierarchy (table 4).

Minerals

There are 15 mineral elements essential for the health of animals. Of these, seven are considered major elements: sodium, chlorine, calcium, phosphorus, magnesium, potassium, and sulfur. The remaining eight are classified as being trace elements: iodine, iron, copper, molybdenum, cobalt, manganese, zinc, and selenium. These essential mineral elements perform many vital functions in the body. They constitute the major components of bones and teeth, maintain osmotic relations and acid-base equilibrium, play an important role in regulating enzymatic systems and muscular contraction, and are constituents of most organic compounds. They are also important in energy transfer.

Under most conditions, calcium and phosphorus are the mineral elements of major concern, although other mineral elements (copper, cobalt, magnesium, sulfur, zinc, and molybdenum) may be locally in short supply. These can be supplemented easily by adding them to salt. For calcium and phosphorus, range animal requirements are expressed as grams per day or as a percent of the diet. For the range manager or revegetation specialist the expression as a percent of the diet is the most useful. Under similar activity, larger range animals need greater amounts of calcium and

Table 4—The protein requirement of selected range animals. Data expressed on a dry matter basis as a percent of crude or digestible protein needed in the diet (Halls 1970, National Academy of Sciences 1975, 1976, 1977, 1978, 1982, 1984).

Animal	Activity	Weight	Crude protein	Digestible protein
		Lbs	- - - - - - *Percent*	- - - - - -
Sheep	Maintenance	110-176	8.9	4.8
	Last 6 weeks of gestation	110-176	9.3	5.2
	Lactation	110-176	11.0	7.2
	Growth	66	10.0	5.8
		88	9.5	5.3
Cattle	Maintenance and gestation	882-1,323	5.9	—[a]
	Lactation	882-1,323	9.2	—
	Growth	661-882	10.2	—
		1,323	8.8	—
Horses	Maintenance		8.5	—
	Gestation		11.0	—
	Lactation		14.0	—
	Growth		16.0	—
	Work			
	Light		8.5	—
	Moderate		8.5	—
	Intense		8.5	—
Mule deer	Maintenance		7.0	—
	Growth		16.0	—
Small range animals (rabbits, squirrels, foxes)				
	Maintenance		22	—
	Gestation		38	—
	Lactation		46	—
	Growth		35	—
Range birds (grouse, pheasant, quail, turkey)				
	Maintenance		12	—
	Breeding		14	—
	Growth		20	—

[a]A dash ("—") means no information available.

phosphorus than smaller animals. With size held constant, lactating animals require the most calcium and phosphorus followed by growth, fattening, gestation, and maintenance as an analysis of the calcium and phosphorus requirements of selected range animals confirms (table 5).

Vitamins

Vitamins are organic compounds needed by the body in relatively small amounts. They are unrelated chemically, but function as metabolic regulators. For range animals capable of supporting fermentation digestion, only vitamin A is of concern. Vitamin A combines with a specific protein of the eye to produce visual purple. A range animal with a vitamin A deficiency may develop an abnormal condition called night blindness. Vitamin A also plays an important role in normal development of bones, disease resistance, and maintenance of healthy epithelium tissues. Vitamin A is manufactured from the plant precursor carotene. Sometimes plant carotene is referred to as provitamin A. As a result the vitamin A requirement of range animals is expressed in a variety of terms, such as, milligrams per day per animal, or milligrams per kilogram of dry matter of carotene, or provitamin A, and as international unit per day, or international units per kilogram of dry matter of vitamin A. For range managers or revegetation specialists, the expression on a per kilogram of dry matter is the most useful. Larger animals with similar activities require more vitamin A than smaller animals. With size held constant, a lactating animal requires the most vitamin A, followed by growth, fattening, gestation, and maintenance (table 6).

Knowing the nutritive needs of range animals is the first step for sound effective range management or revegetation projects. The next task for range

Table 5—The calcium and phosphorus requirement of selected range animals. Data expressed on a dry matter basis as a percent needed in the diet (Halls 1970, National Academy of Science 1975, 1976, 1977, 1978, 1982, 1984).

