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Management of Rangeland Livestock under Drought

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Abstract: Below "normal" precipitation often results in severe drought in arid and semi-arid regions with a reduction in forage for livestock and wildlife. However, the amount of forage produced in any year is dependent upon the amount and timing of precipitation. Plants subjected to overgrazing during severe drought can loose vigor, resulting in loss of cover. Minimizing the negative effects of drought on the range resource, as well as financially surviving the drought are management objectives for range livestock producers. Adherence to the principles of rangeland management prior to, during, and after a drought is crucial in maintaining rangeland productivity. Understanding forage supply and livestock forage demand, in addition to livestock nutrient needs is important in maintaining range condition and livestock health. Stocking rate reductions and weaning practices should proceed in a planned, systematic manner to minimize range degradation and maximize financial returns. Management practices, such as supplemental or substitute feeding should be based on economics. Alternative feed sources may provide emergency rations that are economical. Because droughts are inevitable, especially in arid and semi-arid regions, planning for them by livestock producers, rangeland managers and government policy makers is crucial. Drought plans should include guidelines for stocking rate reductions. Government drought management policies should encourage grazing and land management practices that minimize negative effects of drought. Policies that assist in purchase of harvested feeds are not recommended if they lead to rangeland degradation by delaying destocking.

Key words: drought, plant growth, rangeland management, forage demand, drought planning, destocking strategies, early weaning, feeding management, alternative feeds.

Dryness, the lack of soil moisture, is an ever present feature of arid and semi-arid regions. Often there are periods of time, lasting from a few months to several years, in which precipitation is well below the long-term mean. Short periods of below "normal" precipitation may not constitute a severe drought, and minor adjustments in livestock management may be sufficient so that there is little adverse affect to the land, livestock and people (Brown, 1995). When short-term periods of below "normal" precipitation turn into long-term periods, severe drought is upon a region. During drought, adherence to good range and livestock management practices becomes increasingly important (Hurtt, 1951; Jameson, 1963). At the heart of proper range and livestock management during drought is knowing how plants respond to moisture stress and herbivory. Drought causes significant changes in species composition and forage productivity and consequently livestock production (Weaver, 1968). An understanding of these cause and effect relationships needs to be mastered in order to reduce long-term negative impacts on the rangeland resource. Droughts are an inevitable occurrence of arid and semi-arid zones, so preparation for them by livestock producers, land managers, and policy makers needs to occur well in advance of the next drought. Reactive measures by livestock producers to a drought often result in lost opportunities at best and a severe degradation of the range resource at worst. With severe drought, complete livestock removal may be inevitable. However, many decisions can be made before and during a drought that can lessen the severity and economic impact of stock reductions. This paper attempts to overview principles and strategies related to range and livestock management during drought conditions.

Drought Effect on Plant Growth

Plant growth and metabolism slows as soil water becomes less available (Brown, 1995). As drought conditions persist, leaves wilt, fold, become discolored, undergo early senescence, and may eventually die. Even under mild water deficit conditions, there is a reduction in cell wall formation, cell division, and protein synthesis (Mengel and Kirkby, 1987; Buxton and Fales, 1994). Plants adjust to abnormally low soil moisture by entering dormancy (Brown, 1995). This results in a reduction in the total amount of above- and below-ground plant biomass that is produced in a given growing season. During drought, plants utilize carbohydrates previously produced and stored in the roots and crown (Brown, 1995). Although drought stressed plants may go prematurely dormant, they continue to respire using energy. Brown (1995) suggests that this drain on reserve carbohydrates can result in loss of root vigor and mass as well as reduce the number of basal buds that are developed for next year's potential growth. Thus, moisture stress could cause not only a reduction in forage production in the year of the drought, but also in subsequent years. However, Eneboe *et al.* (2002) found that simulating severe drought conditions over a three year period on a Northen Great Plains range in the United States did not reduce tiller densities or tiller replacement rates of *Bouteloua gracilis* or *Pascopyrum smithii* when grazing utilization of the foliage was 50% or less. Drought, however, did reduce growth for *P. smithii*. These changes occurred despite good grazing management prior to and during imposed drought. Weaver (1968) found that removal of less than 50% of the standing forage is important in maintaining vigorous plants, especially during severe drought. His studies in the central Great Plains of the USA during and following the drought of the 1950's documented that heavy grazing dramatically reduced perennial plant cover, whereas moderate grazing (<50% removal) did not. The little to no change in plant cover of moderately grazed sites compared to a loss in cover with heavy grazing was probably due to a reduction in root biomass. Olson and Lacey (1988) indicated that when in excess of 60% of aboveground tissue is removed a dramatic reduction in amount and depth of root growth occurs.

