United States
Department of
Agriculture

**Natural
Resources
Conservation
Service**

National Range and Pasture Handbook

Chapter 5 Management of Grazing Lands

Chapter 5 Management of Grazing Lands

This chapter primarily contains guidance for planning grazing management on the various kinds of grazing lands. The chapter is divided into three major sections. Section 1, Managing Native Grazing Lands, gives guidance on managing rangelands, grazed forest lands, and native and naturalized pasture. Section 2 is Managing Forage Crops and Pasturelands. Section 3, Procedures and Worksheets for Planning Grazing Management, is procedures and worksheets for forage inventory, livestock inventory and forage balance, determining forage composition and value ratings, stocking rate and forage value rating, and prescribed grazing schedule.

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Section 1 Managing Native Grazing Lands

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Example

The management of plant communities depends on an understanding of the ecological processes and the ecology of the communities to managed. Some processes of change are so universal as to be considered general ecological principles. Others may be less widely applicable (regional) and more closely related to particular communities or individual characteristics of a species.

600.0500 Managing rangelands

(a) Dynamics of ecological sites

The natural plant communities for an ecological site are dynamic. They respond to changes in environment, to various uses, and to stresses by adjusting the kinds, proportions, and amounts of species in the plant community. Climatic cycles, fire, insects, grazing, and physical disturbances are factors that can cause plant communities to change. Some changes, such as those resulting from seasonal drought or short-term heavy grazing, are temporary; others may be long lasting. Changes may cross a threshold and cause a permanent change in the ecological site potential.

Individual species or groups of species in a plant community respond differently to the same use or stress, such as fire, changes in climate, and grazing or browsing pressure. It is normal for some plants to be grazed more closely and frequently than others when grazed by livestock or wildlife. Most plants are sensitive to stress during some stage of growth. They may be severely affected by improper use or stress during critical growth periods, but tolerant at other times.

Many plants respond to changes in the microenvironment in a unique manner that may be different from their associated species. For example, some species are destroyed by fire, while the plant next to it thrives following a fire. The same weather conditions may be favorable for the growth of one species in a plant community while unfavorable for another species in the same community. A growing season in which frequent light rainfall occurs may be ideal for some species. Other species may depend upon deep soil moisture, making frequent light rainfall ineffective for that species even though the total rainfall may be above average. Thus many complex factors contribute to changes in the composition, function, and trend of plant communities. Not all changes are related to grazing by livestock. Many changes may be caused by climatic fluctuations, fire, and extreme episodic events.

To develop alternatives with the decisionmaker for management of rangeland, NRCS employees must understand how an ecological site or association of sites responds to disturbance or other treatment. It is necessary to identify the ecological site and understand the description for that site. The ecological site description has the information necessary to interpret the findings of inventories to determine the rating of an ecological site.

(b) Establishing management objectives

Management objectives are developed and determined with the landowner during the planning process. All inventory and other necessary information for the development of objectives and the application of the grazing management are gathered during the planning process. The objectives of the landowner and those of the NRCS do not need to be the same, but they must be compatible. The management objective must meet the needs of the landowner, the resources, and the grazing animals.

(c) Determining treatment alternatives

For most management units, there are several management alternatives. These alternatives must provide the kind of plant community that provides for and maintains a healthy ecosystem, meets resource quality criteria in the local field office technical guide, produces adequate, available amounts of quality forage for the grazing animals, and meets the needs of the grazing land enterprise(s) and the desires of the landowner. The plant community that meets these criteria is the desired plant community.

After the cooperator has set goals for the site based upon the intended use, the NRCS conservationist provides information and analysis to assist the cooperator in selecting the appropriate plant community to meet these goals. This plant community becomes the desired plant community (DPC). The trend is determined (see chapter 4), and the appropriate plans are made by the cooperator to either maintain the existing plant community (if it is the DPC) or plan the appropriate transition from the present plant community to the desired plant community. This decision sets the stage for the selection of the appropriate conservation practices and resource management systems for the cooperator’s conservation plan.

The NRCS conservationist will use information from the ecological site description, trend determinations, similarity index determinations, rangeland health determinations, and other information to assist the land manager. This assistance will provide alternatives that would most likely lead toward the desired plant community.

This stage of the conservation planning process involves the following steps:

- Inventory the present plant community and determine annual production for each species.
- Identify from the ecological site description the desired plant community that meets the land manager's goals and the resource needs.
- Determine what changes may be occurring (determine trend).
- Compute similarity index of present community to the desired plant community.
- Determine how the ecological processes of the site are functioning (rangeland health determinations).
- Determine what conservation practice alternatives and resulting resource management system will achieve or maintain the desired plant community.
- Provide followup assistance to land manager in plan implementation.
- Provide assistance to monitor trend.

Conservation practices applied on grazing lands are grouped into three categories to reflect their major purposes: vegetation management, facilitating, and accelerating practices.

Vegetation management practices—Practices that are directly concerned with the use and growth of the vegetation. Example are prescribed grazing and prescribed burning.

Facilitating practices—Practices that facilitate the application of the vegetation management practices. Examples are water development, stock trails, fencing, and prescribed burning.

Accelerating practices—Practices that supplement vegetation management. These practices help to achieve desired changes in the plant community more rapidly than is possible through prescribed grazing management alone. In some instances, the practices may be required to achieve desired change. Examples are brush management, range planting, and prescribed burning.

This list of conservation practices is not complete. Definitions and standards for each conservation practice are provided in the National Handbook of Conservation Practices. The local Field Office Technical Guide provides detailed information applicable to the conservation practices discussed, and others available to be considered in development of alternatives with the landowner.

(d) Planning grazing management

The Natural Resources Conservation Service provides assistance to cooperators who wish to apply grazing management. The primary conservation practice used is prescribed grazing. Prescribed grazing is the vegetation management practice that is applied to all land where grazing is a planned use. The grazing may be from domestic livestock, semi-domestic animals (buffalo and reindeer), or wildlife. This practice has been developed to incorporate all the methods and concepts of grazing management. Prescribed grazing is the controlled harvest of vegetation with grazing or browsing animals, managed with the intent to achieve a specified objective.

The objectives developed with the landowner during the planning process determines the level of planning and detail necessary for the application of prescribed grazing. The minimum level of planning for the prescribed grazing practice includes enough inventory information for the landowner to know the proper amount of harvest to maintain enough cover to protect the soil and maintain or improve the quality and quantity of desired vegetation. The available forage and the number of grazing and browsing animals must be in balance for effective management of grazing lands. This is done by developing a feed, forage, livestock balance sheet. This part of the inventory identifies the available forage from the land and the demand for forage by the livestock and wildlife. It identifies where and when shortages or surpluses in forage exist. Procedures and worksheets are in section 3 of this chapter (exhibits 5–1, 5–2, 5–3, 5–4, 5–5, and 5–6).

Grazing is one of the major forces in defining what plant species will dominate a site. Different grazing pressures by different grazing and browsing animals favor different plant species. If the grazing is severe, undesirable plants are generally favored.

Grazing management can be planned and applied that favors a particular plant community or species. This can be done to meet the objectives of the landowner and the needs of the resource. Grazing management has been successfully planned and applied that has favored the re-establishment and increase in woody plants along riparian areas while still providing quality forage for the grazing animal.

Alleviation of grazing pressures that have induced composition changes in a community does not immediately and by itself terminate or reverse the change that such pressures induced. Many plants, desirable and undesirable to grazing, are long lived. If increase of undesirables is related to only the suppression of the desirable species, a change in grazing pressure and management sometimes permits the desirable species to regain their competitive status and suppress the invaders. Such a rapid recovery can occur only when prior grazing has been harmful for a comparatively
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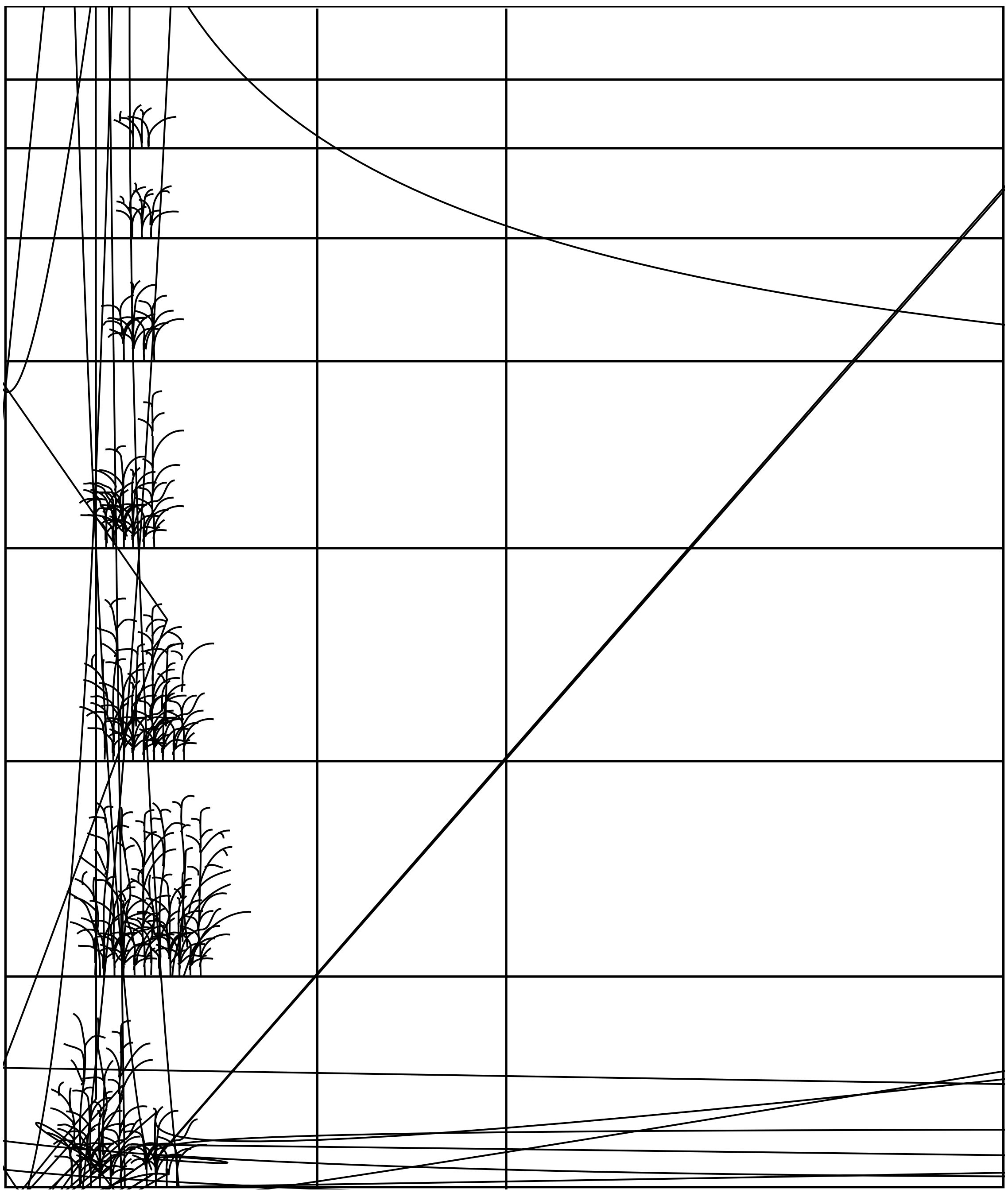
Management of the grazing animal is one of the most economical methods to ensure the health and stability of the grazing land resource. For grazing management to be successful, it must meet the needs of the land, based on the NRCS Field Office Technical Guide quality criteria, the landowner, and the livestock. Meeting these needs is essential to the success of all grazing management.

Figure 5–1 Relationship between grazing and root growth (Crider 1955)



(1) Key grazing areas and key species

The grazing enclosure is the management unit for grazing land. Every management unit has certain characteristics that influence the distribution of grazing. Among these characteristics are soil, topography, size of enclosure, location of water, fences, riparian areas, natural barriers, and the kinds and distribution of plants. In addition, weather conditions, insects, location of salt and minerals, type of grazing management being applied (frequency and severity of grazing), and habits of the grazing animals affect the pattern of grazing use. For these reasons it is impractical to prescribe grazing use for every part of a large grazing unit or to prescribe identical use for all enclosures of a farm or ranch. Determining the key grazing area(s) in each enclosure and planning the grazing to meet the needs of the plants in the key area are more practical. If the key grazing area of a unit is properly grazed, the unit as a whole will not be excessively used. The key grazing area in a management unit is a relatively small area within the grazing unit. This key area(s) is used to represent the grazing unit as a whole.

Most plant communities in a grazing unit consist of several plant species in varying amounts. Even though the entire plant community is of concern to management, to attempt to attain the desired use of every species would be impractical. It is more practical to identify a single species (or in some situations two or three) as a key species to serve as a guide to the use of the entire plant community. If the key species within the key grazing area is properly grazed, the entire plant community will not be excessively used.

Characteristics of a key grazing area:

- Provides a significant amount, but not necessarily the greatest amount, of the available forage in the grazing unit.
- Is easily grazed because of even topography, accessible water, and other favorable factors influencing grazing distribution. Small areas of natural concentration, such as those immediately adjacent to water, salt, or shade, are not key grazing areas, nor are areas remote from water or of limited accessibility. However, riparian areas are of special concern when establishing key grazing areas. Riparian areas are of generally small extent in relation to the surrounding landscape. These areas represent a significant resource in terms of forage production, buffering surface water flows, controlling accelerated erosion and sedimentation, capturing and transforming subsurface pollutants, and providing essential wildlife habitat and local biodiversity. From an ecological basis, their designation as a key grazing area is therefore an important consideration. From the landowner's perspective, properly managed riparian areas will be key in retaining flexibility and control of the property. Table 5–1 is an example of how and when to consider using a riparian area as a key grazing area.
- Generally consists of a single ecological site or part thereof.
- Areas of special concern can also be designated as key areas. Areas of special concern could include habitat for threatened or endangered species, cultural or archeological resources, water quality impaired waterbodies, and critically eroding areas.
- Is usually limited to one per grazing enclosure. More than one key grazing area may be needed for an unusually large enclosure, enclosures with riparian areas, enclosures that have very rough topography or widely spaced water where animals tend to locate, when different kinds of animals graze the enclosure, or when the enclosure is grazed at different seasons. The entire acreage of small enclosures can be considered the key grazing area.

Key grazing areas should be

- Selected only after careful evaluation of the current pattern of grazing use in the enclosure.
- Selected to meet the objectives and needs of the resources, livestock, and landowner. Objectives and needs must meet the FOTG quality criteria.
- Changed when the pattern of grazing use is significantly modified because of changes in season of use, kinds or classes of grazing animals, enclosure size, water supplies, or other factors that affect grazing distribution.

Characteristics of key species:

- Palatability—A relatively higher grazing preference is exhibited for it by the kind of grazing animal and for the planned season of use than for associated species in the key grazing area. (Very palatable plants that have a negligible

production potential should not be selected as key species except as needed to meet management objectives or resource goals; e.g., riparian areas.)
- Provides more than 15 percent of the readily available forage in the key grazing area. A species providing less than 15 percent of the available forage can be selected as the key species if it has a potential for greater production or if it is critical to the needs of grazing animals. A species producing less than 15 percent of the forage may also be selected if necessary to meet the FOTG quality criteria, the needs of the resource, or the landowner's objective. A choice browse species on deer winter range or in a riparian area are examples of such a species. Selection of this kind of species usually necessitates a reduction in the stocking rate, and additional measures may be needed to hasten an increase in the desired species.
- Is consistent with the management objectives for the plant community. If the objective is to maintain or improve the plant community to a near climax state, the key species should be one that is a major component of the historic climax plant community.
- Is a perennial except where the grazing land is managed specifically for annual vegetation or where the grazing unit has only annual species or a mixture of annuals of good forage value and perennial species of little or no grazing value.

Key species should be selected only after the decisionmaker
- Chooses the key grazing area and evaluates the present plant community.

Table 5–1 Decision support for consideration of riparian areas as key grazing area*

Factors	Riparian area characteristics		
Proportion of unit	< 5%	5 – 10%	> 10%
Livestock accessibility	Difficult because of surface rock, steep slopes, debris, etc.	Some difficulty, but consistently used by livestock classes able to deal with limitations (e.g., yearlings)	Readily accessed and consistently used by all classes of livestock.
Habitat/forage for livestock	Livestock do not congregate for protection or forage based on season of grazing, geographic location.	Livestock congregate for water, protection, or forage based on season of grazing, geographic location.	Livestock congregate for water, protection, and forage based on season of grazing, geographic location.
Ecological site	Similar to associated upland	Diffhic aurom (associate)-1146.6(Diffhic aurom (associate) TJ 12.6 -1.2 TD	

J/A

abundant nor uniformly distributed, and they do not have the same ecological status. Thus, a specification based on weight per acre would be impractical. Until a workable procedure is developed, grazing use specifications are to indicate the percentage of annual growth that can be removed from the key plant species in key grazing areas.

- Monitoring Percent Use of Grazing Species form (exhibit 4–3 in chapter 4) is useful for recording planned utilization specifications for key species in key grazing areas. Data concerning actual grazing use for future comparisons can also be recorded. Methods for determining the degree of utilization of key plants are described in chapter 4, 600.0401(e).

(e) Degree of grazing use as related to stocking rates

Because of fluctuations in forage production or loss of forage other than by grazing use, arbitrarily assigning a stocking rate at the beginning of a grazing period does not ensure attainment of a specific degree of use. If the specified degree of use is to be attained and trend satisfactorily maintained, stocking rates must be adjusted as the amount of available forage fluctuates.

When determining initial stocking rates, grazing distribution characteristics of the individual grazing unit must be considered. For example, a Stony Hills Range Site that has steep areas adjacent to a relatively level Loamy Upland Range Site generally receives less grazing use by cattle than the Loamy Upland Range Site. The Stony Hills Range Site may produce enough forage to permit a stocking rate of 2 acres per animal unit per month when it is the only site in a grazing unit. Its grazing use, however, is generally substantially less, in the example just described, by the time the Loamy Upland Range Site has been properly used. The reverse may be true if the grazing animal is sheep or goats. Therefore, initial stocking rates for a grazing unit should not be based directly on the initial stocking rate guides without a careful onsite evaluation of factors affecting grazing use of the entire grazing unit.

Many methods are used to determine the initial stocking rate within a grazing unit. Often the past stocking history and the trend of the plant community are the best indicators of a proper stocking rate. The Multi Species Stocking Calculator in the Grazing Lands Application (GLA) software is one method for determining stocking rates, especially when the area is grazed or browsed by more than one kind of animal. See also Stocking Rate and Forage Value Rating Worksheet in chapter 5, section 3, (exhibit 5–3).

(f) Prescribed grazing schedule

A prescribed grazing schedule is a system in which two or more grazing units are alternately deferred or rested and grazed in a planned sequence over a period of years. The period of nongrazing can be throughout the year or during the growing season of the key plants. Generally, deferment implies a nongrazing period less than a calendar year, while rest implies nongrazing for a full year or longer. The period of deferment is set for a critical period for plant germination, establishment, growth, or other function. Grazing management is a tool to balance the capture of energy by the plants, the harvest of that energy by animals, and the conversion of that energy into a product that is marketable. This is done primarily by balancing the supply of forage with the demand for that forage. Such systems help to

- Maintain or accelerate improvement in vegetation and facilitate proper use of the forage on all grazing units.
- Improve efficiency of grazing through uniform use of all grazing units.
- Stabilize the supply of forage throughout the grazing season.
- Enhance forage quality to meet livestock and wildlife needs.
- Improve the functioning of the ecological processes.
- Improve watershed protection.
- Enhance wildlife habitat.

Many grazing systems are used in various places. Prescribed grazing is designed to fit the individual operating unit and to meet the operator's objectives and the practice specifications. Exhibit 5–6, Prescribed Grazing Schedule Worksheet (chapter 5, section 3) may be used in conservation planning. Other formats that contain the necessary information may also be used. The basic types of grazing management systems follow. Many others can be developed to fit specific objectives on specific lands.

- Deferred rotation
- Rest rotation
- High intensity—Low frequency
- Short duration

(1) Deferred rotation grazing

Deferred rotation grazing generally consists of multi-pasture, multiherd systems designed to maintain or improve forage productivity. Stock density is moderate, and the length of the grazing period is longer than the deferment period. An example of a deferred grazing system would be the four pasture, three herd Mer-rill System. This system grazes three herds of livestock in four grazing units with one unit being deferred at all times. The number of livestock is balanced with the available forage in all four grazing units. Each grazing unit is deferred about 4 months. In this way the same grazing unit is not grazed the same time each year. This type of system will repeat itself every 4 years. Figure 5–2 is a conceptual model of a deferred rotation system.

Figure 5–2 Deferred rotation system model

Year one

Mgt. unit	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec
1			graze	graze	graze	graze	graze	graze	graze	graze	graze	graze
2	graze	graze					graze	graze	graze	graze	graze	graze
3	graze	graze	graze	graze	graze	graze					graze	graze
4	graze	graze	graze	graze	graze	graze	graze	graze	graze	graze		

Year two

Mgt. unit	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec
1	graze	graze					graze	graze	graze	graze	graze	graze
2	graze	graze	graze	graze	graze	graze					graze	graze
3	graze	graze	graze	graze	graze	graze	graze	graze	graze	graze		
4			graze	graze	graze	graze	graze	graze	graze	graze	graze	graze

Year three

Mgt. unit	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec
1	graze	graze	graze	graze	graze	graze					graze	graze
2	graze	graze	graze	graze	graze	graze	graze	graze	graze	graze		
3			graze	graze	graze	graze	graze	graze	graze	graze	graze	graze
4	graze	graze					graze	graze	graze	graze	graze	graze

Year four

Mgt. unit	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec
1	graze	graze	graze	graze	graze	graze	graze	graze	graze	graze		
2			graze	graze	graze	graze	graze	graze	graze	graze	graze	graze
3	graze	graze					graze	graze	graze	graze	graze	graze
4	graze	graze	graze	graze	graze	graze					graze	graze

The fifth year of this type of system is the same as the first year. Note that the actual length of time grazed and deferred depends on the size of the grazing units, the size of the herd, and the weather for the year. The model in figure 5–2 assumes equal size (in terms of forage supply) for the four grazing units in the system.

(2) Rest rotation grazing

Rest rotation grazing consists of either multipasture - multiherd or multipasture - single herd systems. Grazing units are rested or deferred: (1) to restore plant vigor, (2) to allow for seed development and ripening, and (3) to allow seedling establishment. Livestock numbers should be based on the amount of forage that is produced in the pastures that are to be grazed each year. Figure 5–3 is a model of one example of five grazing treatments in which growing season begins first of April and seed ripening occurs in July. Sequence of grazing treatments is an entire year of grazing followed by complete rest the second growing season. This rest period allows plants to regain vigor. During the third growing season, the grazing unit receives a deferment until seeds of the desired plants have ripened and then is grazed the remainder of the growing season. The fourth year is an entire growing season of rest to allow for seedling establishment. During the fifth growing season, grazing is deferred during the early part of growing season to further enhance seedling establishment and then the unit is grazed the remainder of the growing season.

Figure 5–3 Rest rotation system model

Year one

Mgt. unit	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec
1	graze	graze	graze	graze	graze	graze	graze	graze	graze	graze	graze	graze
2	graze	graze	graze									
3								graze	graze	graze	graze	graze
4	graze	graze	graze									
5							graze	graze	graze	graze	graze	graze

Year two

Mgt. unit	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec
1	graze	graze	graze									
2								graze	graze	graze	graze	graze
3	graze	graze	graze									
4							graze	graze	graze	graze	graze	graze
5	graze	graze	graze	graze	graze	graze	graze	graze	graze	graze	graze	graze

Year three

Mgt. unit	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec
1								graze	graze	graze	graze	graze
2	graze	graze	graze									
3							graze	graze	graze	graze	graze	graze
4	graze	graze	graze	graze	graze	graze	graze	graze	graze	graze	graze	graze
5	graze	graze	graze									

Figure 5–3 Rest rotation system model—Continued

Year four

Mgt. unit	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec
1	graze	graze	graze									
2							graze	graze	graze	graze	graze	graze
3	graze	graze	graze	graze	graze	graze	graze	graze	graze	graze	graze	graze
4	graze	graze	graze									
5								graze	graze	graze	graze	graze

Year five

Mgt. unit	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec
1							graze	graze	graze	graze	graze	graze
2	graze	graze	graze	graze	graze	graze	graze	graze	graze	graze	graze	graze
3	graze	graze	graze									
4								graze	graze	graze	graze	graze
5	graze	graze	graze									

(3) High intensity – low frequency grazing

High intensity - low frequency (HILF) systems are multipasture - single herd systems. Stock density is high to extremely high. The length of the grazing period is moderate to short, with a long rest period. Dates for moving livestock are set by the utilization of the forage. Grazing units are not grazed the same time of year each year. Figure 5–4 is a conceptual model of a HILF grazing system.

In HILF the number of grazing units and grazing capacity of each unit determine how often if ever the same grazing unit is grazed during the same period of the year.

Figure 5–4 HILF grazing system model

Year one

Mgt. unit	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec
1	graze							graze				
2		graze							graze			
3			graze							graze		
4				graze							graze	
5					graze							graze
6						graze						
7							graze					

Year two

Mgt. unit	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec
1			graze							graze		
2				graze							graze	
3					graze							graze
4						graze						
5							graze					
6	graze							graze				
7		graze							graze			

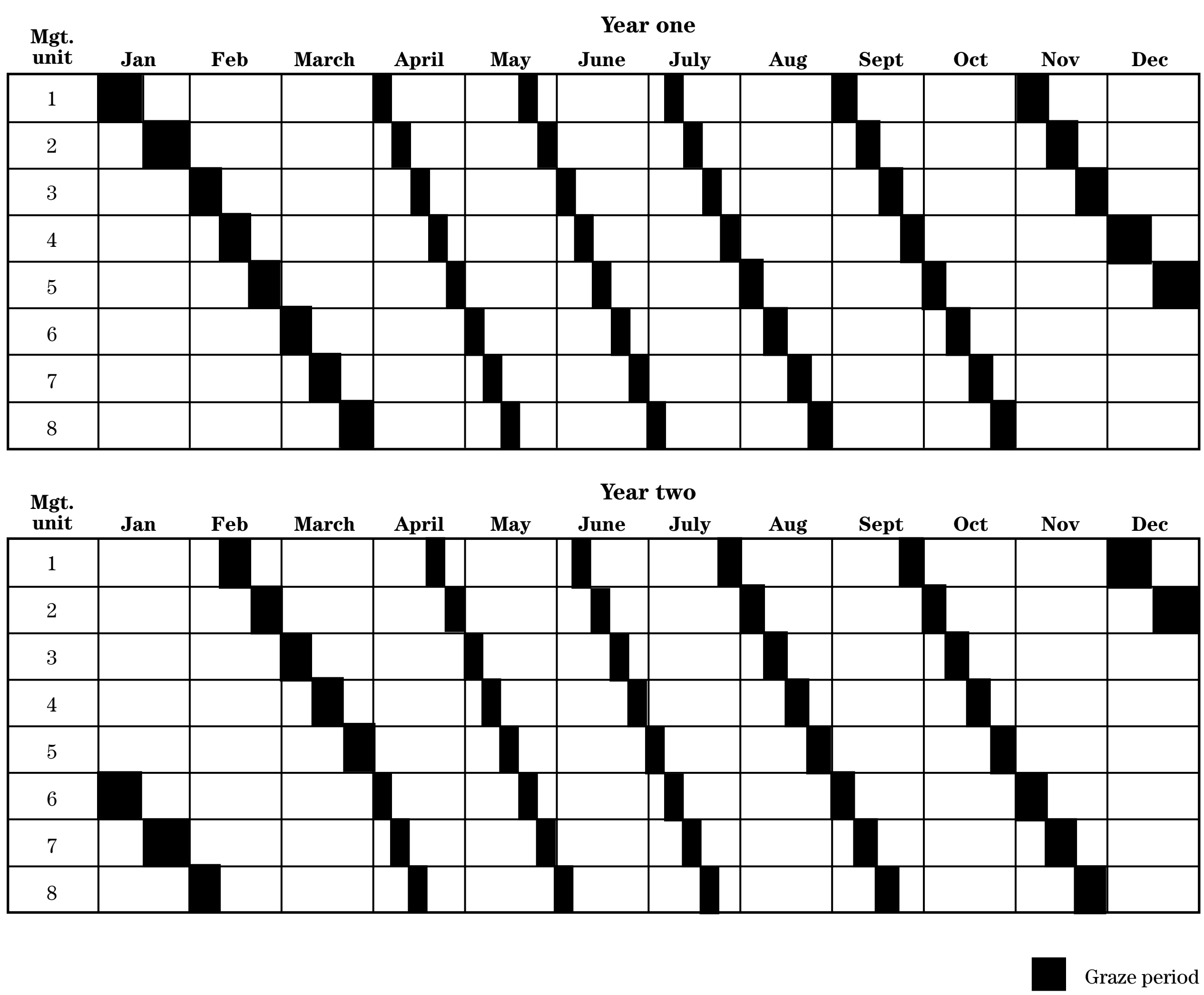
(4) Short duration grazing

Short duration grazing is similar to high intensity - low frequency except that the length of the grazing and rest periods are both shorter for the short duration. Utilization, therefore, is less during any given grazing period. Stock densities are high. Figure 5–5 is a conceptual model of a short duration grazing system.