Animal	Activity	Weight	Calcium	Phosphorus
		Lbs	- - - - - -*Percent*- - - - -	
Sheep	Maintenance	110	0.30	0.28
		132	0.28	0.26
		154	0.27	0.25
		176	0.25	0.24
	Last 6 weeks of gestation	110	0.24	0.23
		132	0.23	0.22
		154	0.21	0.20
		176	0.21	0.20
	Lactation	110	0.52	0.37
		132	0.50	0.36
		154	0.48	0.34
		176	0.48	0.34
	Growth	66	0.45	0.25
		88	0.44	0.24
		110	0.42	0.23
		132	0.43	0.24
Cattle	Maintenance	881-1,323	0.18	0.18
	Gestation	881-1,323	0.18	0.18
	Lactation	881	0.42	0.38
		1,102	0.39	0.36
		1,323	0.36	0.34
	Growth	661	0.31	0.26
		881	0.21	0.21
		1,323	0.18	0.18
Horses	Maintenance		0.30	0.20
	Gestation		0.50	0.35
	Lactation		0.50	0.35
	Growth		0.70	0.50
	Work		0.30	0.20
Deer	Maintenance		0.30	0.25
	Growth		0.38	0.27
Small range animals (rabbits, squirrels, foxes)				
	Maintenance		0.30	0.30
	Gestation		0.40	0.40
	Lactation		0.60	0.60
	Growth		0.40	0.40
Range birds (grouse, pheasant, quail, turkey)				
	Maintenance		0.50	0.25
	Breeding		2.25	0.35
	Growth		0.75	0.38

Table 6—The vitamin A requirement of selected range animals. Data expressed on a dry matter basis as milligrams or international units needed per kilogram of dry matter (Halls 1970, National Academy of Sciences 1975, 1976, 1977, 1978, 1982, 1984).

Animal	Activity	Weight	Carotene	Vitamin A
		Lbs	*mg/ka*	*IU/kg*
Sheep	Maintenance	110	1.9	1,275
		132	2.0	1,391
		154	2.2	1,488
		176	2.3	1,569
	Last 6 weeks of gestation	110	3.6	2,500
		132	3.9	2,684
		154	4.2	2,833
		176	4.5	3,091
	Lactation	110	2.6	1,771
		132	2.9	1,962
		154	3.1	2,125
		176	3.3	2,267
	Growth	66	1.5	981
		88	1.8	1,214
		110	2.1	1,417
		132	2.5	1,700
Cattle	Maintenance and gestation		4.1	2,800
	Lactation		5.7	3,900
	Growth		3.2	2,200
Horses	Maintenance		2.4	1,600
	Gestation		5.0	3,400
	Lactation		4.1	2,800
	Growth		2.9	2,000
	Work		2.4	1,600
Small range animals (rabbits, squirrels, foxes)			8.7	5,930
Range birds (grouse, pheasant, quail, turkey)			5.9	4,000

managers or revegetation specialists is to gain skills at judging the nutritive values of range plants.

Judging the Nutritive Values of Range Plants

Nutrient value of a range plant is judged in terms of the plant's ability to meet the various nutrient requirements of the consuming range animal. Estimates of the value of range forage can be classified into three groups: (1) proximal or other chemical analysis; (2) *in vitro* digestibility (outside-the-living-body digestibility); and (3) *in vivo* digestibility, (in-the-living-body digestibility). From the point of view of range managers or revegetation specialists, nutrient measurements obtained from *in vivo* digestibility are the most useful followed by *in vitro* digestibility and chemical analysis. Unfortunately, information obtained from *in vivo* digestibility is time consuming, expensive, and there is simply not enough information to cover most rangeland situations that confront range managers or revegetation specialists.

Recognizing that all plant substances are not equally digestible, nutritionists have attempted, with varying degree of success, to devise series of chemical measurements that would partition the digestible plant substances from the hard or nondigestible substances.

Proximal and Other Chemical Analyses

One such measurement is called proximal analysis. This analysis is based on dividing plant substances into five classes: crude protein, crude fat, crude fiber, ash, and nitrogen-free extract. The first four classes are determined by chemical means, the fifth is determined by subtracting the sum of the percentages of the first four classes from 100. All classes are expressed on a dry matter basis.