Plants of arid and semi-arid regions have evolved to grow and reproduce under limited soil moisture. Not only the amount, but the timing of precipitation has a great influence. on the types of plants that grow and the amount of forage produced (Rogler and Haas. 1947; Smoliak, 1956; Rauzi, 1964; Currie and Peterson, 1966; Hulett and Tomanek, 1969; Shiflet and Dietz, 1974; Eck *et al.*, 1975; Newbauer *et al.*, 1980). Measuring precipitation and recording when it occurs may be an effective way to predict subsequent forage growth. If a minimum amount of effective precipitation (large events over a short time tend to result in more runoff with less infiltration) has not occurred by a critical date, managers should begin plans to destock. Often range-livestock producers want to retain livestock hoping rains will come and grass will grow. This is not advisable. Precipitation after the critical date will not significantly increase the amount of available forage. This date depends on the types of plants present. Thus, it is advantageous to know the types of plants that grow in the area being managed. Time of year moisture is available for plant growth, along with average daily temperatures, determines the types of plants that grow. On the Northern Great Plains of the United States the predominant forage plants are cool season perennial grasses (C_3 photosynthetic pathway). These plants begin growth when day time temperatures are consistently above 4°C and become semi-dormant when the temperature is constantly above 24°C (Downton, 1971a; Larcher, 1980). Therefore, if soil moisture is not adequate in April and May, plant growth will be reduced (Rogler and Haas, 1947; Smoliak, 1956; Newbauer *et al.*, 1980). Significant vegetative growth will not occur in the summer months (July and August), even if precipitation is above average. Under these conditions, range livestock producers should enact their drought management strategy and begin stocking rate reductions by late spring. It is imperative that managers realize that green leaf material must be present, so photosynthesis can occur and provide energy to the plant's roots and developing basal buds for next spring's growth. On the Southern Great Plains the predominant forage plants are warm-season perennial grasses (C_4 photosynthetic pathway). Early spring rains (March-April) are not necessarily as critical for their growth and production as it is for cool season plants. Spring months can be dry, but if adequate moisture occurs beginning in June and continues through August, total forage production will usually be near "normal" although delayed (Rauzi, 1964; Currie and Peterson, 1966; Hulett and Tomanek, 1969; Shiflet and Dietz, 1974; Eck *et al.*, 1975). Range livestock producers operating under these conditions may need to find alternative feed sources until grass growth occurs. However, they need to be prepared to enact their drought management plan and do so if sufficient precipitation does not occur by early summer. Depending on the plants that make up the predominant forage species, scenarios may vary somewhat. The Shortgrass Steppe, an area of the Great Plains dominated by the warm season short grasses *Bouteloua gracilis* and *Buchloe dactyloides*, can respond better to late summer moisture following drought conditions (Rauzi, 1964; Hulett and Tomanek, 1969; Eck *et al.*, 1975) as compared to warm season grasses of the tallgrass prairie. The latter typically show a limited growth response to late season moisture (Shiflet and Dietz, 1974). While regions with a significant shrub component may not show adverse affects of drought as quickly as grasslands, they also respond more slowly to precipitation once the drought has broken. Because grasses are shallow rooted they use available moisture in the upper soil profile. Once this has been exhausted, grasses conserve moisture by ceasing growth and becoming dormant. If adequate moisture enters the soil profile and temperatures are conducive to growth, grass plants will break dormancy and grow. As a result, grasslands are always in a somewhat dynamic state of flux. Shrublands, however, are a bit more static. Because of their deep root system, shrubs are able to draw on a greater overall portion of the soil profile for moisture and, in some cases, able to tap into groundwater. Although one dry year, especially in semi- arid and arid regions, does not necessarily constitute a drought, it still can have a negative impact on grass forage production in that year and possibly in the subsequent year. Conversely, the negative impact from a single dry year in a shrub-dominated landscape may not be realized until the following year - and then only if the dormant season is also dry. For most shrublands, dormant season precipitation is critical for shrubs because it is this moisture that percolates deep into the soil profile for future use by these deep-rooted plants. In contrast, growing season precipitation that occurs in arid and semi-arid regions is more readily absorbed by shallow rooted plants before it has a chance to percolate beyond their root zone.

Besides knowing the photosynthetic pathway of the predominant range grasses, it can also be useful to the livestock producer to know the growth form of the range grasses and their sensitivity to defoliation. Bunch grasses, generally, are not as tolerant to defoliation as compared to many of the sod-forming species (rhizomatous or stoloniferous), especially during times of moisture stress. Furthermore, defoliation during the reproductive growth phase of bunch grasses can be more detrimental to their health and vigor, resulting in reduced productivity in subsequent years.

Although all perennial grasses have a tremendous amount of root material to absorb moisture and nutrients from the soil, sod-forming species have a more extensive root system that explores a greater soil volume for moisture and nutrients compared to bunch grasses. Over-use of bunch grasses in times of moisture stress can result in the loss of plants. This can open sites for the invasion and establishment of non-desirable species. Although severe overgrazing could result in the loss of clones of sod-forming grasses, vegetative reproductive stems (rhizomes or stolons) of viable clones will recolonize the area once moisture is available - often before seedlings of invasive species can become established. Though overgrazing of rangeland plants should be avoided if at all possible, overuse of sod-grass dominant range sites during times of drought may be less detrimental as compared to bunch-grass dominant range sites.

Rangeland Management Principles and Drought

During drought, adherence to the principles of rangeland management is crucial to ensure rapid recovery. These principles are:

1. graze rangeland at the right time of year and to the right degree;
2. leave adequate leaf area to ensure regrowth;
3. allow each rangeland unit time to be free of grazing animals during the active growth season; and
4. control livestock distribution to minimize selective grazing behavior and

prevent regrazing of plants (Holechek *et al.,* 1989). Stocking rate, livestock distribution, and grazing deferments and rotations are management practices used to manage grazing and meet these principles.

Stocking rate (number of animals per unit of land for a period of time) is the most important grazing management practice with regard to forage and livestock production (Holechek *et al.,* 1989). Stocking at a light to moderate rate (25 to 55% leaf removal) reduces the intensity, and to some degree, the frequency in which plants are grazed (Holechek, 1988). Greater than 60% removal of available leaf material is not advised, even under adequate moisture conditions. If exceeded, inadequate residual leaf area may result in delayed new growth, limiting the plant's ability to take advantage of precipitation that does occur. In summary, the more leaf material present following defoliation, the faster the plant is able to replace lost tissue.

To sustain forage production in arid and semi-arid regions it is important to capture as much moisture in the soil profile as possible. Good cover of standing live and dead vegetation, and litter maximizes effective precipitation. Leaving adequate residual forage minimizes the negative impact raindrops have on the soil surface (soil sealing), reduces runoff, and increases the amount that percolates into the soil profile. Vegetative cover also shades the soil, reducing soil temperature and evaporative losses. Rangelands that have been managed to maintain sufficient vegetative cover are able to respond more quickly to precipitation.

Forage plants also need adequate rest following herbivory. To accomplish this, pastures need to be free of grazing animals for a proper period of time. Practicing some method of grazing rotation allows plants an opportunity to regrow following a grazing event whereas a grazing deferment allows plants the opportunity to grow without being exposed to defoliation during critical phases of growth (i.e., seedstem elongation through hardseed). During times of drought, practicing some method of grazing rotation or deferment can increase the survivability of range forage plants. Because rest from herbivory is key in plants surviving drought, rest periods for each pasture should be longer as compared to non-drought years (Hart and Carpenter, 2001). Increasing rest periods, however, results in longer grazed periods for each pasture, so reducing herd numbers to maintain a proper balance between forage demand and forage supply is crucial.

Livestock grazing distribution is an important management practice under all climatic conditions and even more so under drought. Distributing livestock grazing evenly over the entire grazing unit allows for utilization of more of the available forage and can reduce the intensity of use on individual plants in preferred areas. Improvement in livestock distribution through fencing, water development, and mineral and feed supplements may allow the stocking rate to remain at the pre-drought numbers for a longer period of time before culling practices need to be implemented. Additionally, grazing rotation or deferment practices may also help delay herd reductions.

Generally, most range-livestock producers have good experience and knowledge of sustainable stocking rates on their land.