In the short duration model, the pattern may never repeat itself. The number of grazing units and grazing capacity of each unit determine how often, if ever, the same grazing unit is grazed during the same period of the year.

In many parts of the United States, livestock cannot be grazing on the land the entire year. Where snow or other related conditions prevent yearlong grazing, the concepts of the grazing systems still apply. Figure 5–6 is an example of a deferred rotation grazing scheme where the livestock can only be on the grazing land from April through October.

Figure 5–5 Short duration grazing system model



Conservation planning and application on grazing lands are detailed in chapter 11. How each type of grazing management system works and the advantages and disadvantages of each type must be understood. A landowner rarely adopts any grazing management system exactly as it is conceptualized in a handbook or textbook. The management that gets applied to the land is a combination of things that come closest to achieving the needs of the resources, landowner, and livestock. The NRCS conservationist must understand how livestock graze, the response of plants to grazing, and how rangelands in an area are impacted by different types of grazing management. Generally, the more extensive the grazing management, the slower the response of the forage resource. The more intensive the grazing management, the faster the forage response. However, risk of poor animal performance is increased. All of these factors must be discussed with and understood by the landowner.

Figure 5–6 Deferred rotation grazing scheme (April – October)

Year one

Mgt. unit	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec
1				graze	graze	graze	graze	graze	graze	graze		
2							graze	graze	graze	graze		
3				graze	graze	graze						
4				graze	graze	graze	graze	graze	graze	graze		

Year two

Mgt. unit	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec
1							graze	graze	graze	graze		
2				graze	graze	graze						
3				graze	graze	graze	graze	graze	graze	graze		
4				graze	graze	graze	graze	graze	graze	graze		

Year three

Mgt. unit	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec
1				graze	graze	graze						
2				graze	graze	graze	graze	graze	graze	graze		
3				graze	graze	graze	graze	graze	graze	graze		
4							graze	graze	graze	graze		

Year four

Mgt. unit	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec
1				graze	graze	graze	graze	graze	graze	graze		
2				graze	graze	graze	graze	graze	graze	graze		
3							graze	graze	graze	graze		
4				graze	graze	graze						

600.0501 Managing grazed forest lands

(a) Principles of forest grazing

Managing a forest to produce forage for livestock, desired wildlife habitat, quality water, quality fisheries, timber production, and many other desired forest products requires an understanding of the forest ecosystem and how it responds to the manager's decisions.

Some forest ecosystems managed for timber production have limited capabilities for livestock grazing. Livestock grazing can cause detrimental effects, such as reduced regeneration of desired woody species, adverse soil compaction, or soil erosion on steep, highly erodible sites. A decision must be made to determine if the forest ecosystem will support livestock grazing that is designed and managed to meet the needs of the cooperator and the forest ecosystem. Many forests can be grazed where grazing management is designed to meet the needs of the soil, water, air, plants, and animals.

In most forests, solar energy is the major ecological component affected in the management process. Solar energy is intercepted by the canopy of the tallest trees. This causes a filtering or reduction of solar energy as it penetrates to the next layer of vegetation, whether it is a midstory of woody plants or grasses and forbs growing on the forest floor. Managing the forest ecosystem for the desired plant community and the desired production is, in a large part, accomplished by managing the plant populations in the different stories (overstory, midstory, and understory) to provide the most efficient use of solar energy by the desired plants. Managing forest for forage and timber production requires the Timber Management Plan and the Prescribed Grazing Plan be coordinated to produce the desired effects on the plant community and all of the ecological components.

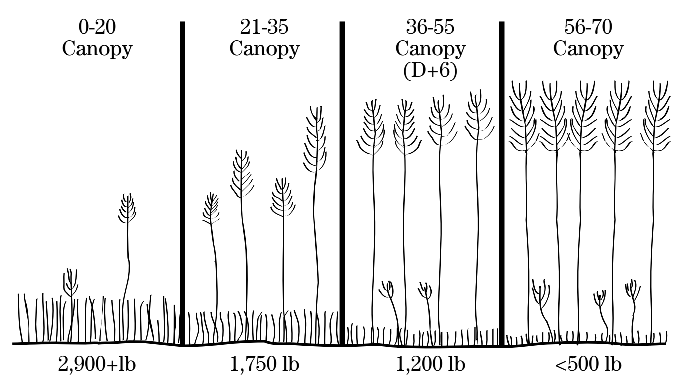
(b) Management of the overstory

The ecological site descriptions for forest land are in Section II of the Field Office Technical Guide (FOTG). They provide information for each forest land ecological site in the field office area. Each forest land ecological site contains a description of the overstory canopy classes that are on the site. Plant species adapted to the site and the amount of sunlight that penetrates to the ground level are listed for each canopy class. The description of the understory composition includes the production (in pounds) of each plant or groups of plants and the total production for the canopy class.

As canopy closes from totally open to totally closed (fig. 5–7, a southeast forest site), the understory species almost completely change from warm-season to cool-season plants. Forage production will be reduced significantly as a result of the species composition change and the near elimination of sunlight penetration to the ground level.

Management of the overstory canopy with timber management practices is essential to the desired production of forage and understory species. The midcanopy densities (21 to 35 and 36 to 55 percent) produce a mixture of the warm- and cool-season plants and in many instances can be managed to maximize timber production.

Figure 5–7 Canopy classes in a southeast forest site



For example, in some southern pine forests the practice of periodic thinning on a 5- to 6-year rotation maintains the desired basal area and canopy of trees for maximum timber production. This canopy allows substantial forage production for livestock and for grazing and browsing wildlife (fig. 5–8) This periodic thinning is continued until the forest matures. At that time, the forest is clearcut and allowed to regenerate, or it is replanted to the desired tree species. The forage and browse production is excellent until the canopy of the regenerated or planted trees closes at about 10 years. Very little understory will be produced for about 5 years. At about the 15th year of the new forest, the first thinning cut will be made. This will again start the maintenance of the 35 to 55 percent overstory canopy that maximizes timber production and allows substantial understory forage production.

If in the above example the periodic cutting cycles are not made, the canopy will completely close and shade out the understory. Forage production will be limited, and the wildlife habitat for grazing or browsing wildlife will be undesirable (fig. 5–9). Pulp wood rotations, where plantings are made and not thinned until they are fully harvested, are examples of this type management. Many privately owned forests are not managed because of a lack of understanding of timber management, grazing management, or other factors. This causes a canopy closure with the same results.

(c) Management of the midstory

Many forests develop a midstory canopy that can completely shade the ground level understory (fig. 5–10). Even if the overstory is managed to maintain the desired canopy, a midstory can severely reduce the amount of sunlight reaching the ground level. The effects are the same as if the overstory was closed. The understory species composition is changed to those that are shade tolerant, and forage production is reduced severely.

In this case, if understory production is desired, the manager must reduce the midstory. In many cases prescribed burning can be used to control the midstory species. In others forest improvement should be planned to manage the midstory to the desired canopy.

(d) Management of the understory

The understory is made up of grasses, forbs, legumes, sedges, vines, and shrubs. When the overstory and the midstory are managed to permit the desired amount of light to reach the forest floor, a plant community develops that is adapted and supported by the amount of light, water, and nutrients available on the site.

Figure 5–8 Forage production clearcut for natural regeneration with periodic thinning

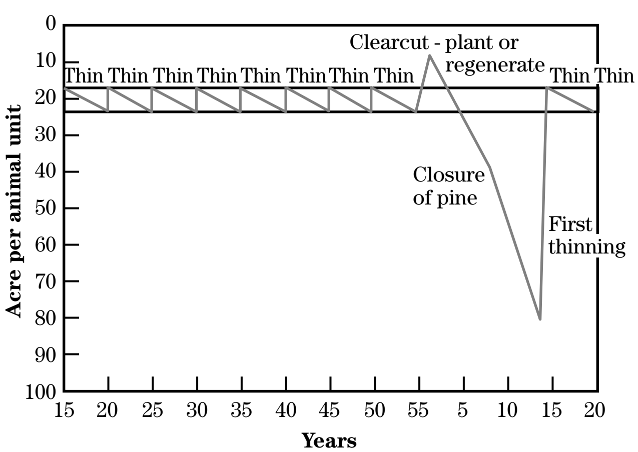
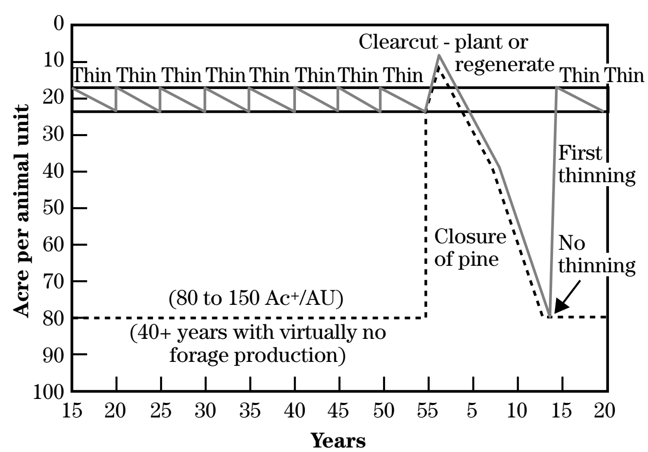


Figure 5–9 Forage production clearcut or natural regeneration with periodic thinning (compared to clearcut or natural regeneration with no thinning)



Livestock and wildlife grazing and browsing on this site select their preferred species. If they are stocked too heavily and for too long a time, they overgraze the desired species. These species are weakened and reduced in percentage composition, while the less preferred species increase in percentage composition. If the process is continued, both the preferred and secondary plant species will be severely reduced and replaced with nonpreferred species (fig. 5–11 and 5–12).

To correct this grazing management problem, prescribed grazing must be applied along with the needed facilitating practices, such as firebreaks, fences, ponds, wells, pipelines, and troughs. Other practices, such as trails, walkways, and roads, may be needed. Range planting may be needed to provide a seed source of the desired species.

Each conservation plan must be tailored to meet the needs of the soil, water, air, plants and animals, as well as the needs and objectives of the landowner.

Figure 5–10 Forage production clearcut or natural regeneration with periodic thinning (effects of hardwood midstory)

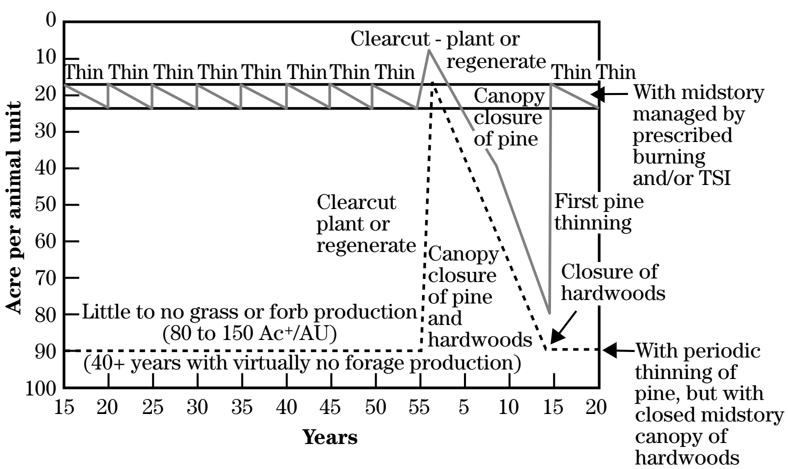


Figure 5–11 Plant community response to grazing management (36 to 55% canopy)

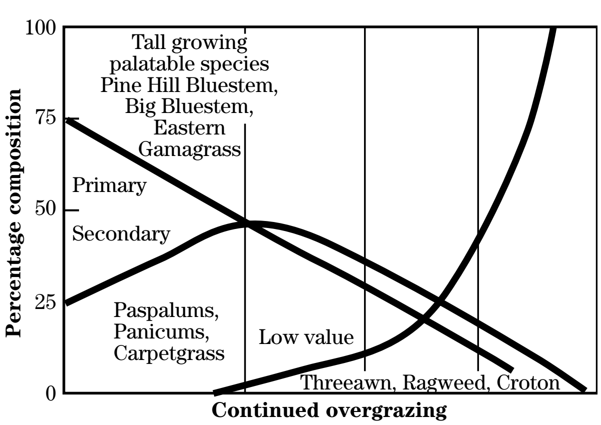


Figure 5–12 Forage production clearcut or natural regeneration with periodic thinning (very high forage value rating vs. low forage value rating)

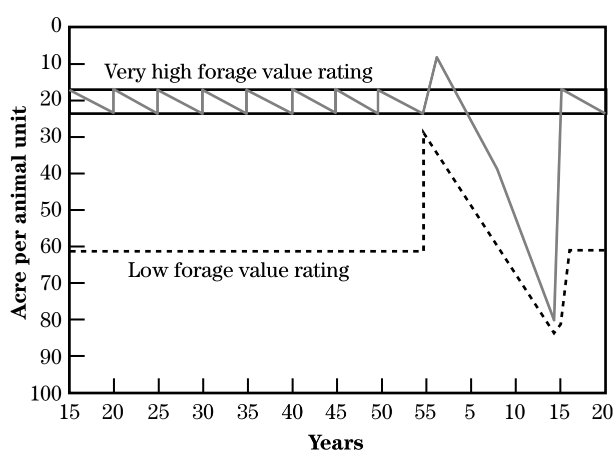
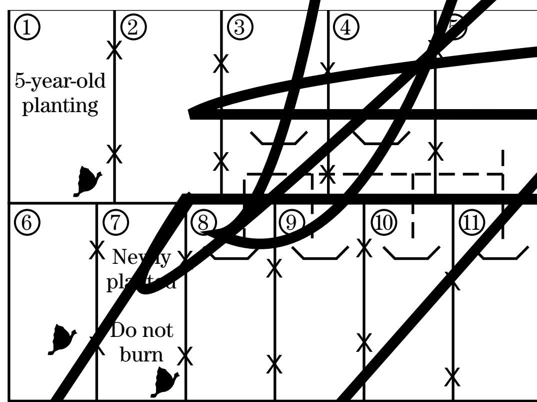


Figure 5–13 is an example of how a plan can be developed in a southern pine forest to meet the needs of a 50-year timber rotation, livestock production, and improved wildlife habitat. Example 5–1 describes a plan for southern pine forest.

Figure 5–13 Clearcut or natural regeneration using a 55-year cutting cycle



Example 5–1 Plan for southern pine forest (refer to figure 5–13)

1. Divide into 11 equal units. Eleven units allow the 50-year production cycle to have one unit cut every 5 years and replanted.

2. Install 30-foot-wide fertilized green firebreaks between units (20 acres per section in example). These also serve as roads for managing timber and livestock and for harvesting timber, clearing for fence lines, trails for livestock distribution, and wildlife habitat.

3. Install a 1- or 2-wire electric fence along each firebreak.

4. Install livestock water in each grazing unit.

5. Thin timber each 5 years in all units except those recently planted. First thinning will be at year 15.

6. Clearcut and plant, or harvest to seed trees, one unit each 5 years. Rest new plantings as needed. Seed to native grasses, legumes and forbs if a seed source is needed for establishment. (Severely overgrazed or old cropland fields may need a seed source.)

7. Prescribe burn established stands on a 4-year cycle.

8. Rotate one herd of livestock through the grazable units in a manner that meets the needs of the pine, forage plants, wildlife, and livestock.

(e) Western native forest lands

Many western forests have naturally open or savanna-like aspect with highly productive understory plant communities. Others naturally develop dense canopies that at maturity will eliminate nearly all understory vegetation.

Savanna forest land overstories are typically managed by selectively removing mature trees for lumber, on a periodic basis, while managing the understory community for wildlife habitat and forage.

Dense forest lands only develop significant understory vegetation after stand removing fire or clearcutting of the site occurs. During this open canopy period, forest reseeding or natural regeneration causes the community to transition back to dense forest. This transition period normally lasts from 10 to 20 years, and, while open, these areas can provide an important forage source for livestock and wildlife. Forest management generally adds new clearcuts to the landscape on a periodic basis while open forest lands transition back to closed canopies on a planned schedule. This ensures that a stable transitory forage resource is always available at some locations on the operation for wildlife and livestock use.

Conservation planning activities must consider both the forest resource and the wildlife and forage resources available to the landowner. Close coordination is needed to optimize the economic gain from these resources while protecting the ecological integrity and diversity of the management area.

(1) Managing grazed forest lands for multiple benefits

Many native forest lands in the Western United States produce multiple forest products including timber, grazing for wildlife and livestock, habitat for many species of wildlife, sustained summer streamflows, and pure water. Careful resource management is required to ensure that proper balance is achieved and that multiple resource values are sustained.

These grazed forest lands range from high mountain spruce-fir ecosystems, to Douglas fir stands at middle elevations, to the dryer savanna-like mixed fir-pine and pure pine sites.

A typical grazed forest land ecosystem in the Western United States would be a ponderosa pine, bitterbrush, Idaho fescue ecological site. This site typically is dominated by an overstory of ponderosa pine. Site indices (SI) can range from a low of less than 40 to more than 120. Wood products are harvested using uneven-aged management techniques. Mature and overmature trees are selectively removed from the stand on a scheduled basis. They are naturally replaced in the stand by younger trees that are released to grow more rapidly once the older competition is removed.

Fire played an important role in this community by periodically thinning out part of the younger trees while causing little damage to the older ones because of their insulated, fire resistant bark. This created an open, savanna-like aspect to the communities, creating some of the most productive wildlife areas in the country, especially during the winter and spring.

Understory vegetation is dominated by Idaho fescue and antelope bitterbrush. These species provide excellent forage and browse for deer and elk, as well as domestic cattle and sheep. Production in the understory is directly related to the density of the overstory canopy.

Even though fire played an important role and is a natural part of these communities, people have aggressively removed fire, causing major changes in the structure and health of many of these forest communities. Dog-hair thickets of young ponderosa pine now occupy the middle canopy layer, effectively shading out the understory vegetation while creating the potential for catastrophic, stand removing crown fire.

Management of these communities requires a knowledge of both the forest resource and the understory grazing resource. Forest products, such as logs, fence posts, and firewood, can be harvested periodically while routinely harvesting the forage for the production of food and fiber.

The first step in managing the forest resource on a site is to complete an inventory of the various timber stands on a site and by determining the growth potential or SI for each stand. A rule-of-thumb for stand management is as follows:

SI > 100	Thin trees to a D+3 to D+6 spacing. Remove merchantable products as part of this thinning when feasible.
SI 80 to 100	Thin trees to a D+5 to D+8 spacing. Remove merchantable products as part of this thinning when feasible.
SI < 80	Thin trees to a D+6 to D+9 spacing. Remove merchantable products as part of this thinning when feasible.

For optimum grazing in these stands, add 1 or 2 feet to the spacing.

The D+ spacing is determined by measuring the diameter at breast height of each leave tree converting this number to feet and then adding the + factor to establish to total spacing for that individual tree for optimum growth. Select the next leave tree at the perimeter of this thinned area and repeat the process. As timber products are removed from the stand, additional thinning may be necessary to keep the stand well managed. Priority should be given for the removal of deformed and diseased trees during the thinning process.

Grazing management of the understory vegetation follows the same principles as for rangeland management. A grazing management plan should be developed for each grazing unit. Prescribed grazing is the National Conservation Practice Standard to be followed when designing practices for grazed forest lands.

Wildlife use in these areas is often significant, and available forage must be allocated accordingly. Grazing plans must also consider existing and planned tree plantations to provide protection during periods when seedlings could be damaged by grazing animals.

(f) Inventorying grazed forest

As described above, the amount and nature of the understory vegetation in forest are highly responsive to the amount and duration of shade provided by the overstory and midstory canopy. Significant changes in kinds and abundance of plants occur as the canopy changes, often regardless of grazing use. Some such changes occur slowly and gradually as a result of normal changes in tree size and spacing. Other changes occur dramatically and quickly, following intensive woodland harvest, thinning, or fire. Significant changes do result from grazing use, however, and the understory can often be extensively modified through the manipulation of grazing animals.

For these reasons the forage value rating of grazable forest is not an ecological evaluation of the understory. It is a utilitarian rating of the existing forage value of a specific tract of grazable forest for specific livestock or wildlife. The landowner or manager needs to understand the current species composition and production in relation to their desired use of the land by specific animals.

(1) Procedure for determining forage value rating

Forage value ratings are to be based on the percentage, by air-dry weight, of the existing understory plant community (below 4.5 feet) made up of preferred and desirable plant species. Four value ratings are recognized:

Forage value rating	Minimum percentage
Very high	50 preferred + desirable = 90
High	30 preferred + desirable = 60
Moderate	10 preferred + desirable = 30
Low	Less than 10 preferred

Introduced species should be rated according to their preference by the animal species of concern and included in the determination of forage value rating. See Worksheet for Determining Forage Value Rating (exhibit 5–4) in section 3 of this chapter.

The production of understory plants can vary greatly even within the same canopy class. Therefore, if the forage value rating obtained by considering only the percentage of preferred plants is very high or high, but the production is less than that expected for the existing canopy, reduce the final forage value rating one or more classes to reflect the correct value.

600.0502 Managing naturalized or native pasture

Naturalized pasture is land that was forest land in historic climax, but is being managed primarily for the production of forage rather than the production of wood products. It is managed for forage production with only the application of grazing management principles. The absence of the application of fertilizer, lime, and other agronomic type practices distinguish this land use from pasture.

Because naturalized pasture was forest in its natural state, it will naturally evolve back to a forest dominated plant community. For the site to be maintained as naturalized pasture, a form of brush management is normally planned to suppress the tree and shrub component of the site. Prescribed burning, mechanical, herbicides, or biological control need to be planned, designed, and applied to create the desired plant community to meet the resource criteria.

Prescribed grazing is planned to meet the needs of the plant community and the livestock and wildlife of concern. The grazing management principles applicable to grazed range and pasture are applicable to naturalized pasture. The prescribed grazing plan must address solving all of the resource problems and concerns identified in the inventory and problem identification process where either livestock or wildlife is a contributor to the cause of the problem.

Range planting may be needed to establish the desired plant community when a seed source of the desired species is not evident. Facilitating practices, such as firebreaks, fences, and livestock water development practices are planned as needed.

NRCS assists cooperators to understand the ecology of their naturalized or native pasture. They assist them in inventorying and evaluating the naturalized pasture productivity and in determining the suitability of present and potential vegetation for the appropriate needs and uses. The Forest Ecological Site Description is to be used as the naturalized or native pasture interpretative unit. The understory descriptions and interpretations, as described in the Forest Ecological Site Description, provide the needed information for inventory.

Forage value ratings should be determined to provide an index for the landowner and manager to understand the value of the present plant community in meeting the needs of their livestock and wildlife.

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Chapter 5 Management of Grazing Lands

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Section 2 Managing Forage Crop and Pasture Lands

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600.0503 General

Efficient use of forage crop and pasture lands requires understanding two basic components of forage growth:

- Each forage's physiological and morphological attributes must be understood.
- How the forage responds to competing plants, climate, soil, machine harvest timing and frequency, human determined inputs, and grazing timing, duration, pressure, and frequency must be known.

Agronomic inputs into forage crop production and improved pastures are seeding mixtures used, selection of adapted cultivars resistant to local diseases or insects, fertilizer, pasture clipping, planting procedures used, soil amendments, pest control, drainage, irrigation, and other crops, if any, used in rotation with forage crop. Animal nutrition variables are off-farm feed supplements, producer production goals, and the kind, number, and class of livestock being fed.

The growth habit characteristics, soil chemical and physical preferences, and palatability characteristics among agronomic forage crops vary widely. This creates a myriad of shifts in plant species composition on forage crop and pasture lands even in so-called monoculture fields. Depending on which species is favored based on climatic and soil conditions and the management the forage stand receives, some species live on and others die out. The shift in forage species composition is swift even under the survival of the fittest scenario. However, a farmer with a plow or sprayer and a planter can cause one crop to disappear and another crop appear in a few days. The same producer can also cause radical changes for good or harm with a herd or flock of livestock.

All management decisions, whether they be agronomic, economic, or animal nutrition driven, must be done within the constraints imposed by the management unit ecosystem at any given moment. If the constraints are ignored, the improvement practice ultimately fails. No conservation or improvement practice should be applied without analyzing what drives the system.

On pastured lands, once climate and soil factors affecting forage growth and production are accounted for, the system is driven by the grazing management regime applied. If producers are unwilling to change their customary approach to grazing management, agronomic solutions to forage growth enhancement will only be as effective as that grazing management regime allows. If the forages are overgrazed, agronomic attempts to improve forage production are likely to fail, or the improvement is only marginal. The accompanying environmental problems resulting from the weakened plant community will be affected little as well.

On cropped (machine harvested) lands, once climate and soil factors affecting forage growth and production are accounted for, the system is driven by planting and harvesting regimes (by grazing animal or machine). If either is done poorly because of improper timing or technique, all the other agronomic inputs add more to the cost of production, but little to improved forage or livestock production. In the meantime environmental problems created by this mismanagement continue to mount.

600.0504 Managing improved pasture

Pasture is harvested principally by the grazing animal; therefore, it must be managed differently than hayland and cropland that are harvested primarily by machine. Seasonal availability or distribution of forage growth is vital to allocating enough feed to the grazing animal without wasting it or overgrazing it. A growing forage is a perishable commodity. As it matures, it lowers in value nutritionally. This is especially true after seed-head emergence on grasses or initial flowering of legumes and forbs.