Crude protein is measured by determining the nitrogen content of the forage and multiplying the nitrogen content, expressed as a percent, by the factor 6.25 (sometimes a worker chooses to give just the nitrogen content of range plants, the range manager or revegetation specialist can calculate the crude protein content by multiplying the nitrogen content by 6.25). Chemical determination of crude protein does not take into account the digestibility of the protein. Fortunately, crude protein content is significantly related to digestible protein. As crude protein increases, so does the digestibility of the protein. In general terms, the higher the crude protein content of a range forage, the more likelihood it will meet or exceed the animal needs.

Crude fat is measured by determining the compounds soluble in ether. Crude fat then is a mixture of compounds including waxes, monoterpenoids, chlorophyll, carotene, triglycerides, and phospholipids. Not all of these compounds are digestible but those that are, such as triglycerides, phospholipids, and fatty acids, yield 2.25 times more energy than do sugars, starch, and protein. Range plants with high and digestible crude fat levels are excellent sources of energy. In general, crude fat is about 45 percent digestible.

Crude fiber is the residue left after plant samples have been alternately boiled in weak acid and in weak alkali. This residue consists chiefly of cellulose, hemicellulose, and lignin. Hemicellulose is more readily broken down into simple sugars by microbial fermentation than is cellulose. Lignin is not digested by microbial fermentation or by the range animal, and may even form a coating around cellulose rendering portions of it undigestible. The digestibility of crude fiber varies greatly among range forages. Crude fiber regulates the bulk in a diet. Bulk, up to a certain point—30 to 35 percent—has a beneficial effect on the digestive tract of a range animal by preventing the formation of a doughlike mass in the stomach. Also, it promotes the elimination of undigested food from the digestive tract. In general, range forages that are higher in crude fiber are less digestible.

Ash is the mineral matter of a range forage. It is determined by burning off all the organic matter and weighing the residue. This chemical analysis gives the total mineral content of a range forage but tells nothing about the individual mineral elements. In general, the values are needed to calculate nitrogen-free extract.

Nitrogen-free extract is determined by calculation but not by chemical means. After the contents of crude protein, crude fat, crude fiber, and ash have been determined, these values are added together and subtracted from 100. The result is nitrogen-free extract. This portion is composed mainly of sugars and starch. In general, range forages that are highest in nitrogen-free extract are among the most digestible.

There are problems with the proximal analysis method. Because nitrogen-free extract is determined by the difference, it accumulates all the errors of the other analyses. Crude fiber fraction does not always divide carbohydrates into digestible fractions. Recognizing these problems, a series of chemical analyses has been devised. This series partitions the plant substance into three classes: (1) cell contents plus pectin, (2) neutral detergent fiber, and (3) acid detergent fiber. Cell contents are very highly digestible and contain sugars, starch, organic acids, protein, and pectin. Neutral detergent fiber is much less digestible and contain hemicellulose, cellulose, and undigestible lignin. Acid detergent fibers is less digestible than the other two fractions because it contains just the cellulose and undigestible lignin. This procedure may, in time, replace the old proximal analysis method. At present, very few range forages have been analyzed by the detergent or Van Soest method. When the information is available, the range manager or revegetation specialist needs to recognize that the higher the cell content and lower the acid detergent fiber the more digestible the range forage.

Other chemical analyses that are useful in judging the nutritive value of range plants are the percentages of lignin, calcium, phosphorus, and carotene. In general, with the exception of lignin, the higher the better. Although the chemical makeup of range forages gives an indication of their probable nutritive value, their digestibility is important in evaluating the ability of a forage to meet the nutrient needs of a range animal. The most useful information then, to a range manager or revegetation specialist, is digestibility.

Digestibility

Digestibility can be determined by either *in vitro* (outside) or *in vivo* (inside) means.

In vitro digestibility is a laboratory technique that simulates natural ruminant digestion. This technique includes the fermentation of a forage substrate with rumen microorganisms in a buffered digestion solution at body temperature, and a neutral to slightly acidic pH. After fermentation, the digestive solution is acidified with hydrochloric acid to pH of 1 to 2, and pepsin, an enzyme that digests protein, is added to the digestive solution. Upon completion of acidified-pepsin treatment, the residue from the test forage is filtered, dried, weighed, and percent of dry matter calculated.