Individuals that stock their range at a heavy rate will experience higher risk: both economic and biological. These risks are lower at lower stock densities. For range livestock producers to determine proper stocking rates, especially during times of drought, they need to understand livestock forage demand and forage supply of the land. Knowledge of livestock nutrient requirements is also necessary. They should also have an assessment of useable forage in a grazing unit, as not all will be available due to inaccessibility and/or factors affecting livestock distribution. Type and size of livestock, age classes, and production status also affect forage demand. In general, a mature non-lactating ruminant will consume about 2% of its body weight in dietary dry matter (NAS, 1996, 1985, 1981). A comparable cecal fermenter will consume 2 to 2.5%, depending on the quality of the forage (NAS, 1989). These amounts can increase by 10 to 30% for lactating beef cows (NAS, 1996) and by 55 to 112%t for lactating ewes (NAS, 1985). Sampling rangeland to determine forage production can be a tedious and time consuming activity. Proper stocking leaves at least 40% of current year's plant growth upon removal of the grazing animals. The manager can elect to physically measure this or use proven estimation techniques (see Cook and Stubbendieck, 1986; Bonham, 1989).

Consumption of toxic range plants by livestock may increase under poor grazing management. Overgrazed range is more prone to a flush of toxic plant growth following precipitation, due to the already weakened state of range forage plants (McGinty and Machen, 1999). Because of reduced grazing selectivity caused by drought, consumption of toxic plants by livestock may increase. In addition, dietary deficiencies in phosphorus or vitamin A may cause livestock to select green plants that may be toxic. Many times toxic plants begin growth before forage plants or remain green and palatable well after forage plants have matured and dried up. Grazing management practices including proper stocking rate, grazing systems, and good livestock distribution all help to maintain an alternative forage choice over toxic plants (McGinty and Machen, 1999).

Livestock Nutrient Requirements and Drought

The previous sections discussed how drought affects plant growth and emphasized the need to adhere to the principles of range management during times of drought. It was stressed that maintaining a proper stocking rate is critical for the sustainability of the range resource, as well as for the health and productivity of livestock. Under drought conditions loss in forage production dictates a reduction in stocking rate. How this reduction occurs can be a major factor in ranch sustainability.

Loss in forage production due to reduced soil moisture can result in livestock having to travel further to meet dry matter or other nutritional needs. Increased travel results in the expenditure of additional energy, confounding losses in body condition and weight due to nutritional stress of lower intake of crude protein, energy, vitamin A, and phosphorus (Brown, 1995). Grazing animals need to consume a relatively greater quantity of dormant forage in order to meet nutrient requirements. However, dormant forage is high in fiber (NDF) and low in

Table 1. Estimated dry matter intake and nutrient requirements of beef cows (kg day^{-1})[1]

Bodty wt. (kg)	Peak milk (kg day^{-1})	Stage of production[2]								
		Early lactation			Late lactation			Gestation		
		DM[3]	CP	TDN	DM	CP	TDN	DM	CP	TDN
450	4.5	10.1	0.9	5.6	10.0	0.8	5.3	9.6	0.7	4.7
	9.0	11.3	1.2	6.7	10.7	1.0	5.9	9.6	0.7	4.7
	13.5	12.4	1.5	7.8	11.4	1.1	6.6	9.6	0.7	4.7
500	4.5	10.8	0.9	6.0	10.7	0.8	5.6	10.3	0.7	5.1
	9.0	12.0	1.2	7.1	11.4	1.0	6.3	10.3	0.7	5.1
	13.5	13.1	1.6	8.2	12.1	1.2	6.9	10.3	0.7	5.1
550	4.5	11.4	1.0	6.3	11.4	0.8	6.0	11.0	0.8	5.4
	9.0	12.6	1.3	7.4	12.1	1.0	6.6	11.0	0.8	5.4
	13.5	13.7	1.6	8.5	12.7	1.2	7.3	11.0	0.8	5.4
600	4.5	12.1	1.0	6.6	12.1	0.9	6.3	11.6	0.8	5.8
	9.0	13.2	1.3	7.7	12.8	1.1	6.9	11.6	0.8	5.8
	13.5	14.4	1.6	8.8	13.4	1.3	7.6	11.6	0.8	5.8
650	4.5	12.7	1.0	6.9	12.8	0.9	6.6	12.3	0.9	6.1
	9.0	13.8	1.4	8.0	13.4	1.1	7.3	12.3	0.9	6.1
	13.5	15.0	1.7	9.1	14.0	1.3	7.9	12.3	0.9	6.1

[1] Source of information: *Nutrient Requirements of Beef Cattle*, 7th Revised Edition, 1996, National Academy of Sciences, Washington, DC.
[2] Months since calving; Early lactation: 1 to 3; Late lactation: 4 to 6; Gestation: 7 to 12.
[3] DM = Dry matter; CP = Crude protein; TDN = Total digestible nutrients.

crude protein. Therefore, intake may be limited. Provision of protein supplements may increase digestibility and thus intake of dormant forage.

A loss in body condition of a lactating female results in a decrease in milk production and reproductive activity. Body condition scores (BSC) of a mature, multiparous beef cow should not drop below 4.5 (on a 1 to 9-point scale) (Spicer *et al.*, 1999), and for a mature ewe not below 3 (Calhoun *et al.*, 1986) at time of parturition and/or upon entering the breeding season. Lower BCS than these will cause lower milk production and fertility, resulting in light-weight offspring and a higher percentage of open females the following year. A reduction in energy intake by sheep as a result of drought can also adversely affect the cross-sectional area of wool fibers by as much as 400% (Calhoun *et al.*, 1986). This reduction in size weakens the fiber resulting in "tender" wool or even a "break" in the wool. Dietary protein levels below 80% of requirement may also result in lower wool production and quality.

Typical dry matter consumption of a mature beef cow (450 to 650 kg) at peak lactation is between 10.5 and 15.5 kg of dry matter per day depending on her weight and milking ability (Table 1). During maintenance she consumes between 9.5 and 12.5 kg day^{-1}. A mature ewe (50 to 90 kg) at peak lactation typically consumes between 2.1 and 3.2 kg of dry matter day^{-1}, but only between 1.0 and 1.4 kg day^{-1} for

Table 2. Estimated dry matter intake and nutrient requirements of sheep ewes (kg day^{-1})[1]

Body wt. (kg)	Maintenance			Early lactation: Suckling singles			Early lactation: Suckling twins		
	DM[2]	CP	TDN	DM	CP	TDN	DM	CP	TDN
50	1.0	0.10	0.5	2.1	0.30	1.4	2.4	0.39	1.5
60	1.1	0.10	0.6	2.3	0.32	1.4	2.6	0.40	1.7
70	1.2	0.11	0.7	2.5	0.33	1.6	2.8	0.42	1.8
80	1.3	0.12	0.7	2.6	0.35	1.7	3.0	0.44	2.0
90	1.4	0.13	0.8	2.7	0.35	1.7	3.2	0.45	2.1

[1] Source of information: *Nutrient Requirements of Sheep*, 6th Revised Edition. 1985. National Academy of Sciences, Washington, DC.