Stored forages (roughages) are a more nutritionally stable commodity if stored properly. However, they generally are of lower nutritional value because they are harvested at a later stage of maturity than are the more timely grazed pastures. When an animal eats standing forage, there is no loss of leaves and no loss of vitamins and dry matter. The forage is directly ingested rather than curing in a field or barn or fermenting in a silo or forage bag, and they can select the choicest forage available. Therefore, pasture management must recognize that ups and downs occur in forage quality and quantity. Pasture must be stocked in concert with growth and availability of forages. If this is done, forage quality will be consistently near its optimum for the time of the year.

Pastured land also differs from cropland and hayland in the way plant material is removed. The grazing animal tends to graze from the top down, but it does this over a period of time. They take a bite, move on, take a bite off another area, and proceed across the pasture selecting what appeals to them. Depending on how much control the producer exerts, the livestock may have free rein to explore the whole management unit or a very small part of it. They may be able to return to the same spot continually throughout the grazing season or be allowed to return only within a few hours and then be off for several days or weeks. In any case, more residual material is always left behind than where forage crops are harvested mechanically unless heavily overstocked or stocked for prolonged periods.

After initial green-up pasture forages generally are less dependent on stored food reserves to continue growth than are machine harvested forages. They still have photosynthetic area to continue producing simple sugars that are synthesized into plant food. Machine harvested forages are dependent on food reserves and basal growing points or axillary buds held below the cutting bar to generate new growth. After machine harvest few or no green leaves are left to carry on photosynthetic activity.

The distribution of plant tissue removal is also quite variable on pasture unless severely overgrazed or rationed tightly under a multiple paddock system. The latter mimics machine harvest in uniformity of removal if managed well. With machine harvest all forage is removed from the management unit uniformly. This variation in plant removal by grazing results from a number of factors:

- Selectivity of the grazing animal
- Differences in palatability among the plant species present
- Differences in maturity and palatability as a result of the previous selective grazing
- Steepness of the terrain
- Presence of barriers that affect livestock movement or behavior
- Distance to water
- Distance to shade when present

Another way pastured lands differ from cropland and hayland is that nutrients are recycled within their boundaries. Most of the nutrients consumed are used to maintain the animal and are excreted. They may not be distributed evenly, but they are continually returned as long as the pasture is occupied by livestock. On hayland and cropland, all nutrients in the harvested crop leave the field. They may or may not be replaced by manure or fertilizer nutrients.

Nutrient removal from pasture as animal products is relatively low. A thousand pounds of milk removes only 6 pounds of nitrogen; 2 pounds each of phosphorus, potassium, and calcium; and negligible amounts of other minerals. A thousand pounds of beef removes 27 pounds of nitrogen, 8 pounds of phosphorus, 2 pounds of potassium, and 13 pounds of calcium. Even under the best conditions, 1,000 pounds of stocker beef is all that can be produced per acre per year. More commonly, gains per acre on good pasture can range from 250 pounds per acre to 750 pounds per acre. If the livestock are fed any supplemental feed or minerals at all while on pasture, no net loss occurs in fertility level and a gain in the less mobile nutrients can occur. High producing dairy cattle on pasture typically are fed stored forages and concentrates to balance their diet for optimum milk production. Import of nutrients from these supplements tend to match or exceed export of nutrients as milk production. See accelerating practice, nutrient management.

(a) Seasonal distribution of growth or availability of pasture

Pasture, in the broader sense of the word, occurs on all three land uses that make up forage crop and pasture lands. Therefore, when allocating standing forage to grazing livestock, more than just when the forage is growing and at what rate must be considered. Often the forage's growth curve does not dictate the forage's grazing availability, a management decision does. For example, forages can be stockpiled. They are allowed to grow and accumulate mass and then grazed at a later date even after the growing season has ended. Forages that retain their leaves and nutritional value are preferred for stockpiling.

Crop residue can also be grazed. Again, a seasonal growth curve is of no value in developing a livestock feed budget that uses crop residue. Instead, what is important is: When is it available? Cornstalk residue, for instance, becomes available after harvest and has a useful life of about 60 to 90 days before weathering or trampling diminishes its usefulness as a feedstuff (table 5–2). This is, of course, dependent on rainfall and temperature. Low rainfall coupled with very cold temperatures prolongs its nutritional quality. Decomposition is arrested or slowed, and no mud is available to be trampled onto the residue.

A basic tool needed to manage pasture and allocate it to livestock is the seasonal distribution of growth or availability table or family of curves that are developed for your climatic area. Three examples of seasonal distribution of growth or availability curves are shown for the Gulf Coast, Upper South, and Upper Midwest in figures 5–14, 5–15, and 5–16. Note change in species as latitude changes. Also note for a crop like alfalfa how the growing season length changes with latitude, short in the north and long in the south.

Seasonal distribution of growth or availability curves should not only be identified by species, but by growing season length as well. Other important factors are the beginning and end dates of the growing season and the distribution of rainfall and growing degree days during the growing season. Two areas of the country with the same growing season length can have different distribution of growth responses due to differences in rainfall patterns and how fast it warms up after the growing season begins. A mid-continent climate is slower to warm up than one along the Atlantic seacoast where the Gulf Stream can quickly warm the region. When the same growing season length region has different beginning and ending dates as it crosses the continent, changes in day length response also take place where long or short day plants are important forages. Long day plants tend to grow faster to make up for lost time where the growing season starts later in the spring. For all these reasons, it is best to use seasonal distribution of growth and availability curves developed in your region. Do not use distribution tables from regions that have greatly differing seasonal rainfall and cumulative growing degree day patterns.

Note in figures 5–14, 5–15, and 5–16 how the different forages are available for grazing during different parts of the year. Warm-season grasses, such as bermudagrass, bahiagrass, pearl millet, big bluestem, switchgrass, and sorghum/sudan, produce during warm weather. Cool-season grasses and legumes produce most of their growth in the cool weather of spring and fall. Cool-season winter annuals actually produce grazable forage in the Gulf Coast States and as far north as Maryland and Kansas during the winter months. Year-round grazing is possible over much of the United States using a combination of these forages by taking advantage of their different availability periods. Cool-season forages can be relied on during the early and late parts of the year. When they go dormant or grow slowly during the middle of the year, warm-season forages can be relied on to fill in the grazable forage gap.

Crop residue, such as cornstalks, can be grazed after the crop is harvested. The proportion of the acreage devoted to either warm- or cool-season forages, or an interseeding of warm- and cool-season forages, depends of the livestock demand fluctuations of the land unit being planned and the ratio of warm-to-cool weather of the climate in which the land unit is located. Crop residue can also be grazed where available and where perimeter fences exist around the management unit. Another alternative is to stockpile forages that keep their quality well and withhold from livestock until a livestock demand as the season progresses. This is typical of a stocker or cow-calf operation where animals are growing. As they gain, animal units mount up.

Table 5–2 Estimated monthly availability of forage for grazing [1/]

Type of pasture	- - - - - - - - - - - - - Percentage available, by month						- - - - - - - - - - - - -
	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
Kentucky bluegrass-white clover, unimproved	25	30	10	5	10	10	5	—
Kentucky bluegrass-white clover + N, P	35	35	8	5	10	4	3	—
Renovated (continuous grazing)								
Birdsfoot trefoil-grass	10	25	25	20	10 [2/]	5 [2/]	5	—
Birdsfoot trefoil -grass, deferred for midsummer grazing	—	15	35	25	15 [2/]	5 [2/]	5	—
Tall grasses + N [3/]	30	30	10	5	10	10	5	—
Tall grasses + N, deferred for fall grazing [3/]	30	30	—	—	—	25	15	—
Renovated (rotational grazing)								
Alfalfa with smooth bromegrass or orchardgrass	20	25	25	15	5	5 [2/]	5 [2/]	—
Supplemental								
Sudangrass or sorghum-sudan hybrids	—	—	40	40	15	— [4/]	5	—
Sudangrass or sorghum-sudan hybrids, deferred for fall and winter grazing	—	—	—	—	—	100 [5/]		
Winter rye	50	20	—	—	5	15	10	—
Miscellaneous								
Meadow aftermath-following one cutting	—	20	30	25	5 [2/]	15 [2/]	5	—
Meadow aftermath-following one cutting, to be plowed	—	20	30	10	20	20	—	—
Meadow aftermath-following two cuttings	—	—	10	35	25 [2/]	25 [2/]	5	—
Meadow aftermath-following two cuttings, to be plowed	—	—	10	25	35	30	—	—
Cornstalks	—	—	—	—	—	100	—	—

1/ Source: Schaller (1967). Compiled originally by W.F. Wedin, Agronomy Department, Iowa State University.
2/ Allowances have been made for winter hardening of legume from about September 15 to October 15.
3/ Smooth bromegrass, orchardgrass, tall fescue, reed canarygrass, or combinations.
4/ Grazing must be avoided between first frost and definite killing frosts because of prussic acid content in regrowth shoots.
5/ All forage becomes immediately available, but may be gazed for up to 3 months if quality and supply are sufficient.

Figure 5–14 Gulf Coast seasonal distribution of growth and availability of pasture (from Ball, et al. 1991)

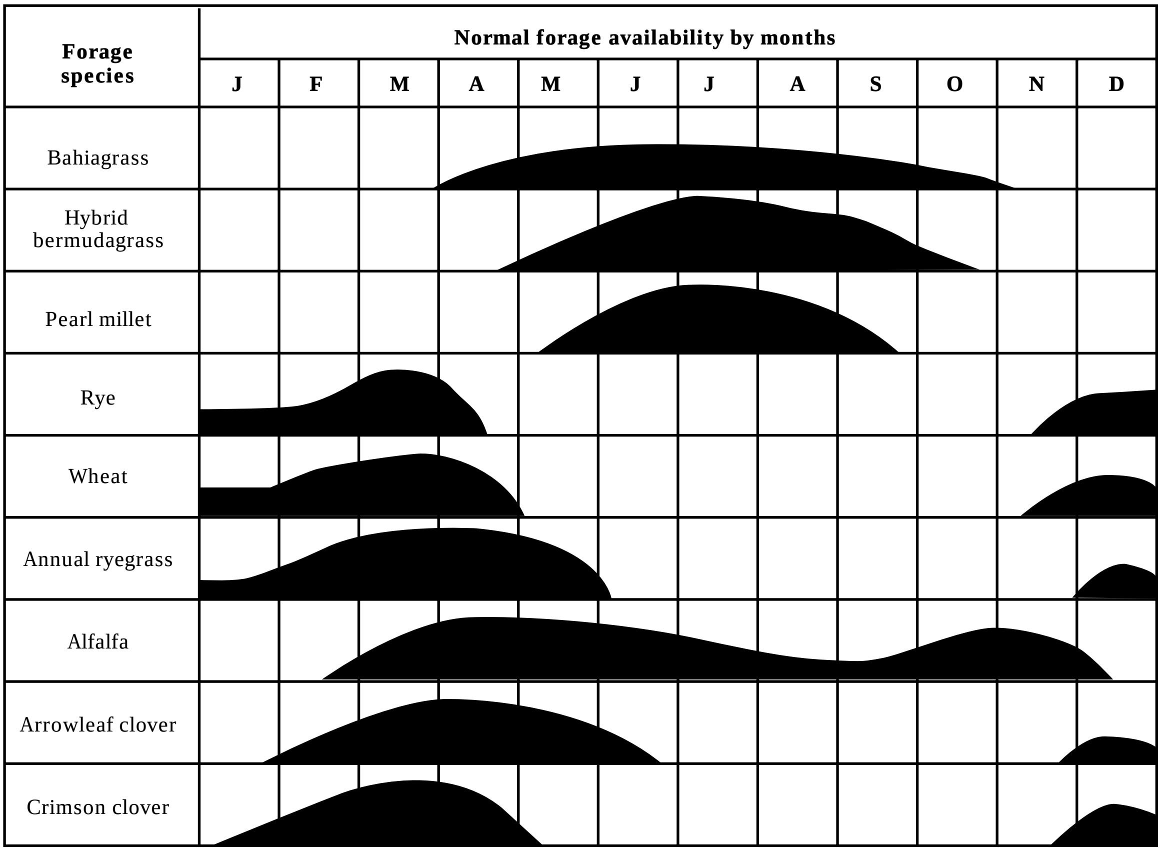


Figure 5–15 Upper South seasonal distribution of growth and availability of pasture (from Ball, et al. 1991)

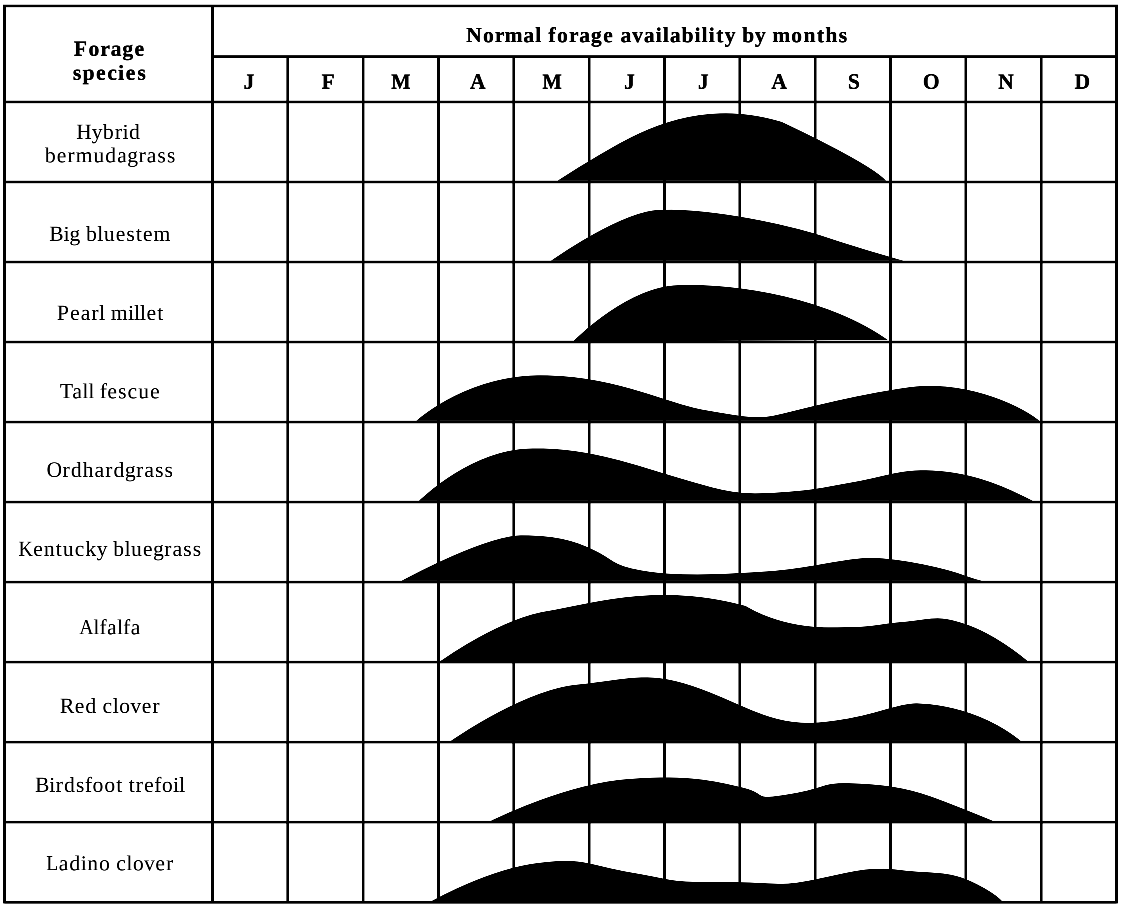


Figure 5–16 Upper Midwest seasonal distribution of growth and availability of pasture (adapted from Undersander, et al. 1991)

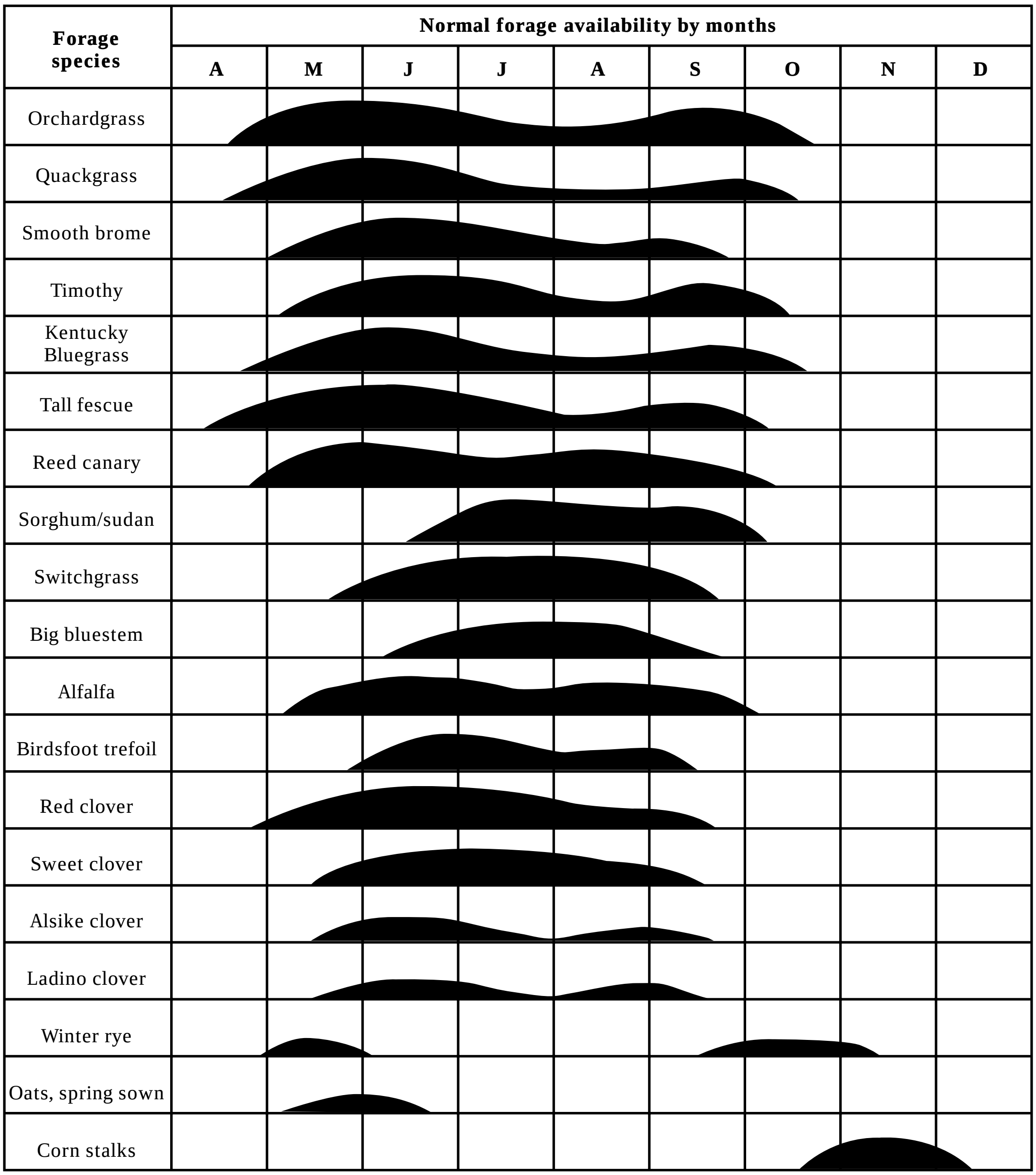


Figure 5–17 illustrates that a cool-season forage pasture produces too much forage early-on, and, as the summer heat arrives, begins to produce too little to meet livestock demand. The use of different forages either in the same pasture or in separate pastures allows the livestock producer to maintain enough forage on-offer to his livestock throughout the grazing season. Using stockpiled forages or growing winter annuals can extend the grazing season past that of the perennial cool- and warm-season forages' growing seasons illustrated in figure 5–17. If grazed rotationally, the warm-season grass could also be stockpiled (not shown) and grazed later in the fall as a standing cured forage if not weathered too badly. The figure also shows that with both the cool-season and warm-season in the pasture system, surplus pasture is available in mid-summer. The excess could be harvested as hay or stockpiled for grazing, depending on operator preference. Meanwhile, at the end of the grazing season, the stockpiled cool-season forage would need to be supplemented with some stored forage if the warm-season grass was not stockpiled for use in November. This is just one example of how the distribution of growth or availability graphs can be used to help formulate a pasture system for a livestock operator.

A drawback of the graphs or growth curves is their lack of specific numbers. They are useful because they quickly point out peaks and troughs of growth or availability. Tables are more useful in doing detailed pasture budgeting. They use units, such as monthly percentage of total annual production, tons of dry matter per acre per month, animal unit months per acre per month, or acres needed per animal unit per month. Table 5–2 illustrates the use of monthly percentage of total annual production. It is the most useful form because the other three assume a fixed annual production value. In regions where soil variability, climate variability, past crop management history, or a combination of these vary widely from farm to farm or field to field, annual forage yields can range widely from one site to the next and from one season to the next. This is illustrated in figure 5–18.

Figure 5–17 Livestock demand versus forage growth and availability during the grazing season where livestock were placed on pasture April 1 (adapted from Barnes, et al. 1995)

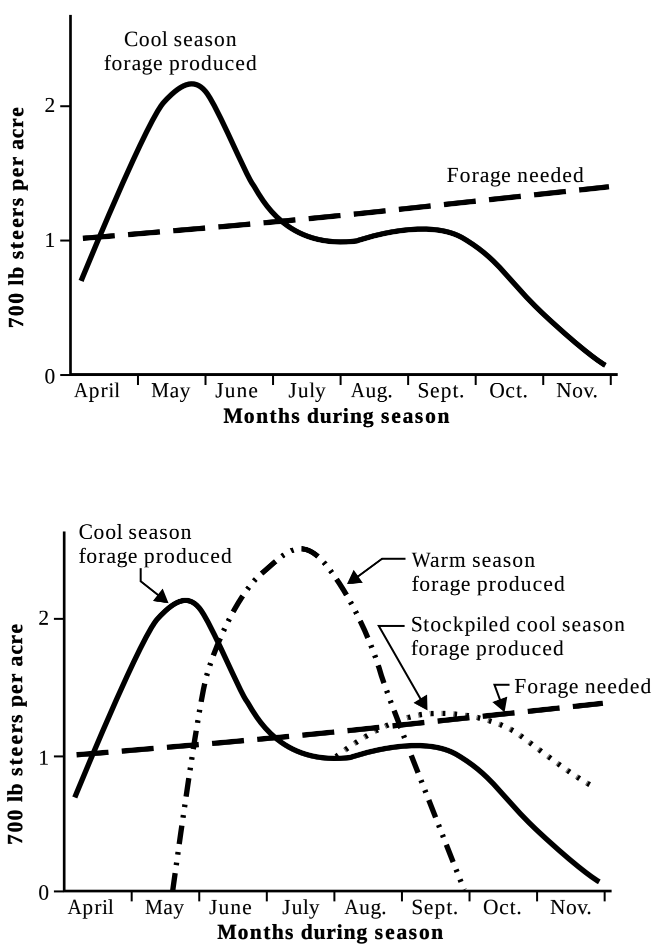
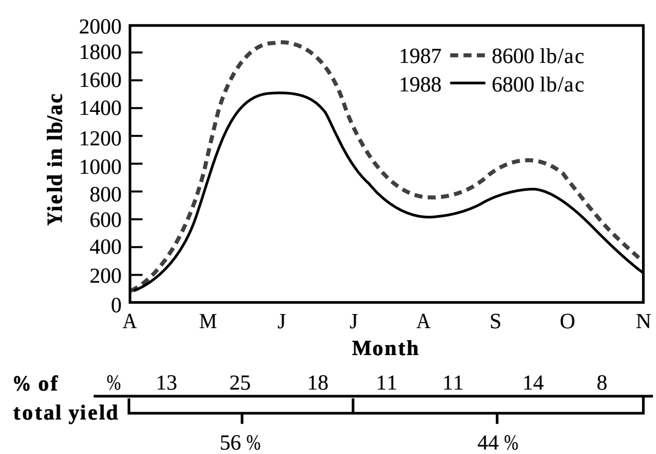


Figure 5–18 Seasonal distribution of growth of cool-season pasture and total production for 1987 and 1988 in southern New York (from Emmick and Fox 1993)



Note that the distribution of forage production remained constant, but forage on-offer was quite different between years as was total annual production. The factors listed do impact the percentage distribution throughout the season as well, but less so. Given the year to year variability inherent with a living system, think of the percentages as being averaged, somewhat inexact constants for doing pasture budgets. Some are constructed from long-term averages. Others come from limited short-term research studies. Therefore, expect some variation from year to year.

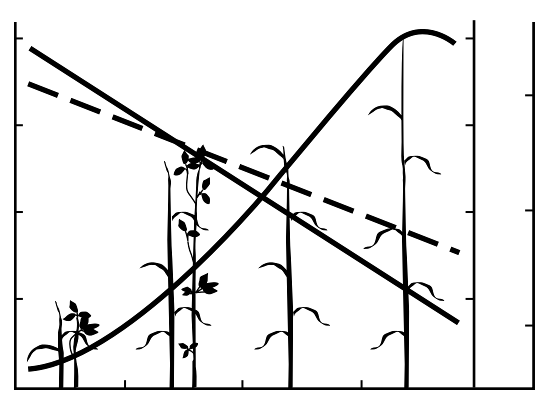
The monthly percentage of total annual production when multiplied times the estimated total annual production indicates the amount of forage grown or available during that month. If forage demand by grazing livestock for that month is known or can be estimated, the acres of pasture needed to feed the livestock that month will be known. This is the essence of a pasture budget. It allocates enough pasture forage to meet forage demand for the livestock being pastured. Therefore, seasonal distribution of growth and availability information is a crucial tool in doing a pasture budget and an overall livestock feed budget for the year. The livestock feed budget is necessary to do whole farm planning of a livestock producing management unit. It dictates ratio of pasture to cropland and hayland and the choice and balance of crops in crop rotations planned on cropland. For instance, an operator may decide to plant a summer annual on cropland to meet a deficit in forage production on the permanent pasture acres. The planner and farmer need to work that crop into the rest of the crop rotation. If not, then another alternative, such as grazing some hay crop acres after first cut, needs exploring.

(b) Forage growth response to the grazing animal

No matter what stocking method is used to allocate forage to grazing livestock, the goal should be to keep pasture forage in a vegetative growth stage. This is when the forage is at its best nutritionally and photosynthetically most active. Cool-season forages lose some of their digestibility especially when allowed to go to head or flower (fig. 5–19). They produce more dry matter, but livestock intake is depressed. In fact, this is why mature forage areas are avoided by livestock in fields that have been spot grazed. They go to the choice spots where growth is still highly vegetative, preflower for tap-rooted legumes or pre-boot stage for grasses.

Warm-season grass loss of digestibility is much lower. However, many are lower in digestibility than cool-season forages to start with, so the warm-season grasses must be harvested even more timely. In comparing pasture to stored forage production, it is critical that the planner not become hung up on total dry matter production. Pasture may produce less total dry matter than machine harvested forage acres. However, it produces a higher quality feed than machine harvested forage acres and similar total digestible dry matter if livestock demand and seasonal forage production are closely matched. Most stored forages are cut after grass heading and initial legume flowering.