Range animal requirements as expressed in terms of *in vitro* digested dry matter is about 50 percent for maintenance, 53 percent for gestation, 56 percent for growth, and 60 percent for lactation. In general, the higher the *in vitro* digestibility of a range forage the higher the nutritive value.

The main advantages of the *in vitro* technique are simplicity, speed, precision, and costs. Disadvantage is that the digestibility of individual nutrients is unknown.

In vivo digestibility technique consists of feeding the range forage of interest, usually alone, to an animal or set of animals and collecting the feces. Using chemical analysis, the amount of nutrients (1) consumed by the test animal(s), and (2) excreted in the feces is determined. The difference between the two would represent the portion of the nutrients in the forage digested by the animal(s). Results of *in vivo* digestibility trials are expressed as digestion coefficients of the various proximate analysis classes, and as total digestible nutrients. The calculating of total digestible nutrients had been described earlier (table 2).

Another way the results of *in vivo* digestion can be expressed is in terms of digestible energy (fig. 1). In general, the higher the digestive coefficients, total digestible nutrients, and digestible energy, the higher the nutritive value of the range forage. Complicating the judging of nutritive value of range plants is the fact that the nutrient content of a given species varies over time and space.

Factors Affecting the Nutritive Value of Range Plants

Factors that affect the morphology and metabolism of range plants also affect the nutritive value of the plants, both quantitatively and qualitatively. These factors include climate, soil, and genetic factors, and express themselves in influencing the speed of the phenological development of the range plants. In general, the qualitative nutritive value of range plants peak in the spring and then decrease, reaching a low level during the dormant or winter season as demonstrated by the range plants big sagebrush, bitterbrush, and unknown grass (table 7). Fall green up on the part of certain grass species during wet falls changes this pattern considerably. Influences on the nutritive content of range forage and on the nutritive requirement of range animals, actual listing of nutritive values of range plants is done according to season—spring, summer, fall, and winter.

Seasonal Nutritive Value of Range Plants

For the range manager or revegetation specialist the task becomes one of balancing range animals' nutritive needs with the nutritive content of range plants. The range manager or revegetation specialist should think in terms of range plants providing so many pounds per acre of total digestible nutrients, digestible or crude protein, carotene, and phosphorus. The other nutrients, with the exception of water, are probably in adequate amounts. Sometimes deficiencies occur but only in local areas. This section is an attempt to list what is known about the nutritive values of range plants. The section is divided seasonally, and the particular needs of the range animals are also discussed.

Table 7—Seasonal variation of crude protein for *Artemisia tridentata* (big sagebrush), *Purshia tridentata* (antelope bitterbrush), and an unknown Nevada grass.

Month/year	Big sagebrush	Bitterbrush	Grass
	- - - - - - - - - - - - - *Percent*	- - - - - - - - - - - - -	
June 1968	11.8	13.4	13.4
July 1968	12.7	12.8	7.8
September 1968	11.8	9.7	9.6
December 1968	10.5	7.5	2.7
March 1969	14.0	9.9	3.4
May 1969	15.0	11.3	21.3

Source: Data from Tueller (1979).

Spring Range

Spring range is a time when the energy, protein, phosphorus, and carotene requirements of range animals are highest. This is due to the growing of young and the lactating of females. From a qualitative view, this is the time when nutritive value of plants is also highest; however, dry matter production is low at this time, but increases in late spring. There are some who believe that early spring range plants do not provide good forage for range animals. Their belief is based on the idea that high water content of the forage is a controlling agent in forage intake. Dry matter, not water content, controls daily forage intake. Grasses and forbs

Table 8—Spring nutritive value[a] of selected range plants. Data expressed on a percent of dry matter, except carotene, which is expressed as mg/kg of dry matter.