[2] DM = Dry matter. CP = Crude protein; TDN = Total digestible nutrients.

maintenance (Table 2).. Knowledge about livestock forage demand and nutrient requirements, as affected by age or genetic make-up, can help managers design drought management and culling strategies.

Besides addressing livestock nutritional needs the manager also needs to maintain the animal's health. Protection against clostridia and reproductive diseases becomes even more critical during drought. As livestock graze on shorter and shorter vegetation the chance of ingesting soil- borne pathogens increases. In addition, as watering areas dry up livestock and wildlife are forced into more concentrated areas, increasing the chance of leptospirosis spreading between species. Internal parasites may not be a problem during drought, but can be once the drought breaks, as they need moisture for reproduction and movement up the leaf to be ingested. However, external parasites can be a problem and should be controlled. Nutritional stress does not need to be compounded by environmental stresses that can be managed.

Preparing for Drought

Proper grazing management prior to onset of drought can be crucial to survival during and recovery after. The implementation of grazing systems coupled with proper stocking rates will help build a healthy forage base. Healthy rangelands have a greater diversity of plants with a high percentage of decreaser species (i.e., highly palatable and productive plants). Generally, decreaser plants are high-seral, deep-rooted plants, able to exploit moisture better than shallow-rooted invader species (i.e., less palatable and productive). In general, range in good condition will support livestock longer and de-stocking will be less severe early in the drought.

Besides maintaining healthy, vigorous plants, conservative stocking rates can provide sufficient "unused" carryover forage that can be used during short-term drought (Hart and Carpenter, 2001). However, if drought becomes severe, destocking and/or the purchase of feed will need to occur.

Flexible stocking rates and herd composition are also recommended, especially in areas where droughts are common. Hart and Carpenter (2001) indicate that breeding herds should constitute no more than 50 to 70% of the total carrying capacity of the ranch in "normal" years. They state that the remaining herd should consist of yearlings or stocker animals that can be sold when drought occurs. Herd flexibility will help the manager match animal forage demand with forage supply on an annual basis. Even during non-drought years forage supplies will vary from one year to the next (Hart, 2000).

Rothauge (1998) suggests that income obtained from the sale of stocker or "filler" animals be saved strictly for other drought management measures such as buying emergency feed or for herd rebuilding after the drought. He also advises that livestock producers should build a fodder bank, that is, an accumulation of feed to be used as emergency feed during times of scarcity.

Both Hart (2000) and Rothauge (1998) encourage managers in arid and semi-arid regions to keep a "forage reserve" in pastures left ungrazed during the growing season that can provide readily available feed. If these rested pastures are rotated systematically across the ranch, this practice will also contribute to an improvement in range condition. Accurate records on breeding herd performance should also be kept to assist in destocking decisions (Hart and Carpenter, 2001). If drought becomes severe enough for reductions in the breeding herd accurate records will help identify the least productive animals that should be culled first.

Depending on available resources, managers should consider diversifying on-ranch enterprises. If there is a high diversity of plants, the most efficient use of the resource may be a combination of livestock (Savory and Parson, 1980). In situations where problem plants exist due to the use of one type of livestock, the addition of another type may suppress as well as effectively utilize those plants. Combinations of more than one type of livestock can lower drought risk as it opens up more opportunities for management. For example, it may allow for de-stocking of one kind of livestock while other types are able to be kept on the ranch.

The manager should also investigate the feasibility of non-livestock income sources. Wildlife and ecotourism may be a potential source of income, even during drought. Wood products or marketable live plants may be a potential source of income. Although good grazing management generally benefits wildlife, there may be specific management practices that benefit certain wildlife populations and enhances the potential income that can be derived from this resource. As with livestock, water development is often key in maintaining good wildlife populations. The development of alternative income sources needs to occur prior to the next drought, not once the drought is upon a region.

Livestock Destocking Strategies

The first, and arguably the easiest option for range-livestock producers during times of drought is to do nothing, i.e., continue to operate as if drought conditions were not present. If the drought is short-term (e.g., one growing season) and the range resource was in good to excellent ecological condition when the drought began, this option may not result in adverse effects on the range resource (Eneboe *et al.,* 2002). However, if the drought becomes severe or the range was in less than good condition during the drought year, this option could result in severe range degradation. Destocking to balance forage demand with forage supply will generally be less financially detrimental to the livestock producer than the long-term ill-effects of not having destocked or destocking after range deterioration has already begun. Prior to the actual destocking of the range, it should be decided what will be done with the culled animals, as well as which animals will be culled and in what order. If the livestock are to be sold, potential buyers need to be identified, especially those from outside the drought-stricken area. During drought, more animals than normal will be marketed, including breeding stock. Depending on how widespread the drought is, local markets may be inundated with animals causing low demand and prices. However, if livestock beyond what the range will support are to be kept, it should be determined whether feed should be purchased and brought to the ranch or if the animals should be moved to where available feed is located. Costs for both of these two options should be determined along with what can reasonably be afforded. Expenses associated with moving animals to feed include transportation costs, and costs for feed and care (Thompson and Tyler, 1993; Peterson and Dunn, 2002). Likewise, expenses associated with purchasing feed include that for the feed, shipping costs, and yardage (time spent finding feed, and costs associated with feeding) (Peterson and Dunn, 2002). However, depleting financial reserves in order to keep livestock is not advised. In most cases, destocking and selling the livestock is advised rather than purchasing feed or sending the animals to non-drought areas. Thompson and Tyler (1993) propose that relocating animals to non-drought areas or purchasing feed may be a way to salvage the value of the livestock. Drought often results in a devaluation of livestock, but after it breaks livestock valuations often increase (Holechek *et al.*, 1989). However, feeding costs, length of the drought, and the potential increase in value of the livestock post drought need to be considered before the options of relocating the livestock or purchasing feed for them is exercised. The great unknown is how long the drought will last and afterwards, if neighboring ranchers will have the financial resources to purchase animals for herd rebuilding. This option may be best reserved, if economically feasible, for a few base herd animals if entire herd liquidation is imminent.