Figure 5–19 Growth stages of grasses and legumes and their effect on intake, digestibility, and dry matter production (from Blaser, et al. 1986)



Forages grazed too close lose green leaf area below that needed to optimally capture sunlight. This delays regrowth and uses stored food reserves. The growth curves are shown in figure 5–20. If grazed too close repeatedly, the forage plant becomes weaker as food reserves run low. Death can result if other stresses or physical damage from hoof action occurs. Forages differ greatly in their ability to withstand close grazing. Forages that have growing points and some leaf area below the grazing height can withstand close grazing (fig. 5–21). Examples of these are Kentucky bluegrass, bahiagrass, bermudagrass, white clover, and tall fescue. Forages that have rhizomes and/or stolons just below and above the ground surface respectively, also have a greater chance of surviving close grazing. Both prostrate stems store food reserves and can initiate new shoots and roots at nodes from those reserves. Close grazed pastures where these forages are climatically adapted will be dominated by these species if introduced there initially. They simply have the competitive advantage in that situation.

Grazing height is therefore the critical parameter in pasture management where regrowth is possible and desired. Different forage species require different residual heights to maintain adequate leaf area to intercept full sunlight. For most forages a leaf area index (LAI, leaf area to ground surface ratio) of 3 to 4 will intercept enough sunlight to maintain maximum photosynthetic activity. The height at which this is attained varies from species to species. White clover and bermudagrass can attain this at a height of only 1 inch. Meanwhile, orchardgrass and tall fescue would need from 1.5 to 2 inches. Table 5–3 lists suggested residual grazing heights for major pasture species.

If grazed to the minimum height required to maintain full light interception and maximum growth rate at all times, as shown in figure 5–20(a), the grazed stubble is higher (schematic inset). Plant or stem density tends to be higher as a result as well. This is necessary where pastures are to be stocked continuously. Because cattle are there continuously, there is no recovery period to allow forages to increase leaf area before they may be grazed again.

Where pastures are rotationally stocked, forages can be grazed closer, as shown in figure 5–20(b). However, enough residual leaf area must be left behind to keep plants in a vigorous, fast growth state. Note in this example the recovery period to the maximum growth rate is about 16 days. A few more days then would be needed to allow forages to grow to the desired available forage mass needed for the class of livestock being fed. Do not interpret figure 5–20 to be graphs showing mass accumulation.

Figure 5–20 Leaf growth rate changes based on residual leaf area left as result of grazing height (from Hodgson 1990)

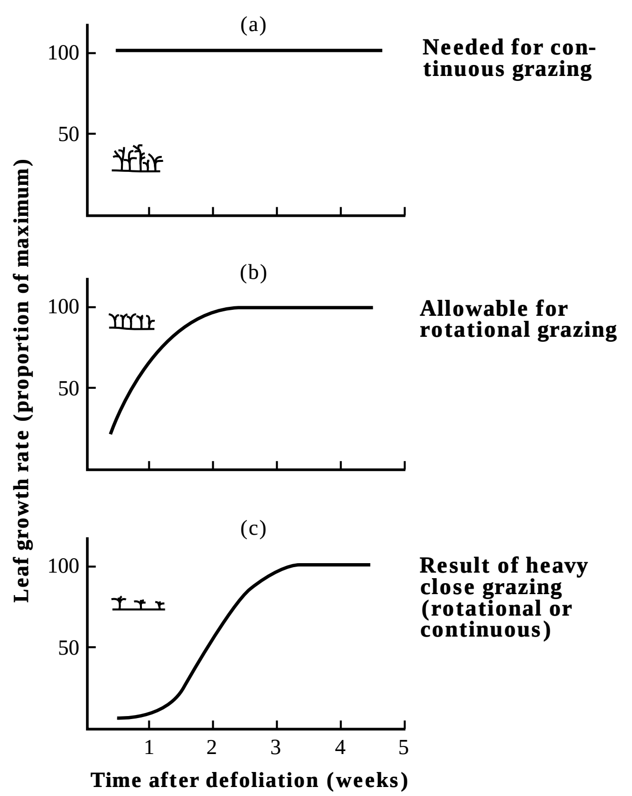


Figure 5–21 Differences in forage plant morphology from one species to the next change their response to grazing height (from Blaser 1986)*

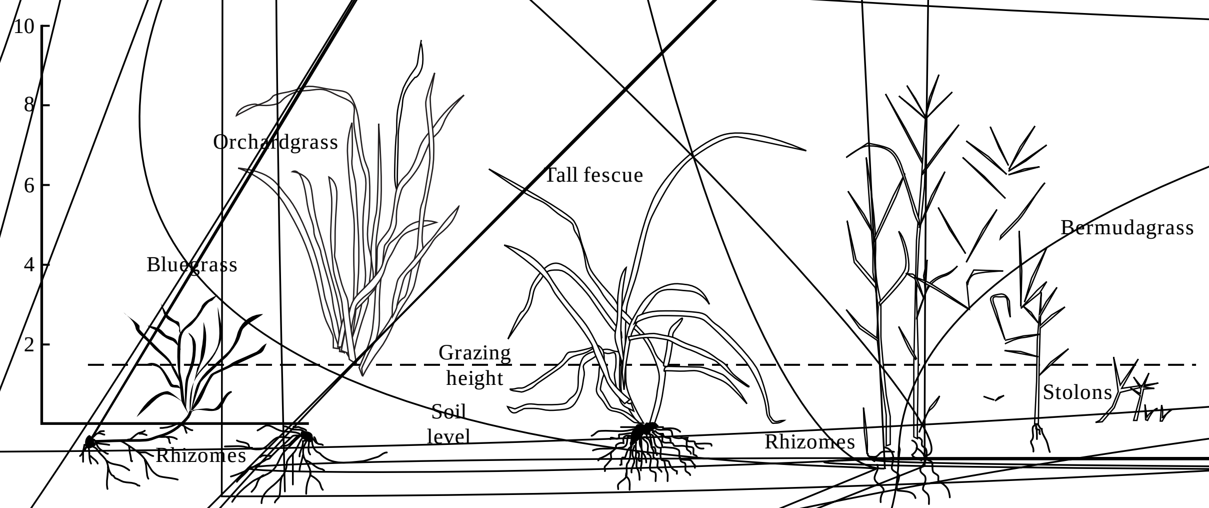


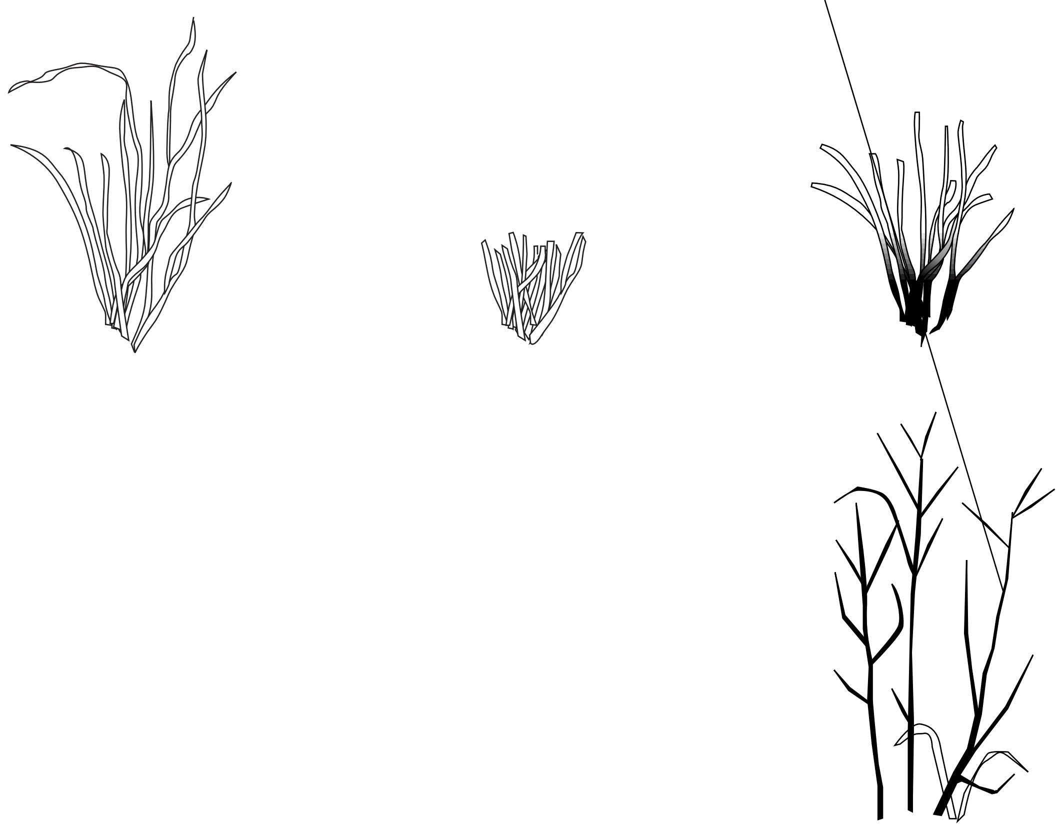
Table 5–3 Suggested residual grazing heights for major pasture forage species [1/] (from Ball, et al. 1991; Barnes, et al 1995; Blazer 1986; Chessmore 1979; Hayes 1966; Serotkin 1994)

Pasture type	Continuously stocked, average height of pasture (in)	Rotationally stocked, minimum height at removal (in)
Predominately grass		
Bahiagrass	1.5 to 3	2
Bahiagrass-legume	1 to 3	1
Common bermudagrass	1.5 to 3	1
Bermudagrass-white clover	1 to 3	1
Hybrid bermudagrass	3 to 6	2
Kentucky bluegrass	2 to 3	1 to 2
K. bluegrass-white clover	2 to 3	1
Bromegrass, smooth [2/]	4 to 5	2 to 3
Orchardgrass	4 to 5	2 to 3
Orchardgrass-Ladino clover	2 to 4	2
Reed canarygrass [2/, 3/]	——	2 to 3 [4/]
Ryegrass	2 to 3	1 to 2
Ryegrass-white or Ladino clover	1.5 to 3	1 to 2
Switchgrass [3/]	——	6 to 8 [4/]
Tall fescue	4 to 5	2 to 3
Tall fescue-Ladino clover	2.5 to 4	1.5
Winter small grains	3 to 6	3
Predominately legume		
Alfalfa [3/]	——	1 to 3 [5/]
Arrowleaf clover	2 to 4	2
Berseem clover [3/]	——	3 to 4
Birdsfoot trefoil, prostrate type [3/]	——	1 to 2
Birdsfoot trefoil, upright type [3/]	——	2 to 3
Crimson clover	2 to 4	2
Ladino or white clover	1 to 4	2
Lespedeza [3/]	——	3
Red clover [3/]	——	2
Rose clover	2 to 4	2
Subterranean clover	1 to 3	1

1/ Heights given are those to maintain stand vigor and longevity. Greater heights may be needed to maintain proper intake for certain livestock types and classes.
2/ Must be grazed before jointing occurs or allowed to mature for hay and aftermath grazed.
3/ Not recommended for continuous stocked pasture use; includes grazing type alfalfa.
4/ Stubble height largely dictated by stiff stems discouraging lower defoliation.
5/ Stubble height of 3 inches for overwinter protection. Grazing type benefits more from residual stubble height during the growing season than does a hay type.

Nonjointed (culmless) grasses maintain their growing points on vegetative tillers below or at ground level most of the year. They send up reproductive jointed stem stalks once per season. These grasses are resistant to close grazing and not very dependent on stored food reserves except at green-up. This is mainly because when grazed, their actively growing leaves continue to elongate. The active meristematic tissue is pushing them up from below and creating fresh new photosynthetic area. These grasses can be continuously grazed provided enough leaf area is left to produce maximum photosynthetic activity. Typical nonjointed pasture grasses are bahiagrass, bentgrass, Dallisgrass, Kentucky bluegrass, little bluestem, orchardgrass, redtop, ryegrass, and tall fescue. Figure 5–22 is a visual comparison between jointed and nonjointed grasses.

Figure 5–22 Response of a nonjointed grass like Kentucky bluegrass compared to a jointed grass like switchgrass* (from Waller, et al. 1985)



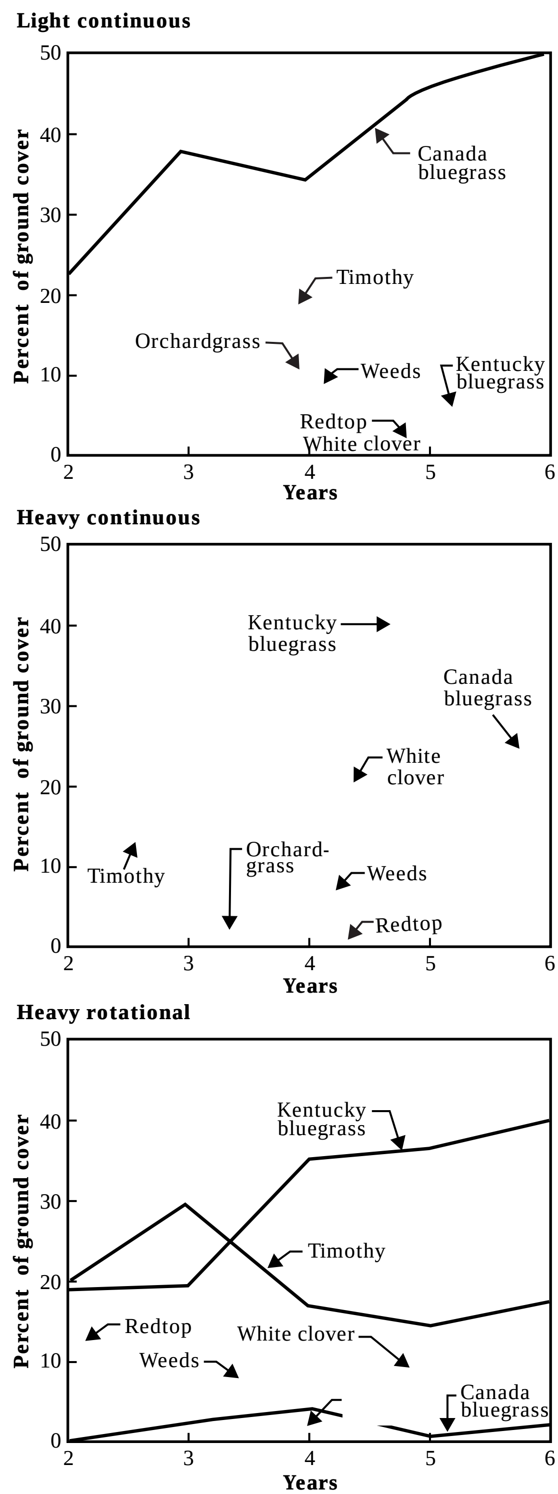
Shifts in plant species composition often occur unintentionally under different grazing regimes (fig. 5–23). In the 6 years of applying three different types of stocking management to three sections of a pasture seeded to a uniform mixture of pasture forages, species composition shifts occurred swiftly. Figure 5–23 starts with year two. The top graph shows the shift in pasture species where stocking was light, but continuous. Spot grazing occurred, leaving high stubble heights in ungrazed areas. The taller upright grasses were favored over Kentucky bluegrass. Canada bluegrass being less palatable proliferated. Timothy decreased after an initial increase resulting from drought in the fourth year. It reached an equilibrium point in years five and six. White clover never gained any ground because stubble heights were too high for sunlight to reach it.

The middle graph in figure 5–23 shows the result of heavy, continuous stocking. Grazed close, this promoted Kentucky bluegrass at nearly the expense of everything else. White clover was initially favored, but decreased in the final two years because of the dry weather. Timothy almost disappeared from the stand as a result of repeated drawdown of food reserves. Canada bluegrass recovery in the final year resulted from a weakened Kentucky bluegrass stand from drought.

The third graph in figure 5–23 shows the effect of heavy grazing rotationally. Kentucky bluegrass and white clover were favored because the grazing height was close. Most taller grasses nearly vanished. Timothy was not grazed during stem elongation while heading out. It was allowed to restore food reserves and remained fairly constant in ground cover. A less palatable grass, such as Canada bluegrass, is eaten where livestock are restricted to a smaller grazing unit. It appears from the rate of gain data in the published report (not shown) that they were not given enough forage on-offer and were forced to eat everything provided.

Grazing height can also be used to intentionally manipulate species composition in pastures. White clover persistence and percentage of the stand, for instance, are readily improved by grazing a pasture to a low grazing height. Under rotational stocking, this temporarily removes the grass canopy grown in association with white clover and allows light to penetrate down to the stolons. This activates growth of new leaves

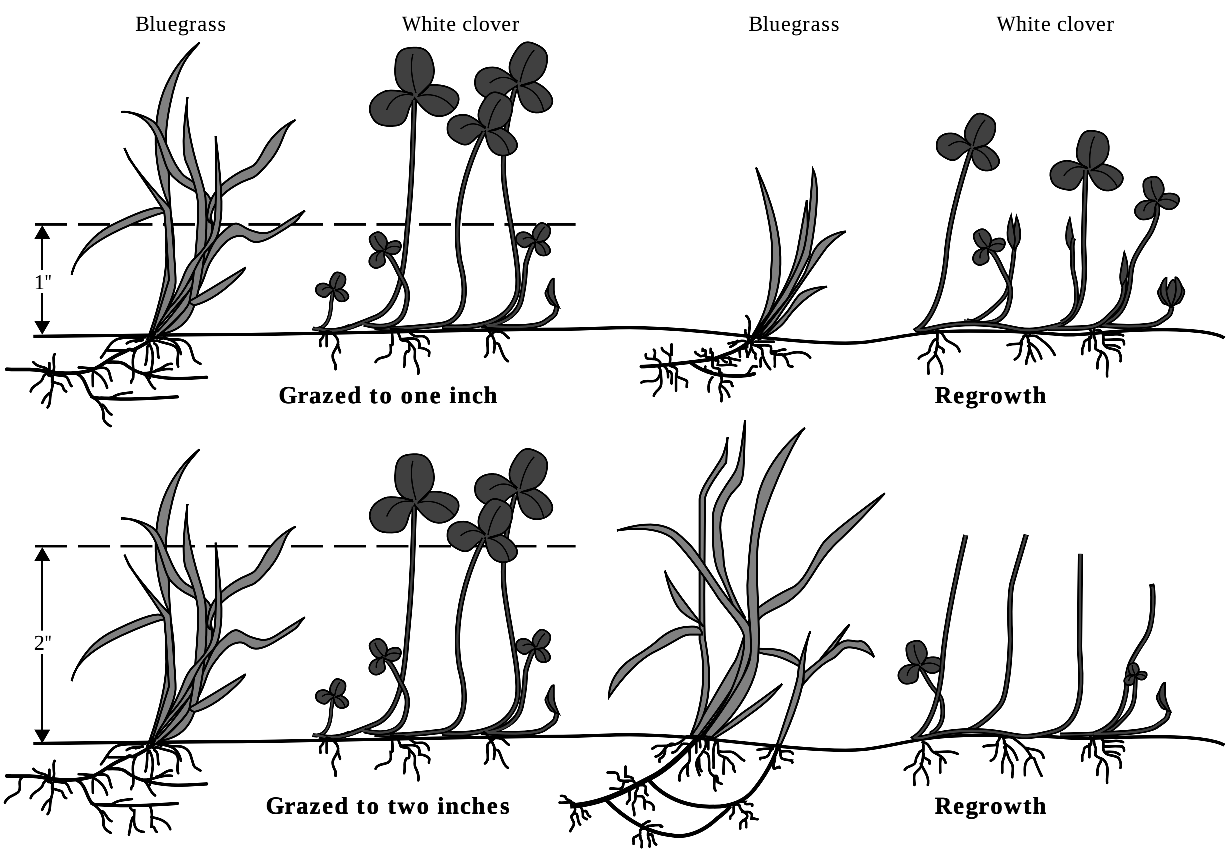
Figure 5–23 Changes in species composition over a 5-year period under different stocking regimes (from Smith 1975)



from nodes (fig. 5–24). The white clover then is able use this light energy to produce food for continued stolon growth and spreads laterally. Yet, if a tall grass, such as switchgrass, is the forage to be retained, maintaining high stubble heights and perhaps taking the first growth off as hay shade out competing cool-season forages.

On humid northern pastures, cool-season grasses, such as bluegrass, are likely to invade warm-season grass pastures if stubble heights and plant densities of the warm-season grass are not kept high. In this case the two grasses are incompatible and, over the long haul,one will win out over the other depending on the grazing height achieved. In the South where cool-season winter annual forage growth and warm-season grass growth do not interfere with each other, it may mean only to graze the warm-season grass close at the end of its growth cycle in the fall. This promotes the onset of growth of an interseeded cool-season grass or legume. The cool-season winter annual grass or legume normally dies back before or shortly after the onset of the warm-season grass growth the following season. An example of this is the combination of bermudagrass and interseeded annual ryegrass or legume, such as arrowleaf clover. A nearly continuous supply of pasture year-around in the same field is possible.

Figure 5–24 Differences in regrowth of white clover as result of grazing height; removal of the grass canopy favors the growth of white clover (from Blaser 1986)



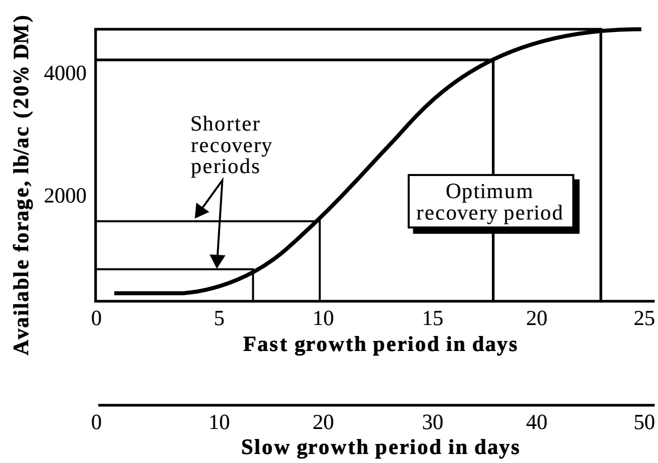
If the photosynthetic area is reduced below an LAI of 3 or the apical growing point is removed because it is elevated into the grazing zone, a recovery period for the forage crop is needed. This is often referred to by other authors as a rest period, which is a misnomer. The plant has undergone major surgery by the grazing animal. It is not resting. It is recovering. Initially, it is using stored food reserves to grow new leaf area. It needs time to restore enough leaf area to intercept as much sunlight as possible. It may also need time to build up the food reserves depleted in initiating dormant bud growth. If the surgery was too radical or food reserves were too low, it may not have enough active meristematic tissue to recover. This can be particularly true if other stress vectors, such as drought, cold, disease, or insects, occur. When this happens the plant population thins. Plants with few active meristems become shaded out by plants that have more actively growing leaves and nondormant buds.

Different forages have different recovery period requirements. Forages with widely fluctuating growth rates throughout their growing season need variable recovery periods. They grow quickly at one time of the year and very slowly at other times. Recovery periods may be as short as 10 days and as long as 60 days or more. Pasture species falling into this category are bluegrass, reed canarygrass, orchardgrass, perennial ryegrass, tall fescue, and white clover. To a large extent, the return of livestock to the pasture is determined by available forage target the operator is willing to accept (fig. 5–25).

Other pasture forages respond better to a fixed recovery period. The legumes in this group when faced with dry, hot weather will go to physiological maturity regardless of stature and vegetative growth will cease. Extending the recovery period only hurts quality and produces no additional forage. The grasses, if grazed too late, go to physiological maturity, and many leaves are lost to senescence. This reduces the quality and quantity of forage ingested. If either of the legumes or grasses of this group are grazed too early, food reserves or leaf area are not restored sufficiently. This can lead to a steady decline in plant, stem, or tiller counts. Pasture species in this category are bahiagrass, bermudagrass, big bluestem, Dallisgrass, alfalfa, red clover, smooth bromegrass, switchgrass, and timothy. A generalized fixed time interval cannot be given because it does vary by species and climate. Recovery times deemed sufficient for long-term forage survival are even debated for some species. Alfalfa, for instance, was stated as being somewhere between 28 to 35 days. With the newer pasture-type alfalfas, some agronomists recommend only a 21-day recovery period. However, this is based on leaving enough stubble with leaves to carry on some photosynthesis.

Forage crops that are going into a winter dormancy period require a special recovery period near the end of their growing season. This allows them to develop enough food reserves to make them cold hardy as well as store energy for next year's green-up period. Normally, a 4- to 6-week recovery period is needed. Under rotational stocking, this can often be accommodated in the regular rotation. Under continuous stocking, some way of reducing stocking density by opening up other grazing areas, such as fields with grazable crop residue, or temporarily removing livestock from the pasture is helpful.

Figure 5–25 Variable recovery period* (from Murphy 1988)



* During fast growth periods, days for recovery are half that of slow recovery period in this example. During prolonged periods of moisture stress, recovery periods can be much longer before available forage target is reached for class of livestock being pastured. Note shorter recovery periods fail to make much use of fast accumulation rate portion of growth curve (typical of continuously over-stocked pasture).

(c) Selective (spot) grazing of pastures

As mentioned earlier, a characteristic of pasture setting it apart from hayland and cropland is that it can be harvested (grazed) unevenly. Several factors contribute to this. However, the primary factor that sets this into motion is the forage supply exceeds livestock demand, either seasonally or season long. Here again, this shows the importance of forage growth curves. If flush periods of growth are not accounted for, forage production gets ahead of the herd's or flock's ability to eat it. The animals tend to go back to previously grazed areas where the less mature (vegetative) plants are because these forages are more palatable. Once patches of mature (reproductive tillers present) forage plants establish from grazing preference patterns, they persist the whole grazing season, or possibly several seasons, unless mowed (clipped). This can lead to severely overgrazed spots and underutilized spots in the same pasture. This does not occur on overstocked pastures nor on rotational pastures that have stock densities in keeping with the amount of forage on-offer. In fact, on severely overgrazed pastures, zones of repugnance (avoidance of livestock eating near their own waste) do not exist around urine and feces spots. Even that does not contribute to selective grazing when animals are underfed. These pastures are grazed uniformly closer than most lawn mowers can cut except for an occasional distinctly unpalatable plant. Forage utilization is high, but production is very low.

(1) Factors involved in selective grazing

The main factors involved in selective grazing are:

- Forage supply exceeds livestock demand
- Plant palatability differences from species to species
- Plant palatability differences within species due to maturity differences or level of anti-quality chemicals
- Plant palatability differences due to terrain and soil conditions
- Avoidance of plants soiled by dung and urine

Palatability differences among pasture species revolve around two main factors: morphological and chemical. Morphological differences are differences in leaf coarseness and stem to leaf ratios. Chemical differences are anti-quality metabolites that impart off-odors or flavors or that induce illness. Other factors, such as succulence and fiber content, affect intake by livestock using other grazing areas, but the differences among pasture species are relatively small.

Pasture species that are quite different in palatability should not be planted together in a mixture. The least desirable species will be shunned. If they can spread by seed or vegetatively, they will. Over time, they will increase in areal extent. The more palatable species will be overgrazed and lost from the stand. This argues against using shotgun seeding mixtures. It is hard to get more than two or three species together without getting a significantly less palatable species added to the mixture.

Some responses by livestock come from what they are conditioned to eating. Often reed canarygrass is avoided by livestock if they are not initially raised on it. This can be for two reasons. One is that it has a large coarse leaf and with age becomes stemmy, a stiff stem at that. The other is that some ecotypes are laced with an alkaloid that causes digestive problems in animals not conditioned to eating it. If it is grown in association with other grasses, it will be left untouched and will eventually cover the grazing unit. If it is rhizomatous and tall, it spreads and shades everything else out.