Plant name Common Scientific[b]	*In vitro* digestibility	Crude protein	Phosphorus	Carotene
	Percent	*Percent*	*Percent*	*mg/kg*
Grasses				
Bluebunch wheatgrass *Agropyron spicatum*	60.6	17.0	0.30	414
Bottlebrush squirreltail *Sitanion hystrix*	72.3	18.5	0.24	3
Crested wheatgrass *Agropyron cristatum*	72.6	11.3	—[c]	—
Desert wheatgrass *Agropyron desertorum*	73.6	23.7	0.36	452
Idaho fescue *Festuca idahoensis*	—	14.0	0.30	92
Indian ricegrass *Oryzopsis hymenoides*	67.1	15.9	—	—
Intermediate wheatgrass *Agropyron intermedium*	74.3	8.2	—	—
Needle-and-thread grass *Stipa comata*	—	16.2	0.40	—
Reed canary grass *Phalaris arundinacea*	—	16.2	0.40	—
Sand dropseed grass *Sporobolus cryptandrus*	—	15.1	0.25	—
Sandberg bluegrass *Poa secunda*	62.2	17.3	0.33	—
Smooth brome *Bromus inermis*	—	23.5	0.47	493
Western wheatgrass *Agropyron smithii*	77.2	17.6	0.45	185
Shrubs				
Antelope bitterbrush *Purshia tridentata*	49.2	12.4	0.19	—
Big sagebrush *Artemisia tridentata*	58.1	12.6	0.25	—
Curlleaf mountain mahogany *Cercocarpus ledifolius*	—	9.9	—	—
Fourwing saltbush *Atriplex canescens*	—	14.1	—	—
Low rabbitbrush *Chrysothamnus viscidiflorus*	—	22.6	0.46	—
Rubber rabbitbrush *Chrysothamnus nauseosus*	—	20.7	0.45	—
Utah juniper *Juniperus osteosperma*	49.0	6.2	0.15	—
Winterfat *Ceratoides lanata*	—	21.0	—	—
Forbs				
Alfalfa *Medicago sativa*	86.8	28.5	0.37	372
American vetch *Vicia americana*	71.3	21.2	—	—
Arrowleaf balsamroot *Balsamorhiza sagittata*	—	28.8	0.43	—
Gooseberryleaf globemallow *Sphaeralcea grossulariifolia*	69.7	19.7	—	—
Oneflower helianthella *Helianthella uniflora*	—	20.0	0.40	—
Small burnet *Sanguisorba minor*	—	17.4	—	—

[a]Values represent the average of a number of studies reported in the literature. References are on file at the Rocky Mountain Research Station's Shrub Sciences Laboratory, Provo, UT. References are also listed in the references section.
[b]Common and scientific names after Plummer and others (1977).
[c]A dash ("—") means information not available.

in the spring exceed the nutritive content of shrubs. This is illustrated in tables 8 and 11, both listing the spring nutritive values of selected range plants. On spring ranges, range managers or revegetation specialists should emphasize the production of grasses and forbs with shrubs as backup during drought. Shrubs are more productive during drought than grasses or forbs.

Summer Range

During the summer, range animals' demands for energy, protein, phosphorus, and carotene is a little lower

Table 9—Summer nutritive value[a] of selected range plants. Data expressed as a percent of dry matter, except carotene which is expressed as mg/kg of dry matter.