The first animals to be culled should be stockers or fillers - weaned young from either the breeding herd or those that were purchased. These animals typically do not gain well on low quality forage. Thus, pastures used for stockers can be made available for breeding animals. Options for stockers include selling when drought conditions appear imminent or moved to drylot and fed raised fodder, grains, or crop aftermath if available. However, the economic viability or "break-even" of such practices needs to be determined.

If further livestock reductions are needed, they will come from the breeding herd. Any cow, ewe or nanny that does not have a suckling offspring at side, regardless of their age or pregnancy status, should be culled. These animals will not provide income in the current year unless sold, and will reduce the amount of available forage for females with suckling young. For beef cattle operations, these cows usually comprise 5 to 15% of the cow herd and for sheep operations from 15 to 25%.

Replacement female breeding stock, whether bought or raised, may also need to be culled at this time. These females will not provide income for a year or more if kept and also require a higher plane of nutrition. Removal of replacement heifers or ewes can result in a further stocking rate reduction by as much as 15% for cow herds and by as much as 25% for sheep flocks. Although the overall reduction in forage demand may not be significant, removal of older sires should be proportional to females culled in order to control maintenance costs. Dams with structural defects (teeth, feet, legs, udders) or production defects (low milk production, unthrifty/low weaning weight offspring, low wool quality) should be culled. In addition, females that produce offspring late in the calving/lambing season should be culled. For sheep and goat operations, the removal of dams that produce only one off-spring at a time would also be candidates for culling. Drought can be used as an opportunity to tighten up the breeding season if needed and to remove the least productive animals. If further culling is needed, determine whether the remaining dams are bred and cull any that are open. For beef cattle operations, calves that are at least 60 days old can be successfully weaned. Calves that weigh 180 kg or greater, should be marketed separately. Calves that weigh less than 180 kg should be marketed with the dams. For sheep and goat operations, lambs and kids weighing at least 20 kg should be weaned and sold separately from the dams. Again, the identification of potential buyers early in the drought may be critical for the selling of cull animals and young stock. Further weaning of young should be based on their age and the need to improve dam body condition (see section on early weaning). Additional culling of the herd needs to be based on the idea that those animals remaining will produce offspring in the following years. Dams with the lowest rebreeding potential should be culled. For beef cattle operations, these would be thin (BCS 3 and under) middle-aged cows and thin to moderate (BCS 4 and under) first- and second-calf cows. These cows have lower probability of conception and wean lighter calves than cows in higher body condition. Cows 8-years old and older should be culled next. These cows will be the first to decline in production potential in the future. For sheep and goat operations the same above criteria would also be used, except ewes and does older than six years of age should be sold. For goat operations, any Angora that is a habitual aborter should be culled, and "Spanish" breed females that do not have cashmere fiber are candidates for selling (Craddock, 1998). Although stocker cattle were indicated above to be one of the first class of animals to be culled from a herd, mutton goats may be the most likely class of goats to survive severe drought conditions. The goat producer should determine if this is the case and make appropriate plans. By this time all that will be left of the herd will be the most productive dams and sires and possibly their off-spring. If forage supplies (grazable and harvested) are not adequate to maintain this base breeding herd the only feasible option is to liquidate the herd. Purchasing forage to maintain this base herd generally is not an economical long-term option in most situations. Another aspect of herd liquidation is tax laws of their country. There may be income tax consequences for livestock herd liquidation. Such discussion is beyond the scope of this paper but the livestock producer needs to be aware of the possibility of taxes on this income, as well as any drought related tax deferments that might be available.

Early Weaning

Early weaning of off-spring is a management option that may help lower herd forage demand and improve body condition of the dams because their nutrient requirements will be less than when lactating (Table 1). Although beef calves under six months of age only consume 15 to 25% of the forage consumed by their mothers (Dunn and Johnson, 2002), the forage saved could provide at least an additional month of grazing for the cows if weaning occurred at four months of age instead of the normal six to seven months of age (Table 1). For sheep, early weaning of lambs may be a more plausible practice as forage demand by the ewes may be reduced by over 50% (Table 2). The livestock producer does, however, need to be aware that early weaned young, especially those younger than 4 months for calves and 2 months for lambs, may have little value if marketed during a widespread drought, and that these young will require more care and management.

Early weaning can increase stress and reduce performance of the off-spring if proper health, nutrition and management practices are not followed (Pirelli and Zollinger, 2002). Conversely, if weaning does not occur until after pastures have severely deteriorated the results may be low weaning weights for the young and low body condition scores for their mothers. As a lactating female loses body condition she experiences a general decline in milk production, having a negative affect on suckling off-spring weight gain (Whittier, *et al.*, 2002). Early weaning should be done mainly to improve dam body condition for entering the dormant season to minimize the need for energy supplementation (Table 1). A dam going into the dormant season in good body condition is easier and cheaper to maintain than one that enters this season in poor condition. Thompson *et al.* (1983) found that thin beef cows required 6 to 10% more energy to maintain their weight through the winter in a cold environment as compared to cows in a moderate to high body condition. Furthermore, females entering post-partum in low body condition are prone to more difficult births as well as delayed estrus (Herd and Sprott, 1987). Culling practices as discussed above should take precedence over early weaning. As young reach the suggested minimum age for weaning they should be weaned, sold, and the dams separated from those still with suckling young to increase management options.

Supplemental and Substitute Feeding

Supplemental feeding is the feeding of harvested feeds to meet the nutritional needs of an animal when forage supplies are adequate but are low in nutritional quality (e.g., protein, energy, or minerals). Substitute feeding, however, is the replacement of standing or harvested forages with a grain (or hay) due to low quantities of the former and primarily done to meet the animal's energy needs (Wright, 2001). Under drought conditions supplemental feeding of rangeland livestock may be necessary to meet their nutritional needs. This assumes that there is sufficient standing forage to meet dry matter requirements. In reality, stock reductions will probably be necessary for sufficient dry matter to be available. Protein supplementation usually results in greater intake of the available forage (Dunn and Johnson, 2002). Supplemental protein alters rumen nitrogen, enhances microbial activity and generally increases both digestible microbial protein and total digestible nutrients (TDN). Thus, increases in rate of digestion and passage occur. If the amount of available forage is not adequate to meet the grazing animal's dry matter needs, supplemental feeding becomes substitute feeding, resulting in greater monetary outlay for the producer. Substitute feeding, especially for extended periods, should be closely evaluated. Often the costs of long-term substitute feeding outweigh potential benefits.