Tall fescue is similarly rejected if grown in association with other grasses. It tends to have leaves that are coarser and tougher than other species. It also has an alkaloid in it caused by the endophytic fungus, *Acremonium coenophialum*. This is toxic to animals causing a number of symptoms: fescue foot, bovine fat necrosis, and fescue toxicosis. The first two conditions can be worsened by high nitrogen fertilizer rates from commercial fertilizer or manures, such as chicken litter.

Within species selective grazing is most often caused by succulence differences. As the plants mature, they become less succulent and more fibrous. Mature seedheads also make the areas less inviting to grazing. Areas that are initially grazed are repeatedly regrazed when animals have the chance to graze more forage on-offer than they can eat completely. The forages in these areas are younger and therefore more succulent. If given a wide latitude, livestock are very selective.

Chemical differences are less important except where endophyte infested tall fescue pastures are renovated and planted to endophyte-free tall fescue. In this case the chances of having a few infected plants survive or germinate from the soil seed bank are quite high. With time these plants may capture more and more ground area as they are rejected and allowed to proliferate over the more palatable and less hardy endophyte-free fescue. The alkaloids that are produced in response to the endophyte make those plants bitter and cause digestive and metabolic problems in livestock.

Terrain and soil differences can cause spot grazing to occur. Shallow, low fertility, and low water holding capacity soils often produce more succulent plants than deep, high water holding capacity soils. These poorer soils produce plants with finer leaves, more leaves, and higher sugar content than plants on the better soils. Because these sites are more fragile to begin with, their attractiveness as food fare only worsens their ecological condition. They will be the first site to show the effects of overgrazing even if other areas of the pasture are not. These areas often occur on knolls and ridge points that have south and west aspects. Often low, poorly drained sites are said to produce washy plants. These plants have coarser leaves, lower sugar content, and become stemmy quickly. Consequently, livestock reject the forage in these areas or use them only as a last resort.

Steep sloped areas will be avoided or underused by livestock if more level terrain is available with adequate forage reserves. This is particularly so in mountainous terrain where distance to water may also be great. Limited water sources tend to cause areas of pasture nearest the water to be overgrazed while areas farther away are underutilized if used at all. Bare areas may encircle the water source, and trailing to and from the water source may become excessive. If the pattern is allowed to occur for several years, ecological succession can begin to progress in areas remote to the water source. Woody vegetation can invade making the fringe pasture areas from the water source become even less desirable to graze.

Shady areas that exist along fencelines or in the pasture itself often influence grazing patterns as well. These areas cause a grazing pattern similar to that around water sources. Close grazing occurs near shady areas, and utilization decreases with distance outward. Because of heavy treading pressure under trees, vegetation may often be lost entirely in the shaded area.

Barriers, such as fencelines, rock outcrops, cliffs, and high walled streams, often disrupt grazing access. The areas made difficult to reach are so infrequently grazed that they become overmature. Once they reach maturity, they are less desirable and perpetuate their status as a little used foraging area. If cattle find them hard to get to, these areas will be left unmanaged by the land unit manager. They may eventually revert to woody vegetation.

The remaining effect causing selective grazing is the **avoidance of grazing near dung or urine spots.** This is less of a problem with sheep and horses than it is with cows. Cattle may reject forage in an area surrounding the dung pat 5 to 12 times the size of the pat. Depending on the controls of forage on-offer and forage species being grazed, the amount of pasture area rejected may be none under an overstocked scenario to as high as 70 percent found in a study conducted on a continuously grazed coastal bermudagrass site after 98 days of grazing.

Commonly, 20 percent of the available forage can be wasted because cattle avoid dung spots. Fresh urine spots are avoided. Older urine spots, on the other hand, may attract grazers especially during drier months. The grasses there tend to be more succulent because of the effect of high soil nitrogen concentrations on the growth of the grass. Plants with adequate to excessive levels of nitrogen remain greener longer under drought stress than other plants in the pasture having less nitrogen available to them.

600.0505 Conservation practices for pasture

(a) Harvest management practice—Prescribed grazing

The prescribed grazing conservation practice is used to provide adequate nutrition to animals while maintaining or achieving the desired vegetative community on the grazed site. The principal agent for vegetative manipulation is the grazing animal. If the controlled stocking of grazing animals cannot effectively change the vegetation toward the desired level of production or forage species composition in the time frame desired, then accelerating conservation practices are employed. These practices are described later in detail.

(1) Principles of allocating forage to livestock—pasture budgeting

The two main goals of the prescribed grazing practice on pasture are:

senesce. This senesced residue shades the ground and causes plant thinning unless the pasture is clipped repeatedly.

Going from a high forage allowance to a lower forage availability status is possible without increasing livestock numbers. As forage plant numbers decline, a less vigorous sod allows weeds and woody vegetation to invade. With low livestock numbers, these plants survive and eventually dominate areas of the pasture. This can impact the five natural resources as well. The biggest impact is felt by the plant and animal resources. The plant community transitions into something less desirable as a forage resource. Browsers may be favored over grazers if succession back towards forest occurs. In advanced stages, areas of overgrazing will co-exist with undergrazed.

Both situations can be reversed back toward the middle of the graph. There the forage allowance given per animal unit is somewhat short of maximum rate of gain per head, but allows for a higher utilization rate of the forage and a much higher output per acre. Therefore, it is critical to know first what the forage requirement is per animal unit. General rules of thumb have been 2.6 percent of body weight for most ruminants and 3.0 percent of body weight for lactating dairy cows. However, these should not be considered absolutes.

Intake is affected by forage quality, temperature, amount of forage on-offer, and animal condition. A normal range of values is 1.5 to 4 percent of body weight. The optimum forage allowance is this required forage ration plus some additional forage mass to cover losses by rejection, trampling, and soiling as well as to make it easy for animals to get a full bite each time. This optimum is expressed where the output per head and output per acre lines cross in figure 5–26. If the actual forage allowance deviates from this optimum, the results are shown in figure 5–26 and were described earlier. If stored feed is fed in addition to pasture forage, this dry matter contribution should be subtracted from the ration.

(ii) Maintain healthy forage base—The second main goal of prescribed grazing is maintaining a healthy forage base on the pasture acres. Forages are a renewable resource when harvested with their needs in mind. This means stocking livestock commensurate with the amount of available forage throughout the grazing season. When overgrazed or undergrazed, forage stands continue to renew themselves, but at lower and lower levels of production. Over time, the stand thins in plant and stem numbers. Invasion by less desirable plants occurs.

For those forages tolerant of continuous grazing and managed that way, it means leaving enough residual stubble height to maintain optimal leaf area for full sunlight interception while guarding against underutilized areas caused by spot grazing. Perennial forage pastures may need to be clipped (mowed) when areas of mature plants produce seedheads. This stimulates those plants to produce new vegetative growth.

For those forages better suited to rotational stocking methods, it means leaving enough residual stubble height to allow recovery of the plants. It also means respecting the recovery period needed by these forages. Delaying or speeding up stocking schedules can do harm to the forage stand as well as cause distortions in feed quality and quantity. Delays can develop because of faster forage growth than expected or the grazing period is extended to use pasture subunits or paddocks better. When this occurs some of the paddocks nearing seedhead emergence or bud flowering should be cut for stored feed unless they can be stockpiled for grazing later. If return interval starts to speed up as a result of grazing periods being cut short for lack of enough available forage, supplement pasture with stored feed or, if available, bring in additional grazable acres.

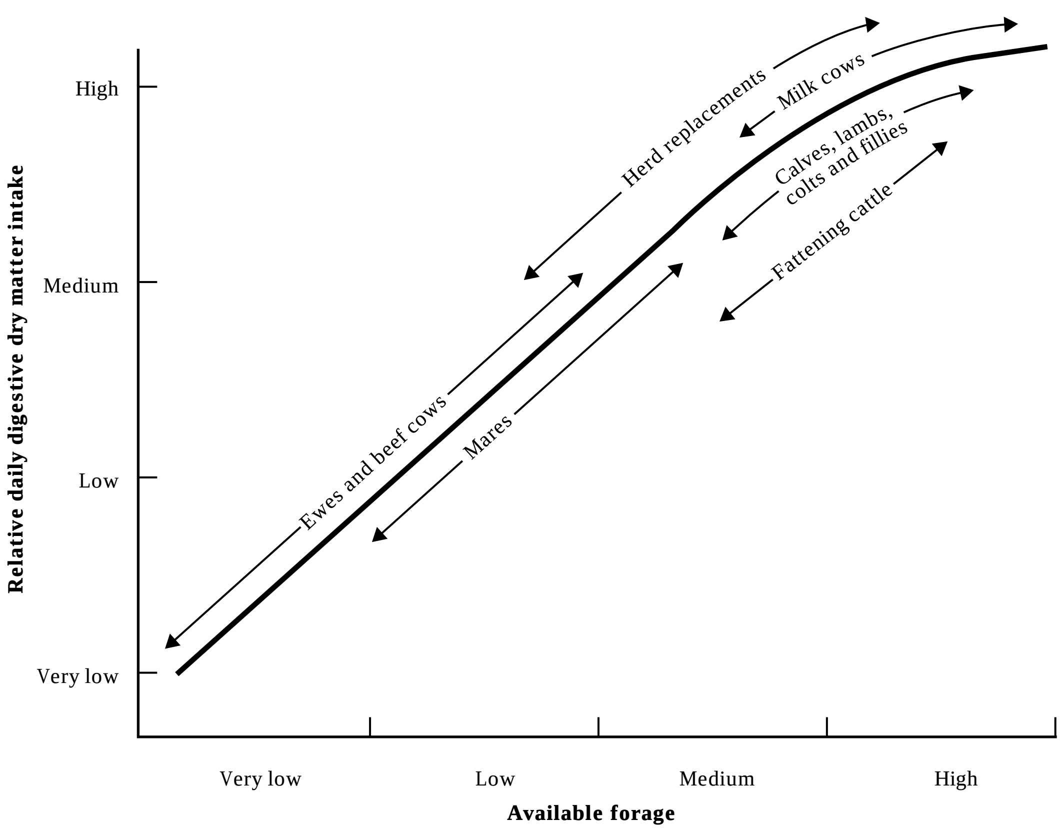
Paddock forage growth should be measured well in advance of the herd. All paddocks should be monitored once per week. If measured and charted, the rate of growth for each paddock can be determined. Considering the rate of growth and any trends observed (declining, flat or rising growth rate), the operator can project when each paddock will be ready to graze based on available forage target. If the projection shows available forage target is exceeded well before livestock will occupy a paddock and several paddocks will be in this condition, either adjust stocking rates upward or machine harvest the number of paddocks required to get to a paddock that meets available forage target. If some paddocks are slower to recover while others are faster, the operator should adjust the sequence of paddock grazing to accommodate the variance in growth rate. These differences are caused by forage species composition, soil type, aspect, or grazing residual height variability associated with the site and season.

Available forage is a critical term needed regardless of grazing method. As applied to pasture, it should be defined as the consumable forage in pounds of digestible dry matter per acre between the allowable minimum stubble height for the preferred forage species being grazed and the plant height achieved before or during grazing. It should not be to the height to which the grazing animal can graze it down. This fails to recognize the harm done to the forage crop when grazed too close, the resource that the animal and producer depend upon for their livelihood. It may be available to the animal, but it is not indiscriminately available if forage persistence and vigor are desired. As it was defined here, it is sometimes called usable forage.

Another key to the definition is that available forage is constantly changing unless forage is dormant or dead. Available forage is changing before grazing. It increases as the forage grows ungrazed. Available forage declines once grazing is initiated in rotational grazing methods. It declines until the animals are removed. It fluctuates up or down under continuous grazing methods depending on how finely tuned grazing pressure is applied and the variability in forage growth rates in relation to livestock stocking rates (animal units per acre). The importance of this moving target is that it must meet each class of livestock's requirements at all times.

Figure 5–27 shows the relative amount of available forage that must be presented to different kinds and classes of livestock. Otherwise, a loss in livestock production occurs when it falls below the minimum required. If rationed too tightly, the animals are not able to maintain intake. In some instances, some classes of livestock, such as milk cows, have a fall-off in production before grazing to the minimum stubble height needed to maintain plant vigor. High producing

Figure 5–27 Available forage requirements for different classes and ages of livestock (from Blaser 1986)



milk cows simply need more available forage or a high forage allowance to maintain a high level of intake. They need to move to pastures that have sufficient available forage or be fed stored feed. Dry matter intake by high producing milk cows falls off rapidly as available forage declines below 1,000 pounds per acre. Other classes that only need to maintain body weight may graze below the minimum stubble height needed for the health of the preferred forage community if lax grazing management is applied. Where too much available forage is presented, spot grazing can occur and animals may be overconditioned (too fat). The latter can lead to livestock reproductive and health problems too and waste a valuable forage resource. Methods for monitoring available forage are described in chapter 5.

The other key to the definition of available forage is the term, **digestible dry matter**. This accounts not only for the quantity of forage available for consumption, but its quality as well. As stated earlier, pasture forage kept in a vegetative state has a higher digestible dry matter content than it does typically when harvested as stored forage. Much of this is related to its stage of maturity, but it is also a reflection of losses suffered by stored roughage during harvest operations and storage. Pasture forage should therefore be allocated based on its quality as well as quantity, or utilization will be less than predicted. A forage allowance based only on total dry matter will be too generous on high quality pastures.

Pastures that run above 65 percent digestible dry matter dampen dry matter intake for many classes of livestock depending upon their energy requirements. For example, see figure 5–28. This illustration depicts dry matter intake versus dry matter digestibility for dairy cows at different milk production levels. The intake of a low producing milk cow drops off starting at 56 percent digestible dry matter. While that of a high producing cow does not drop off until forage digestible dry matter exceeds 75 percent. High producers only get this much digestible dry matter by being fed concentrates along with pasture forage. Pasture forage may be 75 to 80 percent water and will fill the gut before the percent digestible dry matter factor can influence intake.

Forage utilization is the percent of available forage actually consumed by the grazing animal based on net forage accumulation that occurs before and while they occupy the pasture unit. The amount of available forage presented times the acreage of the pasture unit (forage on-offer) must equal the forage allowance required to feed the herd or flock for the period they will occupy the pasture unit unless supplemental feed is fed. In other words, if 15 animals were to occupy a 1-acre pasture unit for 3 days and had a forage requirement of 25 pounds of digestible dry matter per animal unit per day, 1,500 pounds of available forage would be needed on that acre if the utilization rate was 75 percent (1,500 lb/ac x 0.75 x 1 acre = 1,125 lb = 25 lb/au/day x 3 days x 15 au).

A 100 percent efficient enterprise is impossible without unacceptable livestock performance. As livestock move about grazing, some forage is rejected, some ceiling is surpassed, then animal production per acre declines quickly. At the same time some forage areas within the pasture unit will be grazed to stubble heights lower than ideal for persistence and vigor. If 40 percent or less of the available forage is used, individual animal performance is high, but the pasture is undergrazed.

Forage availability or allowance must be high for high performance livestock for them to maximize intake rates that sustain high rates of gain or milk production. Intake declines as soon as dry matter per bite goes down and the number of bites per grazing period goes up. The livestock classes shown at the upper end of the curve in figure 5–27 may need to be followed on rotational pastures with a less demanding herd of livestock. For instance, the milking herd on a dairy farm can be followed by dry cows and replacement heifers. On other farms calves, lambs, and colts may be allowed to forward creep graze ahead of their mothers. Their mothers once past peak lactation have a lesser intake requirement. This increases the overall utilization rate for the good of the forage stand and the efficiency of the pasture system.

To summarize, livestock must be given a forage allowance (pounds of dry matter per animal unit) that covers their forage requirement plus some wastage. The practical limit is 20 percent wastage (80 percent utilization) before intake suffers in a big way and animal production per acre starts to decline. Individual animal performance has already declined at this point. At the 40 percent utilization rate, individual animal performance has peaked, but available forage utilization is low.

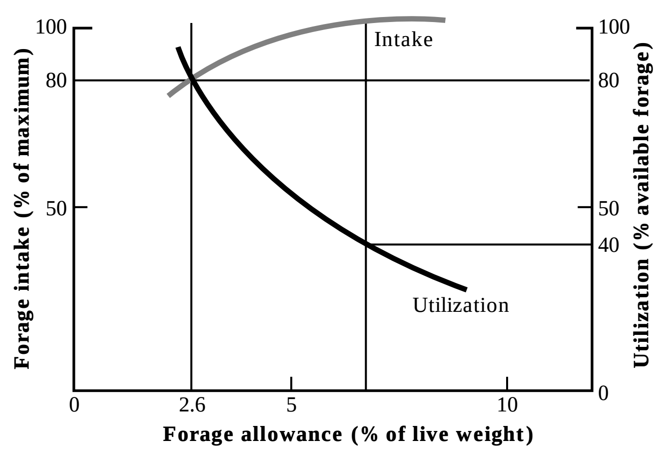
To get the right forage allowance in front of the animal requires a few critical items that are all interrelated and form the basis of a pasture budget. These items include:

- How much forage in pounds of digestible dry matter (DDM) per acre is available?
- The number, kind, and class of animal units to be placed on the pasture.
- Will these animals be fed stored feed while on pasture? If so, how much? This establishes their true requirement for pasture forage.
- Establish length of stay in the pasture unit. This determines the final available forage amount based on its status at the start of the grazing period and the growth rate during the grazing period. It also establishes the grazing period forage requirement for the animal units being pastured, daily forage requirement per animal unit times animal units times number of days of grazing period.

Table 5–4 Rotational pasture estimated utilization rates (from Penn State University, Agronomy Guide 1994)

Grazing period (days)	Pasture utilization (%)
0.5 – 1	80
2	75
3	75
4	70
5	65
6 – 30	60

Figure 5–29 Forage utilization as it affects forage intake* (adapted from Hodgson 1990)



* Available forage can be far in excess of that really needed to satisfy herd appetite if stocking rate is low. Animals can readily get all they can eat, but forage is wasted.

- Estimate a utilization percentage. This is the least precise input, but the practical range is between 40 and 80 percent.

This information helps in determining the forage allowance needed for the whole herd, grazing period forage requirement divided by utilization ratio (step 6). The size of the pasture unit can then be determined t(step 7) by taking the grazing period forage allowance for the herd and dividing it by available forage during the grazing period (lb DDM / lb DDM/acre = acres). This is pasture forage budgeting. The process is simple. Gathering reliable data is the hard part. Note that stocking rate, the number of animal units per acre per specified time period, was never relevant. It is an outcome of the process once livestock demand and forage supply issues have been resolved. It becomes relevant when animals are stocked with little regard to supply-demand issues.

For pastures that have forages with widely fluctuating seasonal growth rates and long grazing periods, such as with season-long continuous stocking, calculate monthly forage production during the high and the low forage growth rate month. This determines the number of animals that can be supported or the number of acres of pasture needed during those two disparate time periods in forage growth. This must be done for rotational stocking as well to determine differences in total pasture acreage needed at these two different periods in forage availability. If more than one forage community is pastured or pastures vary markedly in their productivity, then these same calculations need to be done for each pasture being used.

Herd requirements for forage change with time as well. They gain weight. Some are sold. Milk production during the lactation cycle for dairy cows fluctuates greatly and therefore so does their need for energy. This is especially important in figuring demand for seasonal dairying herds where all the cows are in the same part of the lactation cycle. Therefore, as simple as the forage budget process is, it is necessary to reiterate it as often as needed depending on the complexity of the pasture system being planned and used.

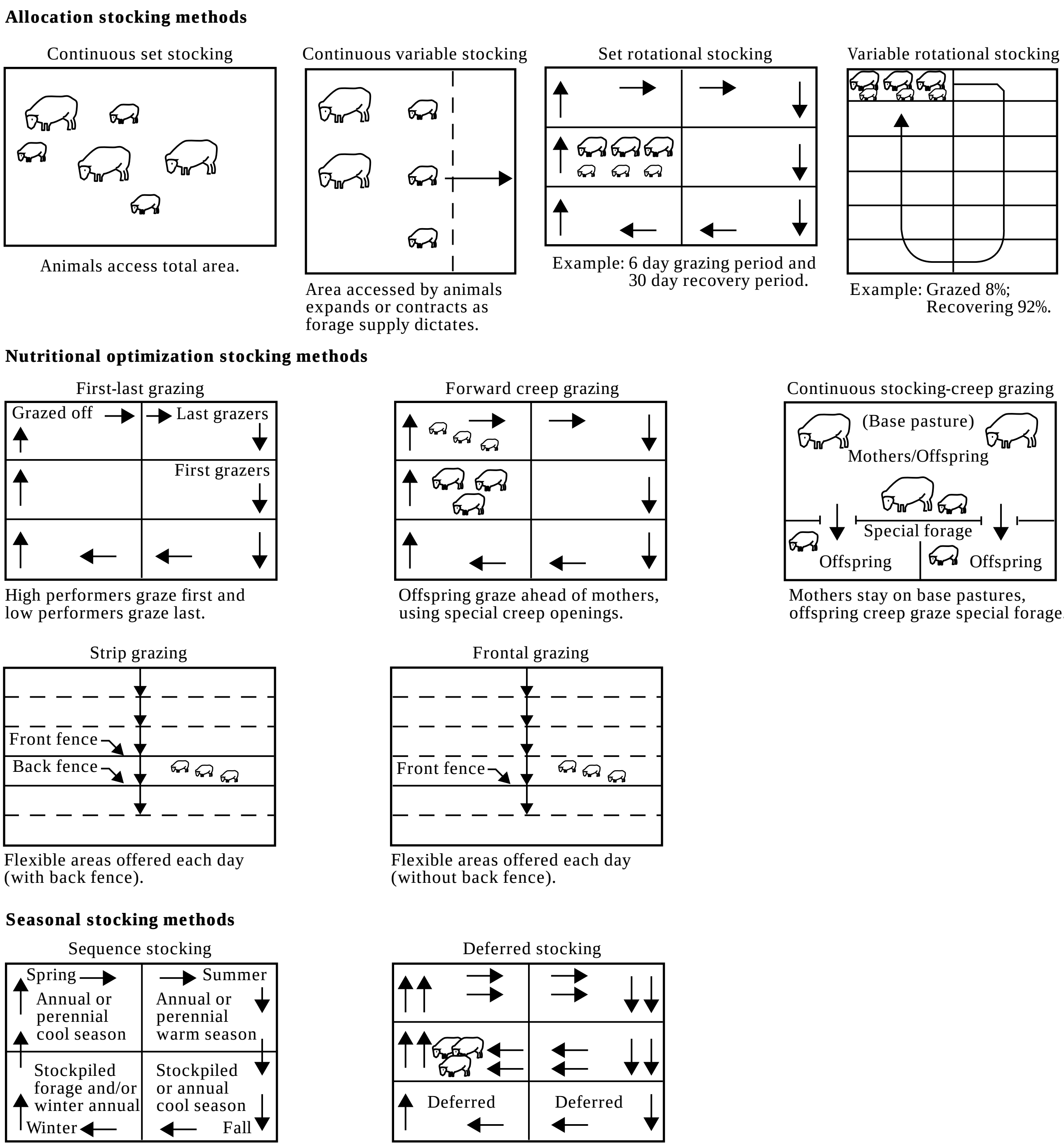
Care must be taken in developing forage budgets. Some budgets ignore forage quality. Others ignore utilization, and some overcompensate for it. Other budget formats ignore both quality and utilization. On high quality pasture this creates compensating errors, and the end result is a remarkably good answer for middle of the road performing livestock. The dry matter forage requirement, 2.5 to 2.6 percent of body weight, assumes a level of digestibility considerably lower than that available from high quality pasture. Because this assumed digestibility is 70 to 80 percent of that available on high quality pasture, the forage requirement already has the forage allowance covered if the utilization rate is in the 70 to 80 percent range.

In figure 5–29 see the forage allowance required at the 80 percent utilization rate. It equals 2.6 percent of body weight, but it assumed only 80 percent utilization of that 2.6 percent of body weight forage allowance. Only 2.1 percent of body weight was actually consumed, and intake was only 80 percent of maximum. Remember this maximizes production per acre and sacrifices some animal performance. The margin is razor thin. After that, animal intake drops precipitously. The curve has to go to zero intake in a narrow range of forage allowance. In other situations, such as low quality forage or maintaining a high availability for high performance livestock, less detailed forage budgets would not work out so well.

(2) Stocking methods

***(i) Allocation stocking methods*—**The four basic allocation stocking methods used throughout the country are continuous set stocking, continuous variable stocking, set rotational stocking, and variable rotational stocking. Herbivores graze, but livestock producers stock them on pasture. Hence, the use of the term **stocking** is preferred over the term **grazing**. Within the four basic methods, applications can vary based on livestock responses desired, climatic considerations, soil and terrain conditions, forage crops being grazed, and management preferences of the producer. The scope of this section is not to cover all the various applications, but it will cover the more common ones. Figure 5–30 is a diagrammatic illustration of each.

Figure 5–30 Three classes of stocking methods and their associated stocking method* (adapted from Barnes, et al. 1995; Hodgson 1990)



* Each method is diagrammed to show how the livestock are deployed about the pastures.

Continuous set stocking method—Continuous set stocking of livestock either season-long or year-long is a common method of pasturing them. Continuous set stocking means the same numbers of animals are on one pasture unit for the whole grazing period. This is a misnomer because although the animal numbers remain constant, animal unit demand for forage often does not. Meat animals gaining weight, and lactating animals have variable forage demands during the grazing period. If set stocking is to be used, an average forage allowance for the grazing period must be calculated. If there is a recovery period, it is at the beginning or end of the grazing period (= season). If the forage being grazed has a very nonuniform distribution of growth, forage utilization will be low. Periods will occur when forage growth gets ahead of livestock and times when it is too slow. During slow growth periods, livestock are forced to consume less palatable and lower quality forage that has collected in ungrazed or less grazed areas of the field. This reduces intake and also lowers utilization. Low utilization at the beginning of the year perpetuates low utilization. First there is too much to eat. Some forage matures. When the season progresses, there is more low quality, high fiber forage than succulent. This reduces intake. Spot grazing is high under this circumstance.

This method is appropriate, however, where both forage growth and animal unit demand are relatively evenly matched throughout the grazing period. Another situation where it can work well is where the forage has made all or most of its growth and it will be grazed until it is gone. This works well on seasonal annual forages and on stockpiled forages. Regrowth is generally of little or no concern. With stockpiled perennial forages, a minimum stubble height should be observed to allow it to go through its dormant period without stand loss. For annual forages leave enough stubble to protect the soil from erosion and allow ones that can naturally reseed themselves time to produce seed, as needed, to get a good stand next season.

This stocking method has been equated with poor grazing management. The method itself is appropriate under the right forage growth circumstances and when managed to provide the proper forage allowance to the class of livestock being fed. Unfortunately, this method is applied all too often with none of that in mind.

Continuous variable stocking method—Continuous variable stocking is a stocking method alternative that adjusts land area or livestock numbers as forage availability changes throughout the grazing period. On commercial operations, this method starts out with a core pasture that is grazed during the high growth rate period of the forage. As forage growth rate declines, this method attempts to add more acreage and available forage to the livestock ration. The additional acreage is often harvested for stored roughage first. It is allowed to regrow. Then, it is opened up to livestock grazing as the core pasture forage growth rate starts to fall behind the livestock removal rate, or the available forage is nearing the desired maximum percent utilization rate. The decision to open up additional pasture is based on forage stubble height, changes in spot grazing behavior, animal performance, or a combination of these. With a milking herd, when milk production tails off and can be correlated to pasture condition, this signals a need to increase forage intake by increasing pasture size. The other alternative for this method is to keep the pasture the same size and vary livestock numbers. This is done in an experimental plot setting, but is not common on commercial operations. The procedure is called put and take. Livestock numbers are varied as forage growth conditions warrant.