Plant name Common Scientific[b]	*In vitro* digestibility	Crude protein	Phosphorus	Carotene
	Percent	*Percent*	*Percent*	*mg/kg*
Grasses				
Bluebunch wheatgrass	3	14.5	0.23	77
Agropyron spicatum				
Bottlebrush squirreltail	59.7	8.0	0.17	1.1
Sitanion hystrix				
Crested wheatgrass	—	—	0.13	—
Agropyron cristatum				
Desert wheatgrass	51.0	12.1	0.23	153
Agropyron desertorum				
Galleta	—	7.7	0.09	0.4
Hilaria jamesii				
Idaho fescue	54.0	9.5	0.18	34
Festuca idahoensis				
Needle-and-thread grass	—	6.5	0.10	0.4
Stipa comata				
Reed canary grass	—	12.4	0.20	—
Phalaris arundinacea				
Sand dropseed grass	—	5.7	0.10	0.4
Sporobolus cryptandrus				
Sandberg bluegrass	—	9.4	0.17	43
Poa secunda				
Smooth brome				
Bromus inermis	60.6	11.0	0.28	103
Western wheatgrass	—[c]	11.8	—	117
Agropyron smithii				
Shrubs				
Antelope bitterbrush	—	13.1	0.22	—
Purshia tridentata				
Big sagebrush	—	13.2	0.40	—
Artemisia tridentata				
Curlleaf mountain mahogany	—	12.2	0.23	—
Cercocarpus ledifolius				
Fourwing saltbush	47.1	12.0	—	—
Atriplex canescens				
Gambel oak	—	15.8	—	—
Quercus gambelii		(leaves)		
Low rabbitbrush	—	12.1	0.35	—
Chrysothamnus viscidiflorus				
Rubber rabbitbrush	—	12.8	0.38	—
Chrysothamnus nauseosus				
Utah juniper	—	8.1	0.21	—
Juniperus osteosperma				
Winterfat	—	13.6	—	—
Ceratoides lanata				
Forbs				
Alfalfa	—	17.8	0.28	109
Medicago sativa				
American vetch	—	17.6	0.20	—
Vicia americana				
Arrowleaf balsamroot	—	17.0	0.26	—
Balsamorhiza sagittata				
Oneflower helianthella	—	12.4	0.31	—
Helianthella uniflora				
Small burnet	—	9.8	—	—
Sanguisorba minor				

[a]Values represent the average of a number of studies reported in the literature. References on file at the Rocky Mountain Research Station's Shrub Sciences Laboratory, Provo, UT. References are also listed in the references section.
[b]Common and scientific names after Plummer and others (1977).
[c]A dash ("—") means information not available.

Table 10—Seasonal variation in the nutritive value[a] of desert wheatgrass. Data expressed on a dry matter basis except carotene which is expressed as mg/kg of dry matter.

Season	*In vitro* digestibility	Crude protein	Calcium	Phosphorus	Carotene
		Percent			*mg/kg*
Early spring	73	23.6	0.47	0.36	452.0
Spring	61	18.0	0.41	0.32	239.0
Early summer	51	12.5	0.39	0.23	153.0
Late summer	49	12.1	0.29	0.18	75.4
Winter	44	3.5	0.27	0.07	0.2

[a]Values represent the average of a number of studies reported in the literature. References are on file at the Rocky Mountain Research Station's Shrub Sciences Laboratory, Provo, UT. References are also listed in the references section.

than during the spring but the nutritive value of range forage starts to decline with grasses declining more rapidly than forbs and shrubs (tables 9, 10). By this time the protein, phosphorus, and carotene levels in grasses are at or just below the needs of most range animals. Energy level of grasses remain above that in forbs and shrubs. This supports the importance of having a mixture of palatable grasses, forbs, and shrubs available for range animal consumption.

Fall and Winter Range

During the fall and winter season, the nutritive needs of range animals, especially wild range animals, drop to maintenance levels. Also, the nutritive content of range plants drops, in many cases, below the maintenance levels. Grasses lead this decline in every category except in energy, followed by forbs, with shrubs showing the least amount of decline. In general, shrubs supply higher fall and winter levels of crude protein, phosphorus, and carotene than grasses or forbs (table 11). Grasses, in general, supply higher fall and winter levels of energy than shrubs or forbs. However, some evergreen shrubs, such as big and black sagebrush and curlleaf mountain mahogany, contain as much energy as grasses. From a nutritional point of view, it is a good range management practice to manage fall and winter ranges for a balance among grasses, forbs, and shrubs.

There are two additional points regarding winter nutritional values that need to be discussed (table 11). First: fall regrowth of grasses (crested wheatgrass) provides excellent winter forage to wintering range animals. But crested wheatgrass cannot constitute the mainstay of a fall and winter range program. This is due to two factors; first, fall regrowth does not occur

Table 11—Winter nutritive value[a] of selected range plants. Data expressed as a percent of dry matter, except carotene which is expressed as mg/kg of dry matter.