When forage resources become scarce due to drought, the range livestock producer is tempted to purchase feeds, whether fodder or grains, to see the animals through the dry period. Purchase of feedstuff beyond what is normally bought in a production year could lead to economic disaster, especially if the drought persists for an extended period and culling of the herd has not been undertaken. Developing a management plan before the drought occurs, and closely following that plan, is crucial for livestock operations in arid and semi-arid climates. As discussed previously, livestock producers need to know the nutrient requirements of their livestock and the quality of their forage resources to be able to determine what level of supplemental feeding is needed, and when it is no longer economically plausible. In addition, culling of animals should be undertaken to minimize the purchasing of feedstuff to that needed only to meet the nutrient needs of the remaining herd.

When providing supplemental feed to livestock, the herd should be sorted into production groups to obtain the greatest benefit from purchased feeds (Carpenter and Hart, 2001). This activity will help prevent over- and under-feeding due to age differences and production status of the animals. The herd should be sorted into the following groups: lactating dams, dry dams, and growing replacement females. In addition, dams can be further divided into age groups. Young females (<4 years of age for cattle and <3 years of age for sheep and goats) will often require a higher plane of nutrition in order to rebreed. The goal of supplemental feeding is to meet the nutrient needs of the animals at the least possible cost. This goal can be more easily obtained if calving, lambing and kidding seasons are short. The less variability there is in the breeding herd the easier it will be to target supplemental nutrients to specific types of animals and for specific periods of time.

Typically, the first limiting nutrient in low quality forage diets (<7% crude protein), is protein. Protein supplements are often a good way of getting additional utilization out of these low quality grazed or harvested forages, increasing total protein and energy supply to the animal. Providing ruminally degradable protein supplements from natural sources stimulates forage intake, digestion and performance (Peterson, 1987; McCollum and Horn, 1990). Additional, less expensive sources of ruminally degradable protein are various forms of non-protein nitrogen (NPN). These NPN feeds such as urea, biuret, and ammonium sulfate provide additional ruminal ammonia (required by cellulolytic bacteria), but often do not generate the same positive response in forage intake and digestibility as ruminally degradable natural proteins. Despite the reduced response, many range supplements include at least a minimal level of NPN to provide a portion of the degradable intake protein (DIP), or that protein that is readily digested in the rumen. Cochran (1995), in an extensive review of supplementation programs, reports that an acceptable level of supplemental NPN depends on the digestibility of the forage, as well as total DIP intake of the animal, but generally, supplying 30% or less of the supplemental DIP from NPN sources allows for an adequate supplement response, while helping to reduce supplement cost.

Additional opportunities for supplemental feeds include many of the by-product feeds, or residues from the cereal grain and oilseed milling and processing industry. Examples of by-product feeds include wheat middlings (produced during wheat flour milling), soybean hulls (soybean oil extraction), distiller's grains (ethanol production) and corn gluten feed (high fructose corn syrup production). By-product feeds are characterized by moderate to high energy values, medium to high protein, and relatively high fiber content. The combination of these attributes result in an excellent supplement that provides additional energy and protein to grazing animals while having minimal to positive effects on forage intake and digestibility. When the cost of harvested forages is high because of low availability but grain prices are low, grains, especially corn (*Zea maize*), can be a good substitute for forages normally purchased for the herd. The substitution of grains for hay is to supply an adequate amount of energy into the animals' diet (see Limit-Fed High Grain Rations section). However, because grains such as corn are high in energy compared to that in forages the substitution ratio is not one-to-one. In addition, as grains are increased in a ruminant animal's diet forage, intake and digestibility decreases (Chase and Hibberd, 1987; Horn and McCollum, 1987; Sanson and Clanton, 1989; Pordomingo *et al.*, 1991). However, providing a highly degradable protein supplement can help overcome the negative associative affects of grain starch on forage fiber digestion (Clanton and Zimmerman, 1970; Pruitt *et al.*, 1993). The cost of supplemental protein in addition to the cost of grain used in place of forages should be calculated. The same salt and mineral mixtures provided during "normal" conditions should be continued through drought. However, phosphorus supplementation may need to be increased. Close attention should also be paid to animal vitamin needs, especially Vitamin A. Drought-stricken forages generally lack sufficient amount of Vitamin A for livestock.

Limit-fed High Grain Rations

Several researchers have evaluated limit-fed grain diets used in wintering programs. Pope *et al.* (1993) evaluated both energy concentration and degree of feed restriction with corn and corn silage based diets offered to weaned replacement heifers. Cattle on the higher energy diet had similar gains, despite having a greater feed restriction. Age of puberty was not affected by the limit-fed diets. Similarly, O'Neil *et al.* (1999) evaluated four wintering rations offered to replacement heifers, ranging from *ad libitum* prairie hay to limit-fed diets of either whole shelled corn, wheat middlings/soybean hull pellets, or barley malt sprouts. Winter gains were similar across all treatments, but reproductive data was not reported. Fewer studies have evaluated the use of limit-fed grain rations with adult cows. Brethour *et al.* (1990) evaluated the use of limit-fed rations as an alternative to summer grazing. Treatments included a traditional pasture grazing treatment with adequate forage vs. two drylot treatments offered milo and sorghum silage. Cattle in drylot received similar rations, however calves were weaned from one treatment after 13 days in drylot. After weaning, the limit-fed ration was reduced accordingly. Summer gains during the 93-day trial were similar, and pregnancy rates were highest for the drylotted, limit-fed cows that were early-weaned, indicating that summer drylot programs are feasible, and weaning the calf early can potentially improve rebreeding rates. More recent, peer-reviewed studies (Loerch, 1996; Tjardes *et al.*, 1998) both indicate that limit-fed winter rations have the potential to reduce winter feeding costs while having minimal effects on cow weight changes and reproductive performance. Loerch (1996) reported data from three trials involving limit-feeding adult cows. Rations used in all three trials varied only slightly from year to year, and contained very little forage, providing only 0.8 to 1.5 kg of hay per day. Cow performance was similar for limit-fed and free-choice hay treatments, although additional hay may have improved contentment. There were no differences in calving difficulty, however two of the three trials showed increased birth weights of calves born to limit-fed cows. Calf weaning weights and cow conception rates tended to favor the limit-fed cattle. Tjardes *et al.* (1998) also evaluated limit-fed diets, including supplemental fat as one of the treatments. They reported no difference in cow weight change, reproductive performance, or calf weaning weights between the *ad libitum* hay and limit-fed diets. A second study evaluated the effect of supplemental fat in limit-fed diets. Cattle on both treatments lost a similar amount of weight, and there was a numerical decrease in calving rate for the fat- supplemented cattle. These studies all indicate that high-grain, limit-fed diets are feasible and have minimal effects on cow performance, reproductive rates, and calf weaning weights. There still are additional questions as to whether supplemental fat is beneficial in limit-fed diets when additional components of the production system are evaluated.