Some pasture forages are not well adapted to continuous grazing. They are alfalfa, big bluestem, Indiangrass, Johnsongrass, red clover, sericea lespedeza, smooth bromegrass, switchgrass, and timothy. Many of these forages disappear completely under continuous grazing while the others persist, but at low levels of production. If managed under a rotational system, some forages respond and increase in percentage of total forage production and ground cover. These forages depend on a cycle that allows them to rebuild food reserves while they reach physiological maturity. Continuous grazing never allows that to occur.

Other forages, such as birdsfoot trefoil, Coastal bermudagrass, orchardgrass, perennial peanut, and tall fescue, are adapted to continuous grazing as long as they are not grazed too closely. If grazed close, they will persist, but in fewer plant numbers and at a much reduced growth rate. Bahiagrass, common bermudagrass, Dallisgrass, Kentucky bluegrass, ryegrass, white clover, and many annual clovers are adapted to close continuous grazing. They hold much of their leaf area and their growing points below the grazing zone. Bahiagrass and common bermudagrass often increase when present in a mixed stand with Coastal bermudagrass.

Set rotational stocking method—Set rotational stocking is a stocking method that falls under several different names depending on what region of the country it is used in. This method is useful on pastures where forage growth rates vary little or physiological maturity is going to occur regardless of forage height and growth rate. These forage crops respond to a recovery period because they need time to build food reserves while gaining in leaf area.

This general method has a set grazing cycle period. A set grazing period and a set recovery period make a complete set time cycle before the livestock return to the same pasture paddock or subunit. It is obvious from table 5–4 that higher utilization rates occur if the grazing period is short. It is rather important to most pasture forage species with elevated growing points that the grazing period not extend beyond a week. Otherwise, regrowth begins that may be grazed off when livestock are stocked at high densities. This can drawdown food reserves and make recovery slow as more growing points must break dormancy and grow to replace the newly initiated, but grazed off points. The recovery period is set based on the recovery period needed by the forage crop. The recovery period time and the grazing period time determine the number of paddocks needed. The recovery period time divided by the grazing period time plus one equals the number of paddocks required. For instance, alfalfa may require from 21 to 28 days to recover depending on the cultivar being grazed, pasture-type versus hay-type, and growing degree days for the region. If a pasture-type is grazed for 1 day and recovers for 21 days, 22 paddocks are needed. If the grazing period is extended to 7 days, only 4 (21/7 + 1), but much larger, pasture subunits are required.

A weakness in the set rotational stocking method is the variability that can occur with available forage in a pasture subunit from one cycle to the next. If it truly is set, it cannot account for changes in forage growth rates well. Alfalfa, for instance, will go to physiological maturity under drought conditions and flower even though it may be several inches shorter than it was when water was plentiful. A paddock that was sized right for optimal moisture conditions is going to be too small under drought conditions. Some fine tuning of paddock size may be warranted. This can be done with portable fences. Another option is to oversize paddocks to strike a balance between projected highs and lows in production. The other option is allow some flexibility in the grazing period seasonally and incorporate another field during low forage accumulation periods. Keep paddocks the same size, but reduce occupancy time to match available forage with forage allowance needed for the herd. Recovery periods remain set, but now more paddocks are grazed during the recovery period than when forage growth rates were high.

Pasture forage crops that respond best to a set grazing cycle period are alfalfa, big bluestem, birdsfoot trefoil (upright), Coastal bermudagrass, indiangrass, Johnsongrass, perennial peanut, red clover, smooth bromegrass, switchgrass, and timothy.

Variable rotational stocking method—Variable rotational stocking is a stocking method that adjusts the recovery period to the variable growth rate of forage species being grazed. The grazing period is generally set. In practice, it often is not. If the grazing period is not set, it tends to only defer problems of too much or too little forage within the area set aside for rotational pasture. The grazing period for high performance animals (intensive or short duration rotational stocking), such as lactating dairy cows, fattening cattle, and youngstock, should be no longer than 3 days, preferably not more than 1 day. For other livestock classes the grazing period can extend up to 7 days, but preferably not more than 4 days to prevent grazing of new leaf growth.

If a first-last stocking method is used, the combined total period of occupancy should not exceed 7 days (3 days for intensive rotational stocking). The grazing period length must be determined by animal performance, forage availability, and target residual stubble height or mass of forage to get rapid regrowth during the recovery period. This is initially determined using the pasture budgeting technique described earlier. If one or more of the estimates used to determine paddock size is off, the decision to deviate from the planned grazing period must be based on available forage and stubble height left at time of viewing.

This method is similar to the continuous variable stocking method in one respect. It relies upon expanding or contracting the area being actively grazed during the grazing season. During periods of high forage growth rates, the number of paddocks and pasture area is least. During periods of slow or arrested forage growth, the number of paddocks and pasture area expand to provide an adequate forage allowance for the herd in each paddock throughout the grazing cycle period. This additional pasture acreage typically is machine harvested until needed for grazing use. Grazing is initiated when enough forage has accumulated in each paddock to meet the herd's forage allowance (available forage x area x utilization rate = livestock demand).

This rotational system can have a high degree of flexibility. Paddocks can be stocked out of sequence when forage growth is variable from paddock to paddock because of landscape position, differing soil fertility and water holding capacity status, forage species composition differences, or past grazing pressure. When forage supply is much higher than expected, fewer paddocks than usual are stocked per grazing cycle and more are machine harvested. If the forage supply is low, additional paddocks are brought into the grazing cycle. In severe shortages the machine harvested forage made earlier when forage was in excess of livestock demand is available for feeding. This becomes critical if pasturing must cease to prevent forage stand loss or prolonged delay in forage recovery after the stress period has passed. Recovery periods range considerably, from 10 days to more than 60 days.

Pasture forages that respond best to this stocking method are ball clover, bentgrass, berseem clover, birdsfoot trefoil (prostrate), Kentucky bluegrass, orchardgrass, perennial ryegrass, redtop, reed canarygrass, tall fescue, and white clover.

(ii) Nutrition optimization stocking methods— These stocking methods are used to selectively feed livestock. They can be associated with either continuous or rotational stocking methods. They are **first-last grazing and strip grazing**. Creep grazing, where young stock graze ahead of their mothers, is generally considered a separate category, but in effect is just a form of first-last grazing on rotational pastures. On rotational pasture, it is called forward creep grazing. On continuous pasture, creep grazing requires a separate pasture of high quality forage which the mothers may never gain access to. Therefore, it becomes its own separate category in that situation. Strip grazing also has a variation to it called frontal grazing. Strip grazing requires a back fence to keep livestock off the previously grazed area. Frontal grazing provides animals with a fresh strip of forage too, but has no back fence. Animals have access to the land previously grazed as well as the new forage being offered. Both major selective methods and their variations are enhanced attempts of offering the appropriate plane of nutrition to the classes of livestock being pastured.

Creep grazing—Creep grazing allows young stock to graze forage their mothers cannot get to. It is used with meat type animals to get higher weaning weights. In either continuous pasture setting or rotational pasture, a gate with an opening just large enough to allow young stock to pass through is placed in the fence between the shared pasture area and the creep pasture. On rotational pastures, the mothers follow the young stock onto the forward paddock after the young stock have had first choice of the available forage. In this instance, it is a first-last grazing method. On continuous pasture the young stock have access to a separate field of high quality forage. The mothers may only get to clean it up near the end of the growing season or never gain access to it. In lieu of creep grazing, creep feeders may be placed in pastures so that only the young stock have access to high energy feeds for faster weight gains.

Another common first-last grazing scenario places lactating dairy cows ahead of heifers and dry cows on rotational pasture. High production lactating dairy cows require a high forage allowance to keep intake from falling off near the end of the grazing period that they are in a paddock. After they are removed, considerable available forage is still left. Heifers and dry cows having lower intake requirement can use forage left behind by the milkers.

Other first-last grazing combinations are rapidly growing weaned youngstock being placed ahead of the brood stock. Because high daily gains are desired of the meat animal, they are removed before intake starts to fall off and the quality of forage ingested declines. Care must be exercised to keep the total occupancy period no longer than 6 to 7 days on rotational pasture when grazing forages with regrowth potential.

Strip grazing—Strip grazing in its ultimate usage is trying to maximize utilization of standing forage by limiting the amount of fresh forage at any one time to the grazing herd. This tends to increase intake because the herd responds to fresh forage on-offer by grazing as soon as it becomes available to them. If intake increases, this will increase milk flow or weight gain. Thus, it is best utilized with high performance livestock. Generally it occurs on fields that are also machine harvested. The interior fences subdividing the field are portable and are removed once the field is readied for machine harvest again. Thus, no barriers are present to impede equipment traffic. Strip grazing may break forage allocation down to units small enough to be grazed off in one to four hours. The forward and back fences are picked up and moved to new positions based on completeness of forage removal. The same purpose and concept is used with frontal grazing except no back fence is provided. The forward fence gets moved as new forage is needed.

Under more lax grazing management, strip grazing may occur where the grazing period is similar to that of an intensive rotational stocking method where the livestock are moved on a half day to daily basis. Single strand electrified fence is used that is portable and can be removed if need be to facilitate machine harvest. This is useful on the fields that are brought into the rotational system during the low forage growth rate period. When not needed for pasture, they are cropped. In fact, the field strip grazed may be a crop field with grazable crop residues, or one seeded to an annual forage crop. Strip grazing serves a useful transitioning tool between cropping and grazing a field in this instance, but does nothing to further enhance animal nutrition beyond what the basic rotational method does.

Frontal grazing—Frontal grazing is a form of continuous variable stocking. As available forage disappears, more area is opened up for grazing. Again, as with strip grazing in variable rotational stocking, frontal grazing is most useful to incorporate a new field into the area being grazed when forage production is low. Instead of stocking the whole field at once and sustaining high trampling and rejection losses, the new field is rationed piece by piece. Forage utilization is higher, and higher intake rates can be sustained until the field is entirely opened up. This method is also more appropriate where the forage being grazed either has little or no regrowth potential. Crop residue, some brassicas, small grains grown for forage use only, and other short-lived annuals are examples. Perennial forages being grazed in this manner should be tolerant of continuous grazing.

When budgeting forage with strip or frontal grazing, care must be taken to not set aside more forage than can be consumed without a significant decline in forage quality when the last is made available for grazing. Entry into the field should begin slightly ahead of full forage growth potential to avoid having to stock animals on overmature forage near the end of the occupancy period.

(iii) Seasonal stocking methods**—**Another class of stocking methods seek to time access to fields to lengthen the grazing season or avoid harming the pasture area. The two main methods are deferred stocking and sequence stocking. They too can be used to varying degrees either in continuous or rotational stocked pastures.

Deferred stocking method—Deferred stocking can be done to stockpile forages or to keep livestock out of pasture areas needing seasonal protection for a variety of reasons. When the grazing season can be extended by stockpiling forages (i.e., tall fescue) that maintain their quality well, some pasture area is deferred from further grazing to allow the forage growing there to accumulate. Later on, this area is reopened for grazing when the other pasture areas are no longer producing grazable forage or need a recovery period.

Another form of deferred grazing is delaying the stocking of a pasture because it is too wet. Other pasture areas are selected that are drier to avoid damaging the sod and destroying soil structure. Soils when wet can compact severely. It is reversible only with mechanical treatment. On saturated soils, hoof prints are left behind that trap water and keep the site wetter longer than normal. The act of leaving these deep hoof imprints is called either poaching or pugging.

Deferred stocking may be used to protect riparian areas from grazing at critical times of the year. Another use might be to protect ground nesting bird habitat from disturbance until brood leaves the nest. Deferred stocking is also used where part of the pasture area is not needed for grazing until forage production slows down. This land typically is machine harvested to conserve the early growth and then stocked once sufficient forage is available for grazing. Deferred stocking may also occur on paddocks that are slow to recover for a number of reasons. They may be skipped over during a rotational cycle or two. A typical site would be a droughty soil paddock.

Sequence stocking method—Sequence stocking takes advantage of the seasonality of forage production. It integrates forages with differing seasonal availability into a diverse group of pastures. All fill a seasonal niche to supply enough forage to meet demand by the grazing herd. Review figures 5–14 through 5–16 and Table 5–2. Sequence stocking attempts to lengthen the grazing season or fill forage production shortfalls during the grazing season. Winter small grains might be grazed in late winter and spring, then early maturing cool-season perennial pastures next, followed by a later maturing cool-season perennial pasture, followed by a warm-season perennial or annual pasture, sequencing back to a cool-season pasture, and following up with a post harvest crop residue field and, where winters are mild, a winter annual pasture. Depending where the farm or ranch is situated in the country, all or part of these seasonal pastures and others not mentioned can be integrated into the forage production system. This stocking method attempts to reduce stored feed production and consumption to an absolute minimum.

(b) Accelerating practice—Nutrient management

Nutrient management on pasture differs from forage crop production nutrient management in two respects. First, most nutrients are recycled within a pasture's boundaries (fig. 5–31). Few of the nutrients brought onto the pasture as feed supplements, manures, atmospheric deposition, or commercial fertilizer leave its boundaries as animal products.

Second, nutrients can be redistributed unequally on pastures by preferential animal movement. Shady areas, watering sites, laneways, salt blocks, rubbing areas, natural waterbodies, windbreaks, buildings, and sunning areas can cause a disproportionate amount of dung and urine spots to be deposited in localized areas. This redistribution of nutrients can cause plant nutrient deficiencies in some areas and excess nutrients in other areas. For instance, rates of nitrogen (N) application at urine spots can range from 200 to 900 pounds per acre. Sometimes the rate is so high as to cause plant burning.

Because of the high application rate, loss of N at urine spots through leaching out of the root zone is possible in high rainfall areas. High losses of urea N at urine spots during dry weather also occurs. From 15 to 18 percent of the total N can be lost within 2 days of urination. The drying of the surface causes the urea to hydrolyze to ammonium. This raises the soil pH in a localized area that causes the ammonium to break down into ammonia, a gas, and a hydrogen ion. Windy conditions speed the process of ammonia volatilization. Surface runoff may also carry nitrogen and phosphorus (P) to receiving water if concentrated livestock areas are near open water and soil infiltration is low as a result of low vegetal cover or tight, compacted soils.

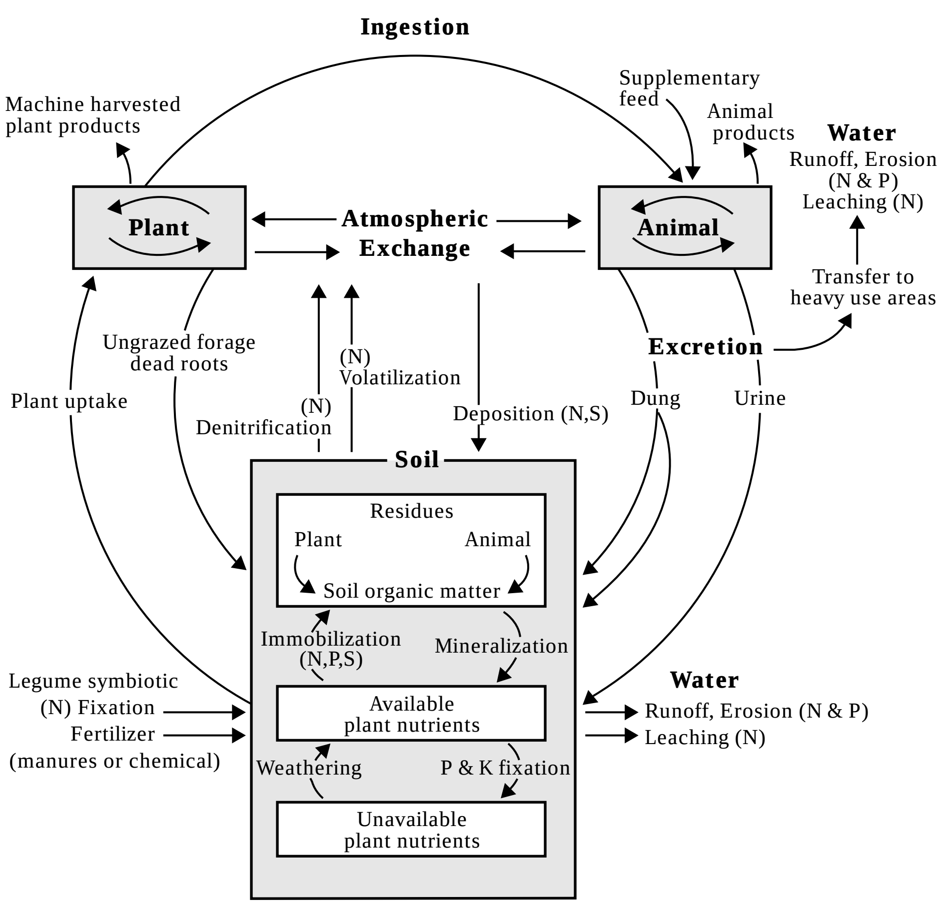
Phosphorus and potassium (K) levels are rather stable in pasture soils. Pastures should be soil tested every 4 to 5 years for these two elements. Plant available P and K should be built to the optimum levels for the soil series sampled. If the soil is already at the optimum level for these two nutrients, no further response in forage yield will occur with the addition of manure or commercial fertilizer containing these elements (fig. 5–32). Normal recycling of the P and K through random placement of dung and urine should maintain levels. If much supplemental feeding of hay, grain, or minerals occurs, soil P and K levels tend to slowly build in the pasture soil. Legumes are heavy users, but inefficient gatherers of phosphorus and potassium. If a legume component is desired in a pasture, P and K levels in the soil should be in the optimum to high range so they can compete successfully with the grasses.

Soil reaction, or pH level, should also be noted when the soil test results return. Keep the soil reaction within the range of acceptable forage production. Most legumes grow best in a slightly acid to neutral soil. Where aluminum toxicity can inhibit forage growth, maintain soil pH at 5.5 or higher. *Rhizobium* activity, symbionts that fix nitrogen in legume root nodules, is also reduced for most strains of *Rhizobium* es thepH, Nitrogen is generally the major limiting nutrient in pastures. As mentioned before, it can leave by three pathways: volatilize, leach, or run off. The distribution of dung and urine under even the best of circumstances is uneven. On an annual basis, a highly stocked pasture receives excreted N on less than 35 percent of its area. Where the stocking rate is an AU per acre, only 16 percent of the pasture surface receives any excretal N.

Intensive rotational stocked pastures tend to have a more even distribution of manure than do continuous set stocked pastures. However, it is extremely important that water, feeding areas, salt and mineral boxes, and shade are evenly distributed on a rotational pasture. If not, dung and urine spots can be distributed just as poorly. Poorly laid out paddocks and single source water, feeding, salt and mineral, and shade areas cause livestock to camp at these sites just as they do on continuous set stocked pastures. Long laneways to these attractive areas can receive much of the excreta as livestock traverse back and forth from grazing area to camp site.

Nitrogen can be supplied for forage growth two ways: apply a nitrogen fertilizer or add a legume component to the forage mixture growing on the pasture. When applying nitrogen fertilizers, organic or inorganic, rates of application should be low enough to prevent luxury consumption by plants and avoid leaching of nitrate through the root zone. Overfertilization of summer annual grass pastures with N can also cause nitrate and prussic acid poisoning in livestock if plant growth is stressed by frost or drought. Early spring growth applications must be avoided on all pastures

Figure 5–31 Nutrient cycling in a pasture ecosystem (adapted from Barnes, et al. 1995)



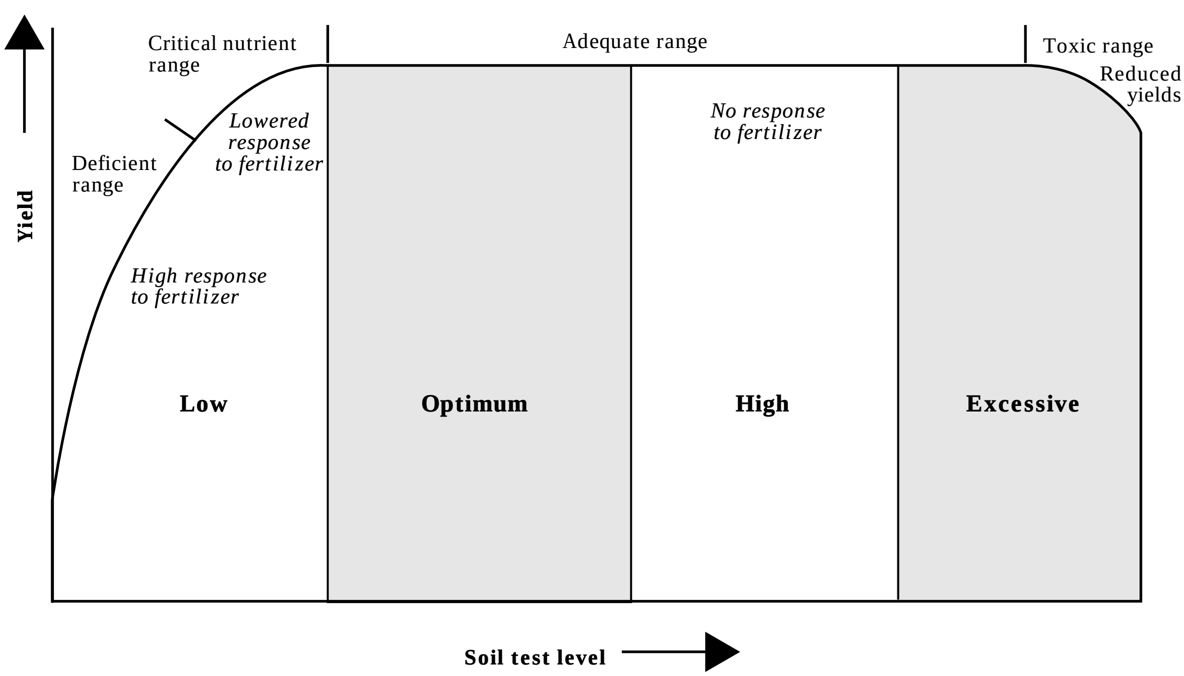
where grass tetany is know to be a problem to livestock. If a legume component is desired to improve animal intake and nutrition, N fertilizer rates and timing should also avoid giving the grasses a competitive advantage over the legumes.

Legumes can fix atmospheric nitrogen by acting as a host to *Rhizobium* bacteria. See table 5–5, Seasonal total of nitrogen fixation by forage legumes and legume-grass mixtures. During the first year of legume growth, no nitrogen is transferred to the grass component of a pasture sward. Thereafter, nitrogen is transferred from the legume to the grass in substantial amounts, providing up to 50 percent of the N requirement of some grasses. Depending on the legume species and its distribution and percent of stand, N transfer to cool-season grasses ranges from just a few percentage points to 50 percent. Stand life average N transfer to grasses from the legumes accounts for no more than 25 to 30 percent of cool-season grass needs.

It appears with some warm-season grasses that compatible legumes grown with them may be able to supply perhaps all their N needs. Ideally, to be effective in transferring fixed N to grasses, the legume should make up at least a third of the stand and be well dispersed. Maintaining the legume component in the stand requires good grazing and nutrient management. Even then, diseases and insects can still take out the legume component. Maintaining legumes in a pasture takes a concerted effort to reintroduce them by overseeding or renovating the pasture from time to time.

Nitrogen fertilizer additions, whether from fertilizers or N fixing legumes, induce long-term soil acidification in the topsoil and subsoil. When added to the soil, 100 pounds of urea, whether from urine or chemical fertilizer, requires 84 pounds of calcium carbonate (lime) to neutralize the soil. In fact, all nitrogen carriers containing either ammonia or urea acidify the soil. Soil acidification results in the loss of exchangeable cations, of

Figure 5–32 Yield response curve to indicated range of plant available nutrients from soil test results* (from Serotkin 1994)



* Note once optimum level for a plant nutrient is reached, no further yield response occurs.

particular importance, calcium (Ca) and magnesium (Mg). Soil acidification is heightened in the surface layer (0 to 2 inches) of the soil of permanent pastures in particular. The N fertilizers are generally surface applied and no, or infrequent, tillage takes place to mix any lime from deeper in the soil profile with the surface soil.

Sulfur (S) is a secondary nutrient of critical importance to forage growth. It is a component of chlorophyll and proteins. Sulfur is similar to N in some respects in that it can be an atmospheric contaminant that is deposited on the soil and can also be immobilized by microbial breakdown of soil organic matter. With the advent of high analysis fertilizers, little or no sulfur is added to the soil when commercial fertilizers are applied unless they are specifically fori*-ded ts

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Use of pastures as sites for manure disposal must be done with some prudence for other reasons. Sheep are susceptible to copper (Cu) toxicity. Sheep should not be allowed to graze pastures with recent applications of poultry litter or swine manure. Both manures may contain high Cu concentrations since Cu salts are fed as wormers to both livestock types. High rates of poultry litter applied to endophyte infected tall fescue pastures can also intensify bovine fat necrosis outbreaks. Ideally, no more than 4 tons per acre of poultry litter should be spread on tall fescue pastures. It also is important not to overload pasture soils with P and K either. As mentioned before, these nutrients are slow to leave the pasture as animal products. Long-term accumulations of these nutrients can induce deficiencies of other essential nutrients in plants and animals. Recently, high levels of K in pasture grasses have been implicated in cases of milk fever in freshening dairy cows grazing them.

Two trace elements of critical importance to livestock production are **copper** and **selenium** (Se). Both are essential for livestock health, but have a narrow range of acceptable concentration in feedstuffs. Induced copper deficiency in livestock can occur in areas where soils contain elevated levels of molybdenum and sulfur. Selenium deficiencies occur in the Pacific Northwest and the Eastern third of the United States. In semi-arid parts of the U.S., selenium may be present in forage in toxic amounts. Soils deficient in these two elements cannot be safely supplemented with either Cu or Se fertilizers. Overfertilization with either is easily done. Feed rations must be balanced through supplementation where Cu and Se deficiencies occur or through dilution when forages containing toxic amounts of Cu and Se are produced.

The trace element **cobalt** (Co) can be safely applied as a fertilizer. It is required in energy metabolism in ruminants and for the health of *Rhizobia* in legume root nodules. Pastures deficient in cobalt can be fertilized with low rates of cobalt sulfate (1.5 to 3 ounces per acre of Co).

Another trace element of importance is **boron** (B). It improves legume growth. Boron can be added to the soil using borax or B-containing mixed fertilizer. It must be added in low amounts (0.5 to 3 pounds of B per acre) to avoid toxicity problems.

Grazing management can be helpful in managing nutrients on pasture. Conscious efforts can be made to ensure the best distribution of dung and urine as is possible with the setting involved. Multiple watering sites no greater than a quarter mile away from each other is a start. If the water is not close to the grass, livestock once at the watering site will tend to camp there. Grass will be underused away from the watering site and receive little manure. Meanwhile, the grass close to the watering site will be overgrazed and receive all the manure. In multiple paddock layouts, water must be at each paddock. Ideally, water is placed towards the middle of the paddock if the length of the paddock exceeds a quarter mile. If water is not available at each paddock, the laneway serving the paddocks will end up with a disproportionate amount of the excreta.

Salt and mineral blocks should not be placed close to other attractive areas. This encourages livestock movement and dispersion of excreta. Shade and hay feeding areas are best kept on higher ground away from streams. Ideally they should be positioned on knolls or hilltops. Manure and urine will be concentrated there, but runoff events tend to wash some of it back down the slope.