Plant name Common Scientific[b]	*In vitro* digestibility	Crude protein	Phosphorus	Carotene
		Percent		*mg/kg*
Grasses				
Bluebunch wheatgrass *Agropyron spicatum*	45.5	3.2	0.05	0.22
Western wheatgrass *Agropyron smithii*	50.2	3.8	0.07	0.20
Bottlebrush squirreltail *Sitanion hystrix*	42.0	4.3	0.07	1.10
Desert wheatgrass *Agropyron desertorum*	43.7	3.5	0.07	0.20
Crested wheatgrass (fall regrowth) *Agropyron cristatum*	50.6	15.0	0.39	432
Galleta *Hilaria jamesii*	48.2	4.6	0.08	0.40
Idaho fescue *Festuca idahoensis*	46.1	3.8	0.08	3.00
Indian ricegrass *Oryzopsis hymenoides*	50.5	3.1	0.06	0.44
Reed canary grass *Phalaris arundinocea*	—[c]	7.8	0.14	—
Needle-and-thread grass *Stipa comata*	46.6	3.7	0.07	0.40

(con.)

Table 11—(Con.)

Plant name Common Scientific[b]	*In vitro* digestibility	Crude protein	Phosphorus	Carotene
	Percent			mg/kg
Grasses				
Sandberg bluegrass *Poa secunda*	—	4.2	—	—
Sand dropseed grass *Sporobolus cryptandrus*	53.2	4.1	0.07	0.50
Smooth brome *Bromus inermis*	47.0	4.1	0.12	—
Shrubs				
Antelope bitterbrush *Purshia tridentata*	23.5	7.6	0.14	—
Big sagebrush *Artemisia tridentata*	57.8	11.7	0.22	17.6
Black sagebrush *Artemisia nova*	53.7	9.9	0.18	8.0
Winterfat *Ceratoides lanata*	43.5	10.0	0.11	16.8
Curlleaf mountain mahogany *Cercocarpus ledifolius*	49.1	10.1	—	—
Fourwing saltbush *Atriplex canescens*	38.3	8.9	—	3.1
Gambel oak *Quercus gambelii*	26.6	5.3	—	—
Low rabbitbrush *Chrysothamnus viscidiflorus*	36.0	5.9	0.15	—
True mountain mahogany *Cercocarpus montanus*	26.5	7.8	0.13	—
Rubber rabbitbrush *Chrysothamnus nauseosus*	44.4	7.8	0.14	—
Stansbury cliffrose *Cowania mexicana*	37.6	8.6	—	—
Utah juniper *Juniperus osteosperma*	44.1	6.6	0.18	—
Forbs				
Arrowleaf balsamroot *Balsamorhiza sagittata*	—	3.6	0.06	—
Oneflower helianthella *Helianthella uniflora*	—	2.8	0.17	—
Small burnet *Sanguisorba minor*	—	6.6	—	—

[a]Values represent the average of a number of studies reported in the literature. References on file at the Rocky Mountain Research Station's Shrub Sciences Laboratory, Provo, UT. References are also listed in the references section.
[b]Common and scientific names after Plummer and others (1977).
[c]A dash ("—") means information not available.

every fall, and secondly, snow can render the green fall regrowth unavailable for the range animal.

The second point of interest is the high nutritive level of big sagebrush (table 11). This range plant species has been, and continues to be, much maligned by range managers due to its general characteristic of being unpalatable to cattle grazing spring and summer ranges. If any single range species could be the mainstay of a winter range program certainly big sagebrush would come the closest. Big sagebrush varies greatly in nutritive value, productivity, site adaption, and preference. Where highly preferred stands of big sagebrush are found they should receive maximum protection from sagebrush control projects. Range managers must make their evaluation of big sagebrush stands before bud break in the spring. Heavily grazed big sagebrush plants can mask the evidence of being grazed within days of bud break. Recent research has shown that these stands of preferred big sagebrush do not affect grass cell wall digestion (Hobbs and others 1985). Also, big sagebrush provides a dependable source of forage during drought for wintering domestic sheep, pronghorn antelope, and mule deer (McArthur and Welch 1982; Medin and Anderson 1979).