Alternate Feed Sources

Drought not only causes a reduction in range forage but often a reduction in hay and grain crops, especially if irrigation is curtailed or not available. Drought also causes prices for harvested feeds to increase due to the increase in demand relative to the supply, whether or not the supply is reduced. Alternative feeds that may have been little used in the past can take on a more important function in times of drought. Within many regions of the United States, crop aftermaths are often used as feed sources (cereal grain straws, maize and sorghum stalks, and beet tops) but are used much more extensively when drought occurs. Even though drought may cause grain crop failures, these crops still can have value as a forage crop for livestock, either by grazing or put up as hay. The livestock producer needs to identify and take advantage of these available forage resources.

Grain crops may be part of the livestock producer's operation and thus some salvage of these crops can occur by feeding them to the livestock. The salvaging of such crops can help keep the livestock thrifty and productive, allowing them to continue to provide food and/or an income to the rancher. If the crops belong to a neighboring farmer that does not have livestock or not enough to fully utilize the available forage, arrangements should be made for the use of the crop as a feed source for the benefit of both producers. Cereal grain straws, if available, may be an alternative forage for livestock during drought, but they are generally of low quality, limiting digestibility and intake, reducing their potential use. However, research by beef animal scientists in the United States and Canada, found that if baled or stacked straw was covered and then ammoniated with anhydrous ammonia it increased in digestibility and consumption (Rasby *et al.*, 1989). Digestibility of ammoniated straw was found to increase by 10 to 15%, resulting in an increase in consumption by as much as 22%. Furthermore, due to nitrogen from the ammonia attaching to fiber parts of the straw, crude protein content of the straw also increased. However, supplementing with a natural protein source to meet the animal's crude protein needs is advised. If grain sorghum crops are to be grazed the producer needs to be cognizant that sorghums contain hydrogen cyanide (HCN) and can cause prussic acid poisoning. Any stress that disrupts normal growth, such as drought, can contribute to prussic acid toxicity. Drought-stricken plants consist mainly of leaves which contain higher levels of HCN as compared to stalks. In addition, regrowth following drought can have deadly concentrations. Poisoning can result from grazing or green chop feeding, whereas it is generally safe to feed ensiled or hayed sorghum. The range livestock producer should also investigate the feasibility of raising cultivated forage crops that have drought tolerance, especially if drought conditions are predicted to persist. These drought tolerant forage crops, in most cases, should be planted on cultivated lands that are generally planted to annual grain crops that because of the drought will probably not produce a crop. The plowing of perennial plant hay fields may be ill-advised during drought because of the increased potential for wind-borne soil erosion if the planted forage crop fails to establish. Besides using failed grain crops and crop aftermath as alternative feedstuff for range livestock, there are some plants, normally not consumed by livestock due to physiological features, that can provide temporary forage for the animals. *Opuntia* species have been used as feed for cattle by scorching off the spines (Holechek *et al.*, 1989; Vallentine, 1990). The weedy annual *Salsola iberica* has been put up as a hay crop, or grazed - in the western U.S. during times of drought - prior to maturation when its leaves become sharp-pointed. Use of other weedy annuals should also be considered. *Kochia scoparia*, a weed of cultivated fields in the U.S., is palatable to all classes of livestock and has been used for grazing, haying, or as silage. The above section and culling practices indicated that if conditions dictate, livestock herds should be reduced to the basic breeding herd or even liquidated to minimize damage to the range resource.

However, such actions reduce or eliminate a source of income and for some societies their main source of food. Utilizing all feed resources available to the herd could mean the difference between surviving the drought or financial ruin, and in some cases starvation.

Nitrate Concerns

Additional feed concerns include checking drought-stressed feeds for nitrate levels, especially warm season annual forages such as sudan and millet hays. Emergency forages, such as *Kochia scoparia*, also have the potential to be high in nitrates. A laboratory test is the only sure way to know whether or not a plant contains high levels of nitrate. General recommendations are that feeds with nitrate (NO_3) levels of 6,000 mg kg^{-1} (1% KNO_3) or less are generally safe. Feeds with nitrate levels of 6,000 to 9,000 mg kg^{-1} (1% to 1.5% KNO_3) are potentially toxic, and should be fed with caution, and those with levels over 9,000 mg/kg (1.5% KNO_3) are extremely dangerous and must be diluted and blended with other feeds. Pregnant animals should not be fed rations that contain more than 2,000 mg kg^{-1} nitrate-nitrogen on a dry-matter basis. It is generally safer to feed susceptible forages to non-pregnant animals, and remember that nitrates remain in the plant, no matter how long the hay is stored. In addition, because nitrates concentrate in the lower third of the stalk, raising the cutter bar when haying, and not forcing cattle to graze these plants close to the ground, can help reduce the danger. Some weedy plants accumulate nitrates and drought exacerbate this accumulation. Under favorable climatic conditions with abundant forage, livestock consume little, if any, of these weedy plants, but under drought conditions with a shortage of desirable forage they may readily eat a quantity that can result in nitrate toxicity. Livestock producers need to be aware as to what plants within their area are nitrate accumulators and either eliminate these plants or keep their livestock from having access to them. However, if these weedy plants can provide a significant amount of forage they should be tested for their nitrate level and fed accordingly.

Water Concerns

As stock ponds get low, one of the nutrition and health concerns is the quality of the remaining water. Adult cows typically require 26.5 to 41.5 L of water per day depending on outdoor temperature and her stage of production. Ewes typically require 7.5 to 11.5 L per day. Poor quality stock water can actually decrease water intake, putting additional stress on the animal. Most water tests report Total Dissolved Solids (TDS) as a measure of the concentration of dissolved salts. TDS levels less than 3,000 mg kg^{-1} are generally safe for livestock (NAS, 1974). Levels of 3,000 to 5,000 may not dramatically affect adult livestock, but young, growing livestock may have poor performance and characteristic looseness. TDS levels of 5,000 to 7,000 should not be offered to pregnant or lactating animals.

Another water quality concern is sulfate levels. High iron and sulfate levels can affect trace mineral absorption, especially copper, but high sulfate water can also increase the risk of polioencephalomalacia or "polio". Symptoms of "polio" cattle include blindness, signs of nervousness, and uncoordinated movement.