(c) Accelerating practice—Pasture planting

At times, grazing management cannot provide the desired species mix or quantity and quality of forage on a pasture in a timely fashion. Also the seedbank may not store enough seed of the desired species missing from the stand. When confronted with these problems, planting seeds or sprigs is necessary to achieve pasture production objectives. Several good reasons to resort to pasture planting include:

- Reintroduce legumes into the stand.
- Replace low producing common varieties of grasses with improved varieties.
- Replace grasses with low palatability or high alkaloid content with improved varieties of the same species or altogether different species.
- Replace disease or insect prone grasses or legumes with new resistant varieties.
- Plant forage species on land being brought back into pasture use as part of a crop rotation cycle or as a land use change.
- In lieu of other corrective measures to change the site conditions of a field, replace poorly suited forage species presently growing on the field with forages better suited to soil and climate.
- Replace some existing forage stands on part of the land unit to better match livestock forage demand throughout the year by providing sequential stocking areas of high forage availability. (For instance, reintroducing some warm-season grasses on a part of a land unit currently without any warm-season pastures to provide summer pasture when cool-season grasses are dormant.)
- Plant annual forage crops to extend the pasture season into a dormant period for the perennial species growing on the site or provide emergency or supplemental feed when other pasturage is low in quality, quantity, or both.

Keep pasture forage mixtures simple, not more than four species. In permanent pastures the soil seedbank provides several adapted alternative forage species anyway. Therefore, it is not real critical to achieve instant diversity and run the risk of planting a mixture that really does not persist as formulated anyway. Select species that have similar maturity dates and palatability, compatible growth characteristics, and are adapted to the same soil and climatic conditions.

Use certified seed to get superior cultivars of known resistance to pests common to the production area and high seed quality of known purity and germination percentage. On soils with variable drainage, planting several forage species with differing adaptability to the drainage conditions on the site might be warranted. However, much of the seed sown will end up in places where the particular species will not thrive or perhaps survive. Therefore, do this only on sites where random variability of drainage is too complex to seed areas separately with different seeding mixtures.

Pasture plantings should be accompanied by good nutrient management practices. Soil tests should be taken to ensure the nutrient status of the soil is adequate for the species being planted. When the soil sample is sent in for nutrient analysis, it should state the species to be planted and the yield goal desired. If soil amendments of lime or gypsum may be required, take soil samples at least a year in advance of the planting time. Soil amendments should be applied at least 6 months ahead of planting to have sufficient time to react with the soil. On soils that tend to fix phosphorus, fertilizer should be band applied at planting rather than broadcast over the field.

Pasture plantings should also be accompanied by good pest management practices. Weed control before and after planting is critical. Many of the forage species are slow to germinate and establish themselves. Weeds that survived seedbed preparation or that germinate after planting can quickly shade and smother out young forage seedlings. Late season seedings of cool-season forages can avoid the heaviest weed pressure. Undesirable stoloniferous or rhizomatous grasses and broadleaf weeds should be killed with an herbicide several weeks in advance of tillage. No amount of tillage effectively controls them. Damping-off of seedlings can be controlled with fungicides labeled for use. Insecticides should be used as needed to control insect feeding. Severe plant thinning to total loss of stands can occur if insect pressure is high while seedlings are young and tender. This can also occur if slug feeding is high.

If pastures are to be tilled prior to planting, they should be grazed closely the year before planting to reduce the amount of organic residue incorporated. Otherwise, getting a seedbed that is firm, smooth, and not too trashy is difficult. This leads to overworking the soil to get it firm, smooth, and free of large amounts of residue. Overworked soils can crust over and dry quickly. This can jeopardize seedling germination and emergence. Tillage for forage establishment should only be used on fields with little or no erosion potential.

Once fields have been tilled to incorporate soil amendments and fertilizers and to produce a firm, smooth, granular seedbed, several implements are available to choose from to apply seed. Drills, cultipacker seeders, broadcast seeders, and band drills are the primary types. Band drills put down a band of fertilizer between rows of drilled seeds. Drills without press wheels and broadcast seeders should be followed with a culti-packer to get better seed-to-soil contact. Otherwise, these two seeding implements need to be followed by a soaking rain to get good seed-to-soil contact.

Forage seedings may be seeded clear (forage seed only) or with a companion crop. Clear seedings get a fast start, but weed growth generally needs suppression. Mowing or top grazing weeds off above forage seedlings is one method. Applying herbicides is another. However, there are no herbicide products that can be used on mixed grass and legume seedings. Straight grass mixtures can be treated with broadleaf herbicides labeled for use. Straight legume seedings can be treated with either broadleaf or grass herbicides labeled for the legume being protected. Companion crop seedings are not generally recommended south of the 39th parallel.

Bermudagrass may also be established by using sprigs, the stolons and rhizomes of the grass. Tillage should commence in the fall to kill existing sod where the bermudagrass is to be planted. It is left rough to cut down on soil erosion. Sprigs are dug with a sprig digger or spike tooth harrow from a nursery of a known cultivar. They are windrowed with a side delivery rake and can be baled to improve handling ease. Sprigs are planted either with a sprigger or broadcast, disked in, and the ground rolled to improve sprig-to-soil contact. To avoid weed competition, herbicides should be applied immediately after sprigging to control competing grasses and broadleaves.

Timing of plantings is regionally dictated. General strategies are to plant when moisture and temperature conditions are most favorable for the species being planted, enough growing season is left to ensure maturity or overwinter survival, and weed, disease, and insect pressures are best avoided. For instance, late summer to fall seedings of legumes can avoid major weed competition and damping-off diseases in some areas. However, in other areas, they may succumb to late season disease problems, such as Sclerotinia crown and stem rot.

Sod seedings (no-till) have become a more popular way of seeding pastures since improved no-till drill designs have become available. Sod seedings can be used on sites susceptible to high erosion rates and on soils that tend to dry out quickly or crust if tilled. To start, suppress or kill existing vegetation. The decision to suppress or kill depends on the value of the forage species remaining on the site and their abundance. If enough desirable forage plants cover the site, the suppression option can be chosen. Vegetation may be suppressed by grazing close for several weeks before planting. Ideally, seeding should come later in the growing season when it is unlikely that the suppressed vegetation will come back strong. This is very useful when planting cool-season annuals in warm-season grass pastures, such as bermudagrass.

Suppression can also be done using a burndown herbicide, one that burns back the green growth of perennials, but does not kill the crown or roots. This herbicide can either be broadcast or banded. Band spraying to leave alternate strips of green and burned back vegetation allows for an early return to grazing when spring sod seeding a legume into a grass pasture. Weed suppression is also greater. There is less need for herbicide as well. If the present pasture has little forage of any value and aggressive spreading low quality forages and better cultivars of existing forages are desired, then the existing stand should be killed. Ideally, this should be done towards the end of the previous growing season for an early seeding the following year. This is particularly needed if unwanted rhizomatous or stoloniferous vegetation is present. It gives time to react to less than a 100 percent kill and treat the area again.

A low technology method of sod seeding is frost crack seeding. This is used in areas of the United States where late winter alternate freeze and thaw cycles causes the soil to honeycomb at the surface. Successful clover seedings can be done in this manner by broadcasting the seed over the existing sod. These seedings eventually come in good contact with the soil during the freeze and thaw cycles to germinate when the soil warms enough to trigger germination. Further seed-to-soil contact can be promoted by allowing livestock to tread the seed in when the soil is firm enough not to become poached badly. They must be removed before germination.

Seed depth is critical for small seeded forages. Most require a shallow depth (0.25 to 0.50 inch) to get good emergence and survival. In drier regions, depths may need to extend further in the ground (up to 1 inch) to get adequate moisture for germination. Even in the same MLRA, seed depth must vary according to soil type. Greater seed depth is required in sandy soil than in silt or clay loams. Seed depth recommendations for various forages should be based on their specific requirements, surface soil moisture conditions as affected by soil texture, and time of year of seeding.

Seeding rates should be based on pure live seed, the percentage of pure seed that will germinate from the seed lot being planted. Seeding rates should be adjusted for soil textural differences. Sandy soils can be seeded at lower rates than heavy clay soils since emergence is less inhibited by soil crusting. Soils with low water holding capacity should be seeded at lower rates because they cannot support as many plants as soils with high water holding capacity. Seeding rates should be adjusted based on seeding equipment and method used. If seed is broadcasted or drilled without press wheels or trailing culti-packer, seed rates need to increase by 25 percent. Seedling mortality will be high because of the hit or miss soil coverage of the seeds. If clear seeding, adjust seeding rates upward to crowd out weeds and maximize first year forage production.

Mortality is high with forage seedings. Commonly only a third of the seeds become emerged seedlings. Of that, only 20 to 50 percent survive at the end of the establishment year. Oversown fields, where seed is spun on and lightly harrowed or frost crack seeded, have very high seedling mortality; 10 percent survival is typical. This is why seeding rates are as high as they are. For instance, where alfalfa is seeded at the rate of 15 pounds PLS per acre, there are 77 seeds per square foot. At the end of establishment year, 20 to 50 alfalfa plants per square foot is considered optimal. If 50 percent of the seed survived to be plants at the end of the establishment year, the number per square foot would be 38. If only a third survived, then 26 alfalfa plants per square foot remain.

Given the cost of seed and the expense of preparing the ground to plant it, it is wise to take care in planting it. If the planter used cannot by itself ensure good seed-to-soil contact, then a pass with a culti-packer or shallow set harrow is worth the time spent. Fungicides and insecticides can also be effective in reducing seedling mortality. Livestock should not return too soon to new seedings. Treading damage and ripping of plants out of the ground during grazing can result.

All legume seed should be inoculated with the proper strain of *Rhizobium*. Most of the alfalfa and clover seed sold today is preinoculated. When the seed is preinoculated, it must be sown before the inoculant expiration date on the seed tag. Otherwise, it must be retreated with inoculant. For untreated seed or expired treated seed, apply the humus based inoculant to the seed with a sticking agent just before sowing.

(d) Accelerating practice—Prescribed burning

General rule of thumb: Burn warm-season grasses as needed. Never burn cool-season pasture forages.

Bermudagrass pastures can be burned a week or so after the last killing frost in the spring to control winter annual weeds, some leaf diseases, and insects, such as spittlebugs. It also removes low quality dead grass and hastens green-up. Tall warm-season grasses, such as switchgrass, big bluestem, and indiangrass, should be burned periodically in late spring to improve forage quality and remove invading cool-season grasses. Burning should take place before any regrowth of the warm-season grasses; otherwise, stand thinning occurs.

Burning of cool-season forages is not recommended. In fact, it is a control measure to get them out of warm-season grass stands. Despite an early green-up when dead residue from previous years is burned off, experimental results have shown substantial decreases in forage yield for the season after a burn. An exception to this rule might be where previously abandoned/unused forage stands have large amounts of dead, low quality residue and invading brush and weeds on them. In this case a prescribed burn would hasten the return to good forage production and kill the brush. First year production would have been low anyway because forage plant densities had declined as a result of long-term shading from mature plant material and competing vegetation.

Burns should be fast and done when the soil is moist to protect roots and crowns from damage and under low wind conditions. They should be done by qualified people in accordance to local statutes and the NRCS Prescribed Burning conservation practice standard.

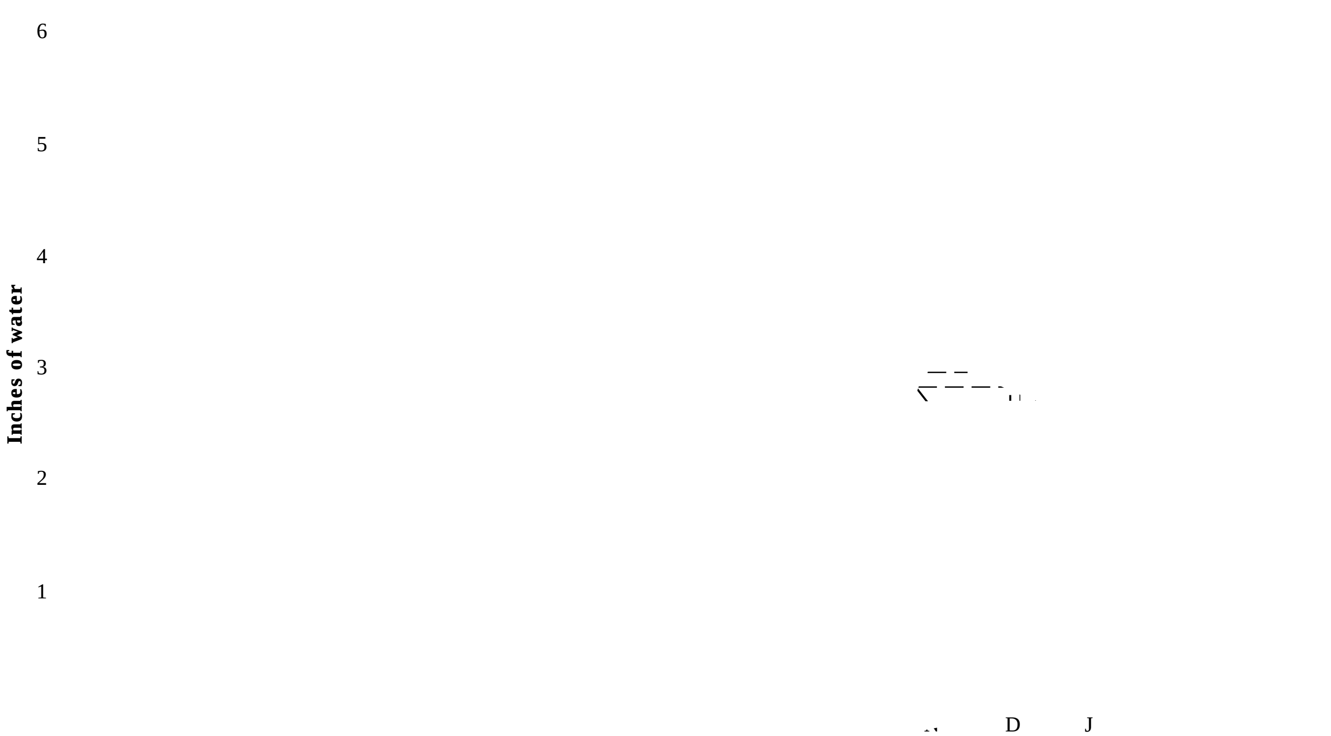
(e) Accelerating practice—Irrigation water management

Irrigated pastures are commonly used to complement rangeland and other types of permanent pasture. They can provide dependable pasture when other pastures are dormant. These pastures can also be used to achieve higher average daily gains on calves and stocker cattle. This results in more pounds of beef for sale at the end of the grazing period when the cattle are moved to the feedlot. Similar production gains can be had with other livestock types.

Irrigation of pasture is put to best use in areas where precipitation and stored soil moisture fall well short of potential evapotranspiration needs of the pasture. Water ends up being the limiting nutrient during the seasonal height of pasture growth. Figure 5–33 shows a typical yearly water budget. In the example displayed in this figure, nearly 11 inches of water is needed to meet the pasture's need for water during the summer months. Plant available soil moisture for this particular soil and forage species is 4 inches. This water is used up during the spring months since plant uptake requirements exceed precipitation by mid-March. After plant growth begins to slow down in the fall, precipitation exceeds plant uptake. Soil moisture begins to be restored. Once plant available water is restored, the rest entering the soil becomes surplus and leaches below the root zone. Rainfall exceeding the soil's infiltration rate will runoff as well.

Irrigation water management described here focuses on management only as it specifically relates to pasture. A more in-depth description is in the section, Forage crops.

Figure 5–33 Typical water budget showing where the seasonal need to irrigate occurs and the magnitude of that need (from Baver 1961)



Many of the forages grown for pasture have relatively shallow root systems or at least have 70 to 80 percent of their root mass in the first 4 to 6 inches of the soil. This limits the amount of water that can be stored in the effective root zone for these forages. Irrigation applications need to be more frequent and at relatively low rates to be certain the water is used by the forages and not percolating by their roots. Deep percolation is sometimes necessary to leach salts and sodium from saline and sodic soils. On these soils heavier application rates are necessary to keep the salts from accumulating in the root zone and burning the forages. When irrigating forage mixtures, the species having the shallowest root system generally controls the irrigation schedule. It will suffer the most if irrigation is delayed.

Flood and sprinkler irrigation are the most commonly used pasture irrigation methods. When flood irrigation is used, large heads are required to get quick coverage and uniform distribution of water over the flooded area. This is because pasture sods reduce overland flow velocities quickly and create an absorbent soil surface. The distance between head ditches that are used to flood the pasture must be close spaced because of these vegetal retardance and soil porosity factors. If not, some areas of the pasture receives all or most of the water while others remain too dry for top yields. When feasible, land smoothing should be done to remove high and low spots in the pasture.

Sprinkler irrigation gives a more uniform water application especially on rolling topography and highly permeable soils.

Rotation grazing of irrigated pasture facilitates the scheduling of irrigation after a grazing event. This avoids having livestock on wet soil where poaching damage can occur to the sod. Having the pasture divided into two or more subdivisions, allows the manager to graze one subunit while irrigating another immediately after the livestock are removed. Livestock should remain off the irrigated subunit long enough for the ground to firm up and permit enough regrowth to meet available forage requirements. Set minimum allowable grazed stubble heights on irrigated pasture to achieve rapid regrowth recovery of the preferred species. Maintenance clipping of irrigated pastures minimizes selective grazing, enhances forage quality by setting all plants back to early vegetative state, and thereby increases utilization rates by livestock.

In arid regions, irrigated pasture soils generally are low in nitrogen and phosphorus. Legume-grass mixtures can overcome the nitrogen deficiency. Fertilizing with superphosphate fertilizers promotes excellent growth of these forages. Soil nitrogen tends to build with time as long as legumes remain a component.

Irrigated pasture can be used in rotation with other crops to improve soil tilth through increasing soil organic matter content and soil particle aggregation. Being under a crop rotation also allows the pasture to be renovated on a scheduled basis to maximize forage production when it is in pasture.

Annual forage crops grown on irrigated pasture benefit by being irrigated just before or immediately after planting. Germination and initial growth proceed quickly and produce grazable forage faster and more predictably than rain-fed crops. Irrigated pasture also enhances cool-season forage growth during the midsummer slump period. The lack of moisture is more critical than the high temperatures in suppressing their growth

(f) Facilitating practice—Water development

To get maximum use of available forage, water must be within a quarter mile of the forage producing site on level to undulating topography. Where slopes exceed 25 percent, watering sites should be no more than 600 feet away, 1,200 feet between watering sites. When distances get greater than this under the slope conditions mentioned, forage past those distances are lightly grazed if at all. At greater distances to water especially with fence barriers blocking movement, pastures become overgrazed near the watering site and undergrazed at more remote locations.

Water development can take many different forms. Several forms are described in this section.

(1) Pipelines

Most farmsteads and ranch headquarters have wells. Where distances are short to pastures, it may be easier and cheaper to extend pipelines from the well to water troughs. Many pipelines using polyethylene tubing are laid across the ground surface or buried. Hydrants with connecting valves are located at convenient intervals to temporarily attach water hoses that lead to a water control valve in a water trough. Polyethylene tubing is preferable to other materials because of its resistance to corrosion, resiliency, and lower friction resistance to water flow. In locales where water freezes in the winter, exposed pipelines need to be drained of water or have sufficient water flow-through to remain unfrozen. Buried pipelines need to be placed below the frost line, or drained during the winter months if rock limits depth of excavation. The decision to bury or let the pipelines lie on the surface depends on the permanency of the pasture layout, amount of vegetal cover present to shade the pipe, and ultimate temperature of the water at the trough. Water temperature above 75 degrees Fahrenheit decreases water intake and milk production in dairy cows. Lactating dairy cows produce the most milk when drinking water is between 50 and 65 degrees Fahrenheit.

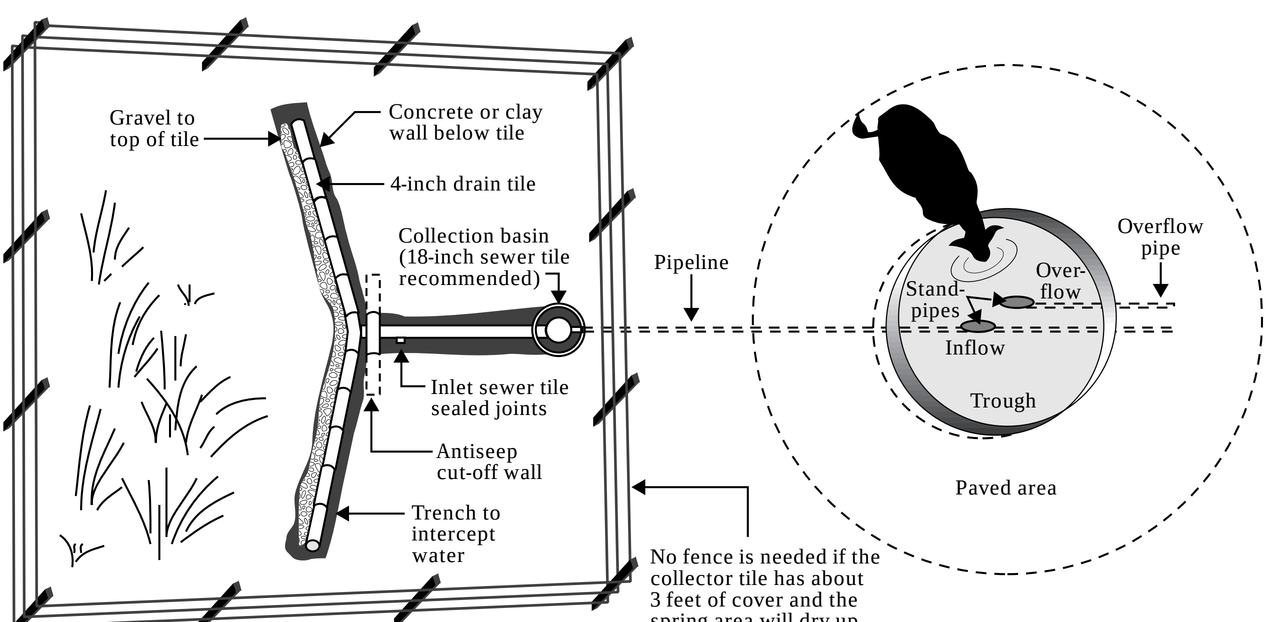
(2) Springs or seep areas

Springs or seep areas often occur in pastures at elevations above creek and river bottoms. These areas are useful as water sources for livestock on pastures remote or isolated from headquarters or farmstead wells. Livestock normally use these water sources as they naturally exist. However, this can lead to degradation of the seep or spring area. Eroding banks, water fouled with excrement and mud, poaching of the wet soils around the fringe of the open water, and damage to riparian vegetation are the most apparent problems. Weaker seeps and springs can be so badly disturbed that they become unreliable watering sites except during high flow periods. Spring developments are used to provide a reliable source of high quality water to livestock, exclude livestock from the riparian area of its source, and convey the overflow back to an adequate outlet with a minimum of contamination and warming. Figure 5–34 shows a typical installation. It has three major components: a collection system, pipeline, and trough.

(3) Ponds and streams

Ponds and streams are often used as water sources. In a pasture setting, limiting access to these water sources helps to prevent contamination of the water by excreta. Coliform bacteria counts can often be quite high in these situations. Blue-green algae blooms can occur during hot weather in nutrient rich ponds. Livestock deaths have resulted from blue-green alga blooms when the concentration of toxins was high at the water surface. Basically, the water quality can be less than desirable for the drinkers as well as the downstream recipients. Several options are available to limit or remove livestock from open water sources altogether.

Figure 5–34 Spring development showing collection system, pipeline to and from trough, and trough



(i) Controlled access options—An option that limits access is a paved ramp or stream ford. Paved ramps can be used at the shoreline of a pond to allow cattle to drink, but not wallow around on the muddy pond bottom. Siting of these ramps is critical so as to avoid severe trailing erosion and resultant fouling of the water and burial of the pavement. The ramp should not be near the inflow point of the pond and not on the embankment or in the emergency spillway where provided. Paving material can be crushed rock, concrete, asphalt, or other durable paving material. In frost prone areas a good base is required to prevent frost heave damage to the pavement. The rest of the pond and any dam or spillway are fenced off to leave a vegetative filter of grass between the grazed area and open water. At the ramp the fence extends into the water at the sides and has a front fence that prevents wading beyond the ramp.

Stream fords are constructed in a fashion similar to paved ramps at points where livestock show an inclination to cross. Stream fords not only provide water, but allow access to pasture areas on either side of the stream. They should be sited and constructed to prevent trailing erosion sediment from flowing directly into the stream. Pavement should extend to an elevation equal to the top of upstream streambank. Paving materials should be resistant to dislodging caused by the maximum expected water velocity achieved at bankfull flow. Concrete grid pavers or confinement floor slat seconds are good choices because they are not likely to dislodge and form a cleated surface to prevent livestock from slipping on the wet surface. Stream corridor fencing ordinarily is combined with this practice to get full benefit of the stream ford. Some contamination of the water will still occur, but there is a substantial reduction in sediment loading. Paved areas can be made uncomfortable enough to make livestock move through faster than if it were a natural site that was easier on the hooves and legs. Where fences are used with this practice, flood gates of various designs are used up and down stream to flank the ford. They can be simple breakaway devices to swinging gates, or simply a one strand electrified wire with a curtain of chains or wires hanging down within a few inches of the water and stream embankment.

(ii) Pond and stream devices—Gravity feed pipelines or siphons can provide water from ponds and streams if proper elevations can be achieved in a reasonable distance within the pasture. These pipelines extend to a trough or series of troughs that either are equipped with a shutoff float or overflow stand and outlet pipe. The inlet of the pipeline must be equipped with a filter or screen to prevent sediment and algae from flowing through the pipe and fouling the water at the trough or clogging float valves.

A water ram is another device that can be used. In this case water is needed at higher elevations than that of the pond or stream. The water ram is dependent on some pressure head to pump water to higher elevations. It is convenient to use in rugged terrain where pastures have no other source of pressurized water and no high elevation sources of gravity flow water. This device requires someone experienced in its installation. It requires careful design to deliver the proper amount of water under the specific site conditions with which it must work. The placement of the inlet pipe and its intake site is also critical. If not done properly, the intake can be silted over. The ram itself must be placed in a safe area so that it is not dislodged or destroyed during a flood event. It may be piped to a storage tank or reservoir before going to a trough. The siting of a ram should be accessible to the operator on a daily basis to check for proper functioning.

A nose pump or pasture pump is another device used to pump water for livestock. They pump water using the force produced by a drinking animal when it pushes against a nose plate while drinking water from a cup positioned underneath the nose plate. When the animal quits drinking after emptying the cup of its water, the piston behind the nose plate goes back to the rest position. When it does this, water is drawn into the cup from a hose that goes to a pond or stream. The inlet must be protected from sediment. A natural pool should be selected instream that remains relatively free of bottom sediment. These pumps are appropriate for small herds that have immediate access to them. They are inappropriate where the distance is far enough to cause the herd to go en masse to drink. The dominant animals will drink and spend the rest of the time harassing the others. Figure 5–35 shows a typical pasture pump installation.