Besides TDS and sulfate levels, the manager should be aware of the potential for blue-green algae (cyanobacteria) poisoning from stock ponds where the water becomes stagnant due to drought conditions. As the water level in a pond drops, less oxygen is available, resulting in death of algae cells. Live algae cells are homogeneously suspended in the water, but when large numbers of them start to die, gas is produced inside the cells, and colonies float to the pond surface (Epperson, 2002). The organisms concentrate downwind to form a "scum" on or just below the pond surface. If an animal drinks in this scum it may die immediately or succumb hours or days later.

To prevent blue-green algae poisoning the manager should monitor stock ponds for algae blooms, especially during hot weather (Epperson, 2002). To reduce risk of poisoning, downwind drinking areas of the pond can be fenced off, forcing livestock to drink where concentrations are less likely to occur. Other options include pumping water from several meters below the surface to an above-ground tank; providing water from other sources if available; or, adding copper sulfate to the water as an algacide prior to the presence of large concentrations of blue-green algae. Fencing the pond off from livestock and pumping the water to an above-ground tank has the added benefit of reducing stress caused by the animals wading through boggy conditions to get a drink.

Management Following Drought

Determining that a drought is over can be difficult. It may be assumed that a drought has broken when enough precipitation over a long enough time period has occurred to fill the soil profile with moisture. It is this subsurface soil moisture that provides moisture for forage growth and production between rainfall events. Although a drought may have broken, the negative effects of the drought on the range will linger. How long these effects last is dependent upon how the range was managed during the drought, its severity, and management after the drought. Prior to restocking range conditions should be assessed so proper management decisions can be made. Signs of severely deteriorated range conditions include: a decrease in desirable plant species and a lack of seedlings; an increase in less desirable plants; absence of sufficient litter and crusted soils; stooling of plants; formation of new gullies; excessive development of livestock trails; and a decrease in water infiltration. The severity of these indicators will influence management practices selected to reverse these negative trends. Reece *et al.* (1991) suggest that pastures most likely to provide the largest increases in forage production should be given management priority.

Restocking too early is probably the most common error livestock producers make following drought. Allowing perennial forage plants an opportunity to recover from the adverse effects of moisture stress is critical to returning the range to its pre- drought condition. The natural restocking of rangelands by wild ungulates - through a decrease in mortality and an increase in natality - is slow, increasing as forage availability increases. This natural lag in the population increase of ungulates provides time for the perennial range vegetation to grow and produce new plants through seeding and vegetative clones. Rangeland livestock managers should take note, and learn from nature. Reece *et al.* (1991) suggest that specific management practices beneficial for assisting plant recovery are:

1. Rest the pasture for an entire year.
2. Use the designated pasture only for dormant season grazing for one or more years.
3. Use pastures intensively when least desirable species are green and palatable. Remove livestock once they begin to graze key forage species.
4. Defer grazing until key forage species have developed mature seed. Utilization should not exceed 50%.
5. Defer grazing until grasses have reached the four to five leaf stage. Remove livestock when key grass species reach the late boot stage.
6. Utilization should not exceed 50%.
7. Graze at a time when a key grass species is least preferred by livestock. This often is after seed production.

If livestock producers reduced stocking rates by culling then restocking will probably follow a more natural state as it generally takes time to rebuild herd numbers. However, if a significant portion of the breeding herd was moved to other regions for pasture or feeding, it may be necessary to bring the animals back to the home range before full recovery occurs. If fields are available, seeding of cereal grains or annual forage grasses such as sudan grass or millets should be done to provide grazing (Dunn and Johnson, 2002). This may be a viable option to help defer grazing on range pastures for at least one growing season.

Grazing management plans should be developed, implemented, and adhered to following a drought. Grazing plans developed to meet management objectives should consider the land, livestock, and people collectively. A good plan incorporates the fundamental tools of grazing management. Stocking rates, livestock distribution and degree of use were previously discussed. Consider also the types of animals that may best utilize available forage during the restocking plan. Large herbivores (cattle, bison, horses, elk, etc.) prefer grasses and as a result, over-grazing by them can lead to a decline in grasses and an increase in forbs and browse on rangeland. Comparatively, intermediate feeders (sheep, antelope, etc.) consume more forbs, and browsers (goats, deer, etc.) more woody species (Vallentine, 1990).

Livestock producers should be aware that the return of good moisture often results in an initial flush of annual weeds, especially on severely deteriorated ranges with bared soil. Although these annual weeds may provide short-term forage for livestock, it can not be depended upon for an extended period of time. Sustainable stocking rates should be based on available perennial forage plants for recovery of the range. In addition, invasive weeds that have no forage value should be controlled as they compete with perennial forages for available soil moisture and hinder range recovery. Range reseeding is one option for ranges that have lost a significant amount of perennial forage plants. However, reseeding is generally expensive and high risk in arid and semi-arid regions. When seeding is necessary do not allow grazing on seeded pastures until plants have fully established.

Management Summary and Recommendations

Surviving a drought is accomplished through proper planning and management before, during, and after the drought. Livestock producers should implement grazing management plans that incorporate proper stocking rates, improve livestock distribution, provide adequate rest for each grazing unit, and not allow more than 60% removal of plant foliage. They should increase herd flexibility with filler or stocker animals, consider multi-species grazing, and develop other potential income sources. Livestock producers should also develop comprehensive drought management plans that will serve as a guideline in making decisions. This plan should include de-stocking strategies that will include strategies and timing for culling, as well as identifying potential buyers. In addition, the plan should include what possible alternative feed sources would be available and their potential costs. Government entities involved in agriculture and natural resource management education and technical service should be consulted in development of grazing and drought management plans. Many times funding sources are available through government agencies for the development of rangeland watering facilities, fencing, or brush control practices that enhance a producers ability to cope with drought.

Purchasing feed during drought beyond what is normally purchased in non-drought years is generally not recommended. Such actions can lead to greater range degradation because animals are kept on pastures for too long. This results in an exacerbation of the effects of the drought on the range resource lasting well after the drought has broken causing greater economic hardship. Government policies that provide funds for feed purchases during severe drought are many times counterproductive. Government policies need to encourage good land management practices that result in rapid recovery of natural resources.

Purchasing additional feed, or raising and keeping more fodder than annually used during non-drought years may be an option that can help livestock producers survive a mild drought. Herd reductions should still be considered, as length of the drought is not predictable. The ability to predict forage production with significant reliability based on amount and timing of effective precipitation is lacking for many arid and semi-arid rangelands. This information could be a valuable tool for range livestock managers. By knowing that the amount of precipitation received by a certain date results in a certain amount of forage, livestock producers will better know when and if they need to enact drought management plans. An effective early warning system such as this could reduce range degradation and the adverse affects of drought on the people making a living from arid and semi-arid rangelands through livestock production.

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