Water troughs are made of several materials: g[redacted]
nized steel, reinforced concrete, polyethylene, [redacted]
(including used tires), and wood stave. Water [redacted]
come in all sizes. Their size depends on:

- Number of head being served, their daily [redacted] time intake
- Number of head at the trough at any give[redacted] instance
- Delivery rate of the pipe or valve deliver[redacted] water
- Whether the trough is being used as a st[redacted] reservoir as well as a watering site

If water troughs are close by the grazing reso[redacted]
refill quickly, they can be small because anim[redacted]
up individually or in small numbers to drink. [redacted]
to the water trough requires a long walk, the[redacted]
tend to herd up and make the voyage togethe[redacted]
trough is being served by a low flow system [redacted]
3 gallons per minute), the trough should be [redacted]
large enough to handle the whole herd at on[redacted]
table 6–7 (page 6–12) in Chapter 6, Livestoc[redacted]
tion, Husbandry, and Behavior, for water re[redacted]
for livestock given in gallons of water drank[redacted]
various types of livestock. These daily requ[redacted]
vary widely. They depend on the water, pro[redacted]
salt content of the forage and feed being ea[redacted]

[redacted]ring
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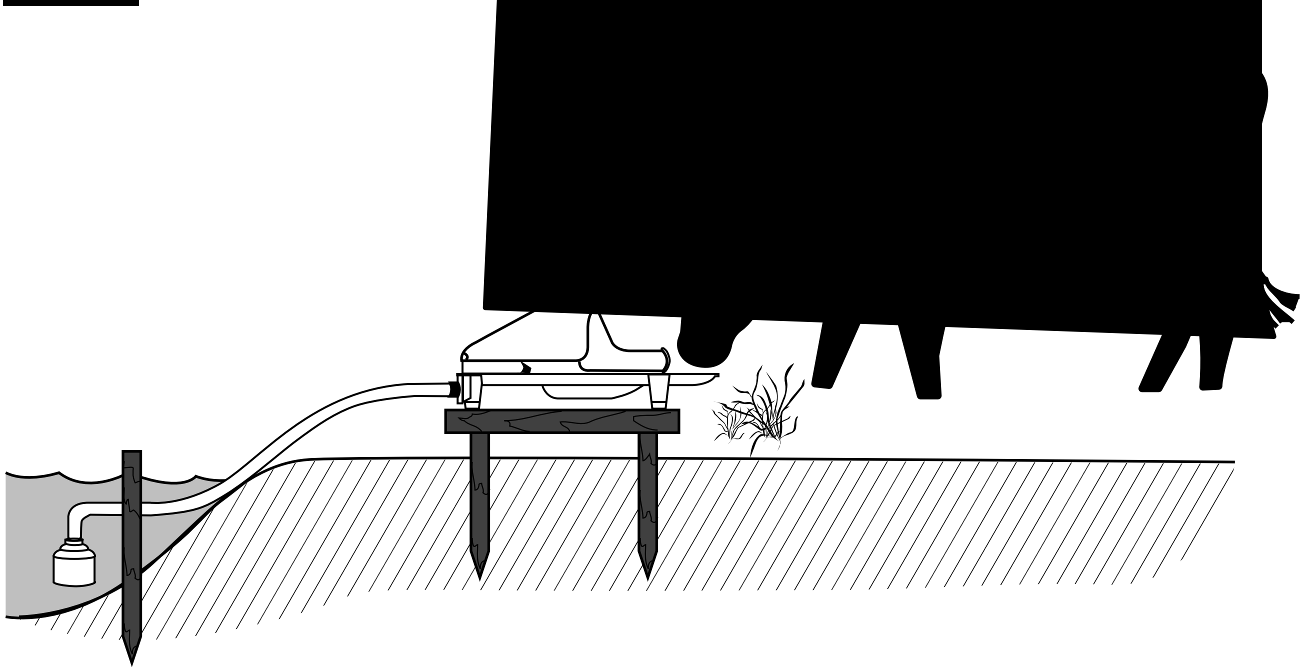
Figure 5–35 Pasture pump installation



(4) Water quality

Water quality is extremely important to consuming livestock. See table 6–8 (page 6–12) in Chapter 6, Livestock Nutrition, Husbandry, and Behavior, for water quality standards for livestock. New sources of water should be tested to see if they are suitable for the livestock to be watered. Important water quality parameters are nitrates, sulfates, total dissolved solids (TDS), salinity, bacteria, pH, and pesticide residue.

Nitrates can kill ruminants if ingested at high dosages. The nitrates are converted to nitrites in the rumen. These are absorbed in the blood stream. The nitrites attach themselves to the blood hemoglobin forming methemoglobin. This does not allow the blood to carry oxygen, so the animal can die of asphyxiation. Animals so affected have chocolate brown blood. Nitrates at lower concentrations can cause reproductive problems in adults and reduced gains in youngstock.

High sulfate and high TDS or saline water causes diarrhea. Dehydration may occur in severe cases. Salt water toxicity can also upset the electrolyte balance of the afflicted animal as well.

Bacteria, especially total bacteria count, can increase calf losses, cause animals to go off-feed, increase infections, and cause chronic or intermittent cases of diarrhea. Acidic water (<5.5) or alkaline water (>8.5) can cause acidosis and alkalosis, respectively. Animals become unthrifty, go off-feed, have infertility problems, and get infections easier. Although most pesticides are not directly harmful to livestock, the milk and meat produced by them may become contaminated if not broken down during digestion or eliminated.

The organophosphates are most dangerous to livestock directly. As mentioned briefly earlier, blue-green algae can kill livestock drinking from ponds contaminated with them. It happens suddenly without warning. A brief algal bloom and wind drifted accumulations at the drinking site can spell quick death. There is no way to test ahead of time, just a post-mortem. This perhaps is the best incentive not to allow livestock direct access to ponds at least during hot, dry weather. The cost of one animal lost can build several rods of fence and pay for a stock tank.

Watering site layout on improved pastures needs to provide even distribution of grazing to enhance forage utilization. Livestock can travel longer distances than what is needed to get optimum forage utilization. However, other improvements will fail to deliver if the animals do not graze areas well remote to water. With rotational pastures a trough or other watering facility should be in each paddock. Depending on layout and distances involved, two to four paddocks might be served by one watering facility strategically placed at a fenceline or the intersection of two fencelines. The watering facility must be sized correctly and positioned to avoid crowding. In continuously grazed pastures, troughs or other water sites should be evenly distributed. This avoids having underused or overused areas or corners of pasture.

(g) Facilitating practice—Stock walkways or trails

On improved pastures, stock walkways or trails are most often referred to as lanes or laneways. They facilitate livestock movement. The lanes may be paved, unpaved, or a combination of both. Dairy pastures are better served by paved laneways because the cattle need to move back and forth from pastures to the milk parlor at least twice daily. Paving is also critical where laneways must cross wet soils to provide the most efficient or the only way to get to all pasture areas.

Constructed fords, culvert crossings, or bridges need to be provided at live streams unless the streambed and approaches are firm and relatively stable. Culvert crossings or bridges should be used sparingly. They should not be used at all if the stream is prone to flooding. Maintenance of crossings and bridges is high. Debris can easily plug the entrance. Downstream cavitation at the outlet can cause bank instability and eventual undermining of the culvert or bridge abutments. Damage to downstream areas caused by successive washouts of either abutment can also be excessive. This can be avoided by providing a designed floodway channel that creates an island at the culvert or bridge during a flood. This is rarely done, however.

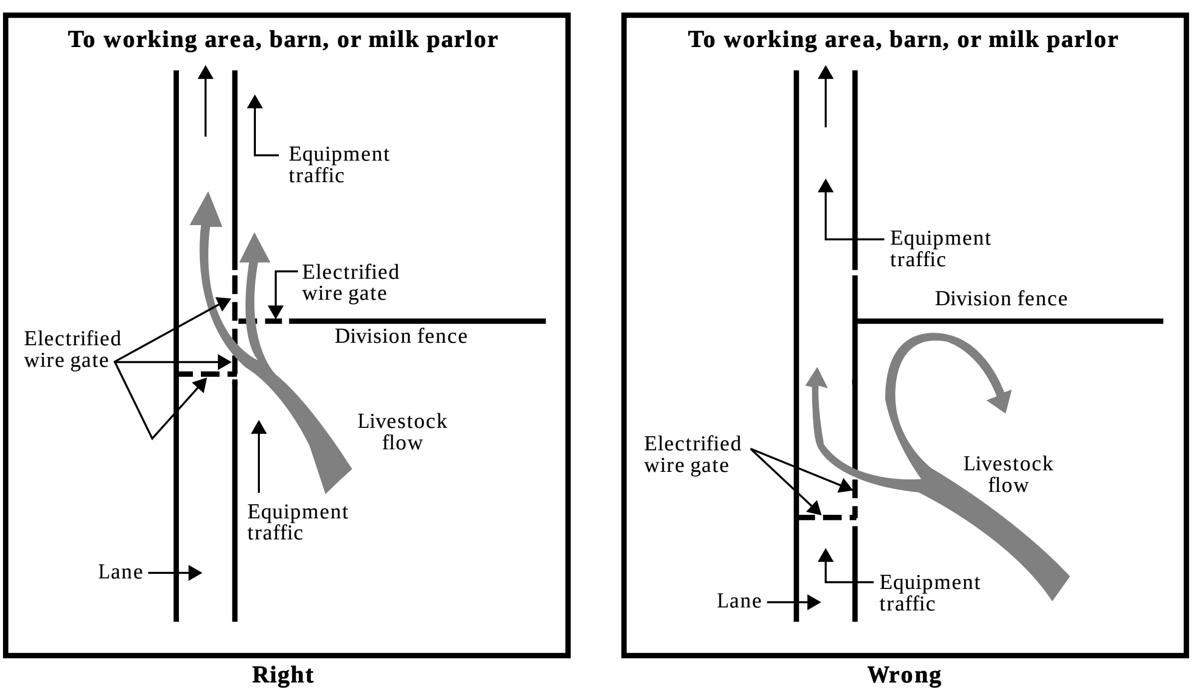
Position lanes to most directly access the fields or paddocks to be grazed, including crop or hay fields grazed temporarily from time to time. Some lanes may be temporary and be formed by two parallel single strand electrified fences. When lanes serve rotational pastures, they should be positioned to create paddocks that are as near square as possible. On very steep ground, rectangular paddocks that have their long axis across the slope may be preferable if forage utilization becomes stratified from top to bottom of the slope. Placing lanes directly up and down steep slopes should be avoided if at all possible and still get a good paddock layout. If this is not possible, the lane should be paved with an erosion resistant material, graded to have water diverters placed at regular intervals, or both. Equip any lane with long continuous gradients with water diverters to break up waterflows directed down the lane.

Width of the lanes is dependent upon the size of the livestock, herd size, and expected equipment traffic.

The operator should keep lanes as small as they and their livestock feel comfortable with. Lanes tend to become unproductive grazing areas. Building wide ones wastes the pasture resource.

Avoid driving equipment up and down unpaved lanes. Livestock use the slightest wheel rut as a preferred trail. Continual use kills out the vegetation and causes erosion to begin where water can channel and gather velocity in the trail. Some producers that need machinery access along laneways create a parallel accessway. This can be done by using a three-gate opening (fig. 5–36) where each paddock division fence intersects with the lane fence. This also cuts down on lane traffic by livestock because they can go from one paddock to the next without setting hoof in the lane. It also allows easy egress no matter which way direction of flow must be out of the paddock.

Figure 5–36 Three-gate opening*



* Always position gates along lanes in the corner nearest next move. The three-gated opening labeled **right** can facilitate a move up or down the lane shown. It also allows for equipment movement outside the cattle lane to avoid causing wheel track trailing in unpaved laneways.

(h) Facilitating practice—Fencing

Fence layout and design require forward thinking. The number of divisions and their size come from the pasture budget described in Accelerating practice—Prescribed grazing section of this chapter. This is determined by the productivity of the field being subdivided, the forage species growing there, the number of head being fed, their size and growth rate or milk flow, and the grazing period they will be on the pasture unit. Other questions to answered when planning include:

- How much of the farm will be used for grazing? Annual production of pasture must be determined. A realistic utilization rate must be set. It must match the livestock demand for forage for the grazing season. If crop and hay fields are to be used seasonally, the fence and lane layout need to provide easy access to them at points that create the least amount of trailing or poaching damage. They need secure perimeter fences, access to water, and possibly temporary interior fences to strip graze off forage.
- Will some of the pasture be machine harvested? If so, which portion is the best site for that activity? This area will be best served with interior temporary fences that can quickly be taken up to open up a large area for harvest. This increases machine harvest efficiency. These same fences will also be easily replaced once machine harvest and any topdress fertilizing are complete.

Fencing, therefore, depends upon a whole farm forage budget, which will be detailed in the section on Forage crop production management. This budget integrates and allocates all the forage and feed resources that are produced on the farm. Fencing facilitates this allocation of the forage resource to livestock. With modern, light-weight, portable fencing materials, this becomes much easier to do than in the past when fencing, once in place, was rarely moved.

Fencing materials are diverse. Woven wire, steel welded panels, barbed wire, smooth high tensile wire, polywire, polytape, polymesh, board (plank or stockade), rail, chain link, steel rail or pipe, cable, concrete, stone, and plastic are all used. Each has their place. Woven wire, barbed wire, and smooth high tensile wire are good, economical fencing material for livestock control along the perimeter of grazing areas. Smooth high tensile should be electrified for best control. Wood board, rail, chain link, concrete, stone, and plastic can be also used for perimeter fencing, but are used for decorative, screening, or security reasons as well as control. They tend to be expensive to install and maintain. Plastic fence is being used to replace wood board fences because they do not rot or require repainting. Fences in working areas where livestock are crowded and seeking ways to escape need strong materials. Heavy planking, steel rail or pipe, welded panels, and cable are often used. Stone and concrete have been used some for corrals and barnyards. When used, they must be sunk to a soil depth below the frost line.

The posts used to hang the fencing materials come in diverse materials and sizes as well. Post materials are treated wood, untreated native wood, fiberglass, plastic, steel T-posts, angle iron, or pipe and reinforced concrete. Wood and concrete posts are the most rigid and can handle high lateral loads without bending or breaking. Steel can bend under heavy loads. Plastic and fiberglass tend to get brittle with age and can break under moderate loads. Sudden impacts are more likely to shatter them than when just being leaned against.

The choice to use electric fence hinges depends on the ability to provide electricity at the site conveniently and reliably, the miles of fence to energize and maintain, the permanency of the fence, the degree of control that is needed or desired, and to a large extent, the inclination of the producer. Woven wire and barbed wire have served well for years. Their initial cost is rather high compared to most electrified fences. However, with timely maintenance their degree of control is as good and they do not rely on an electrical shock that is often hard to consistently maintain to control livestock. Some arguments have been raised about the longevity of woven and barbed wire compared to high tensile wire. However, in humid and subhumid climates, the wood posts on which the fence is suspended will rot off at ground level before or about the time the wire fails. Steel T-posts longevity is generally in the same timeframe. New steel posts can be seen in several old wire fences. Many soil types are highly corrosive to steel. Pitting of the steel occurs at the ground line within a few years and the posts eventually break.

Several guidelines should be followed to ensure that electric fences operate consistently all the time:

- Voltage must be maintained at all times for adequate livestock control. To achieve this exacting standard requires a reliable charger or energizer, first. Low impedance, high voltage energizers meet this requirement. These energizers produce a short, high energy pulse. This short burst of high energy can be sent down a long length of wire that may be partly grounded by weeds and still provide shocking power. Various sizes are available and are selected based on the amount of fence to be charged. They are rated in joules or in miles of fence. Both ratings can be misleading. The delivery of amperage that causes the shock is dependent on the pulse rate as well as the joule rating. If the pulse rate is slower, less amperage is delivered down the wire and less shock delivered as well. Miles of fence ratings assume no brush, weeds, or grass clinging to the fence, nor inadequate grounding or poor insulation of the wires.
- Good insulators must be used to suspend the wire from all wood and steel posts, or nonconducting plastic or fiberglass posts used instead.
- The fence and charger must be properly grounded.
- Lightning arrestors should be installed to protect energizer from damage.
- Vegetation growth along the fence line must be controlled. Sometimes, this is easily achieved where the livestock can graze under the lowest wire. They often preferentially graze these areas very close.
- Maintain fence integrity, check for proper tension and post damage.
- Surge protectors are important when served by power line electricity.

Energy sources for electric fences can be regular farmstead service lines or batteries, or it can be solar or wind powered units. Choice is dependent on the length of fence, degree of reliability needed, cost, accessibility, and length of service needed.

All livestock need to be trained to respect electrified wire. This can be done at infancy if raised on the farm or ranch where electric fence is used. If new animals are brought in, they should be trained in a confined area before being placed on pasture.

Regardless of whether a wire fence is electrified or not, construction principles for them remain the same. Brace assemblies at the corners, gate openings, ends, and wire stretching points must be built to handle the stress placed on it by wire tension. If these are built improperly, the end and corner (anchor) posts will slowly pull out or the bracing will collapse, or both. Whenever possible, posts should be driven on permanent fences. If not driven, they must be backfilled and tamped well to remain solidly in place. Brace assemblies should be placed at corners, at sharp breaks in slope, and at no more than 660 feet on straight runs to stretch wire (stretcher-post assemblies).

Curved fences built to follow land contours should have stretcher-post assemblies in straight sections, not in the curve itself. Curved fences, whether in the vertical or horizontal plane, require posts with great rigidity and must be set well to avoid tipping or bending. If steel T-posts are used to save time and labor, wood posts should still be used and spaced at regular intervals between steel posts to alleviate some of the strain.

Generally, posts of permanent fence brace assemblies should be a minimum of 5 inches in diameter and 8 feet long and buried at least 3.5 feet deep. In some places it may be necessary to drill into rock to get this. For light weight fences (single or double strand), short runs of permanent fence under 330 feet long, and temporary fences, an anchor post with a diagonal brace set into the ground or on a brace block in the direction of the pull is appropriate. The anchor posts can also be used in shallow soils when full post setting depth cannot be achieved easily. Backfill over-widen anchor post hole with concrete. Allow concrete to set and cure before stretching fence on the assembly.

Always place fencing materials on perimeter fences on the side where the livestock are most likely to be pushing on it. Stretch wires with wire stretchers built for the type of wire being used. There are several models. Never use vehicles or tractors to stretch wire other than as a dead anchor. Board ends should abut on posts wide enough to accommodate double nailing. Fence heights, spacing of wire or boards, and mesh opening must vary by the type and class of livestock being controlled. Type of fencing material is often dictated by animal safety concerns. Wide meshed woven wire and barbed wire can cause serious injury or death, but accidents also happen with other materials as well. Well-fed animals are less likely to test fences unless under duress.

Temporary division fences can be nothing more than electrified single or double strand wires suspended on short, hand driven posts for most types of livestock, including sheep. These fences are quite portable and have spurred renewed interest in rotational stocking. If mistakes are made in allocating forage to livestock, they can be easily corrected by repositioning the fences. These fences can either be rolled up on a spool or collapsible so that wheeled vehicles, people, or livestock can go over them when necessary. The plastic posts often used to suspend the wire on these portable fences come in many different designs. Some are downright unhandy and may cause inadvertent contact with a live wire. Others are not very durable after prolonged sun exposure. Some fiberglass rods splinter and are nasty to handle barehanded.

All fences require checking and maintenance, especially as they age. Fence wires can age more quickly if crimped by staples or fasteners at posts, abraded, or damaged by the stretcher used to string it up. Wood should be pressure treated to increase useful life. Plastic and fiberglass need an ultraviolet light (UV) protection formulation. Galvanized wire should be coated to class III specifications. Heavier gauge lasts longer than thinner gauge and has more strength. The difference in price is not worth the aggravation later.

Gates for ingress and egress also vary widely in the material used and strength. They may be simple one strand electrified wire, electrified rod swinging gates, electrified spring wire with insulated handle, barbed wire suspended on two or three poles, tubular steel, board, plastic, woven wire suspended on a steel frame, chain link suspended on a steel frame, or welded panels on a frame. Cattle guards can be used at heavily used gateways where livestock never need to walk through. Their use avoids continually opening and shutting gates. Gates need to be wide enough to pass vehicles and livestock through without damage to the fence or the by-passers. Angle of approach and turning radius need to be taken into account to achieve proper width.

Floodgates are used at points where fences must span creeks and ditches. These too can be made of different materials. They must be constructed to allow floodwater to pass through without their continual destruction, not pull down sections of fence adjacent to them, and keep cattle from leaving the field via the creek or ditch bed or bank. This is not always easy to do simultaneously. Brace assemblies at these points must be built extra strong, at least two brace posts plus the anchor post. These assemblies should be at least at top of bank and safely away from potential bank undercutting or protected with riprap. If the stream current is swift and passes a large volume of water by the floodgate, the brace assemblies for the floodgate should be a separate set from the ones used to extend the fence to the stream.

Swinging floodgates work well for nonelectrified fences. They can be suspended from cables attached to the brace assemblies. Many different styles have been designed to lessen the collection of flotsam on them. They should be buoyant so that they ride up with the rising water.

On electrified fences, a single strand of high tensile wire or cable can span the stream or ditch. Regularly spaced hot wires are suspended down to within a few inches of the water or bank to keep livestock from passing through. These are hard to take out unless the suspended wire is too low or a large branch or tree floats by and snags it.

Floodgates will break away from time to time in major storms. To a certain extent, they should be designed to do that. Cables should be attached to J-bolts that hook on to O-bolts bolted into the anchor post, not wrapped around anchor posts. When forces exceed tensile strength of the bolts they straighten out and release the cable. This avoids major repairs to adjoining fences or to the brace assemblies holding them. Inspect after every flood event to remove debris or repair as needed.

Exclusionary fences can run from single strand electrified to permanent perimeter type fences. If stream corridors are to be fenced, the simpler the fence is, the better it is in flood prone areas. From a maintenance standpoint, a single strand electrified fence kept as high as possible and yet still get adequate animal control is best. This limits debris buildup on the wire. A minimum of posts should be used to have the least number of debris collection points and still suspend the wire adequately. Setbacks from open water should provide at least a 15-foot grass vegetative filter. The filter takes out most suspended sediment and some dissolved nutrients. Fences around woodlots should not be built using the trees at the edge for posts. Hardware becomes imbedded in the logs and is the bane of loggers and millers.

(i) Accelerating and facilitating practice—Pasture clipping

This practice is a bit of both, accelerating and facilitating. It stimulates forage regrowth by cutting off reproductive stems from forages. This causes new vegetative shoots to appear. Pasture clipping can be used to get rid of competing vegetation or reduce canopy shade to favor forage growth. This makes it an accelerating practice. It also influences the movement of grazing animals by removing undesirable patches of undergrazed forages. It can be used to change the pattern of spot grazing. This makes it a facilitating practice. This practice can largely be avoided if the utilization rate is kept high. It is far better to graze fewer acres and machine harvest the rest than to graze a larger acreage and then sacrifice leftover forage by clipping.

Pasture clipping can also be used as a weed and brush control practice where the livestock mix does not control the species invading or existing on the site. Although goats and sheep often eat plants that cattle will not, mixed species grazing rarely happens on commercial farms and ranches. Clipping does not immediately control weeds or brush, but repetitive cuttings just before flowering prevents further seeding of weeds. Clipping does not eradicate or even provide very good control of rhizomatous or stoloniferous perennials. It controls annuals provided they are mown off before flowering. Some weeds not eaten by livestock when green, once cut, are eaten because as the weeds dry, their sugar content is enhanced. Clipping is appropriate on new seedings where livestock control of weeds could damage young seedlings by trampling or uprooting. Weeds should be clipped often above forage seedling height to keep amount of clipping residue down. Too much residue can smother seedlings.

Removal of seedheads and other tall vegetation may also improve livestock health. Fewer eye infections occur if the irritants and disease transmitters are removed.

Clipping can improve forage species mix if certain aggressive established species shade other species' seedlings coming up through the canopy. Clipping avoids the need of waiting for sufficient regrowth to produce a hay or silage crop. This may often take too long or be untimely, and cause shaded seedlings to die. There also may simply be too many acres to graze down to the height needed to release the seedlings.

Rotary mowers work best in pasture setting. Duty rating of mowers is important. Woody species require heavier duty mowers. Pastures can be mown while livestock are present. Almost everything mowed will be eaten. In rotational pastures, mow rejected areas after the livestock leave. This tends to make the rejected areas more acceptable next time, at least, the urine areas.

600.0506 Managing forage cropland

Hayland and cropland produce machine harvested forage primarily, but are often used as sources of supplemental, emergency, and seasonal pasture. On some farms forage crops have totally supplanted pasture as a source of feed for forage consuming livestock. These farms have gone to total confinement. The livestock may not always be in freestall barns, barnyards, or feedlots. Milk cows may also be placed in loafing areas on dairy farms. Loafing areas are adjacent to the milking parlor and barn. Farmsteads sited along creek and river bottoms often locate loafing areas in riparian areas to avoid using tillable acres. Other dairy farms only use pasture for youngstock and dry cows on any marginal land not fit to crop. These areas are not very productive and often are highly erosive.

The movement away from pasture production to forage crop production, particularly with dairy farms, was partly caused by the perception that pasture was an inferior forage production option. USDA Miscellaneous Publication 194, *A Pasture Handbook,* in 1946 stated that closely grazed pasture "produces about three-fourths as much digestible nutrients as the hay." In terms of dry matter it states, "Closely grazed pasture produces about two-thirds as much dry matter as the same plants would produce if they were allowed to grow nearly to maturity and then cut for hay." This basic set of premises has been used repeatedly in different wording for the last 50 years. The same misleading premises stay even with the different wording.

First, closely grazed continuous pastures have a poor growth rate. They are kept at the low end of sigmoid curve displayed in figures 5–20(c) and 5–25. We can agree that this is common practice and happens on many pastures. However, with better grazing management, we can keep forages growing in the rapid growth rate range. The tighter the management, the more this can be maximized. In fact, it can be more easily done on pasture than on hay cropland. Hay crops are allowed to mature and end up on the slow growth upper end of the sigmoid curve.

Then, some authors begin to talk about hay and the ideal premise is brought out, not the common practice. The same producers that are overgrazing pastures probably are not cutting their hay at peak quality either. Much hay is not harvested at the nearly to maturity stage, but at advanced maturity stages. A large percentage of it is also damaged by rain, humidity, and sun exposure. Then it sits in storage and loses dry matter. Equally well managed pasture and hay cropland will produce the same amount of digestible dry matter at the time of feeding. Both leave stubble in the field. Livestock avoid some forage above the grazing height. Preserved forage, whether it be hay or ensilage, also leaves harvestable material behind. The material includes leaf shatter, respiration losses, leaching losses if rained on, fermentation losses if ensiled, spoilage, and feeding losses. The end result, as shown in figure 5–37, is somewhere around a 20 percent loss of harvestable digestible dry matter even if the stored forage crop is handled right.

(a) Forage crop production

Forage crop production is capital, labor, and machinery intensive. It requires silage storage, dry hay storage, sometimes automated feeding systems, a full line of machinery from seedbed preparation to harvest, feeding operations, waste handling, and often livestock confinement facilities.

Forage crop production is approached in two basic ways. One avenue is used to support pasture production. In this approach to grassland farming, forage crops are only produced to carry the livestock through periods when pasture is dormant or in low supply. With this approach, the balance between pasture and forage crop production shifts from time to time depending on pasture availability and which is most economical to produce and feed.

The other avenue totally supplants pasture production. This is often done to achieve economy of scale. Farms with large herds and a low land-to-livestock ratio find this most convenient. They may import varying amounts of feed to the point of being totally dependent on purchased feed.

Whichever avenue the producer chooses, management of forage crop production remains essentially the same. The goal is to efficiently produce high quality forages to the maximum potential of the site and efficiently convert it into a salable livestock product.

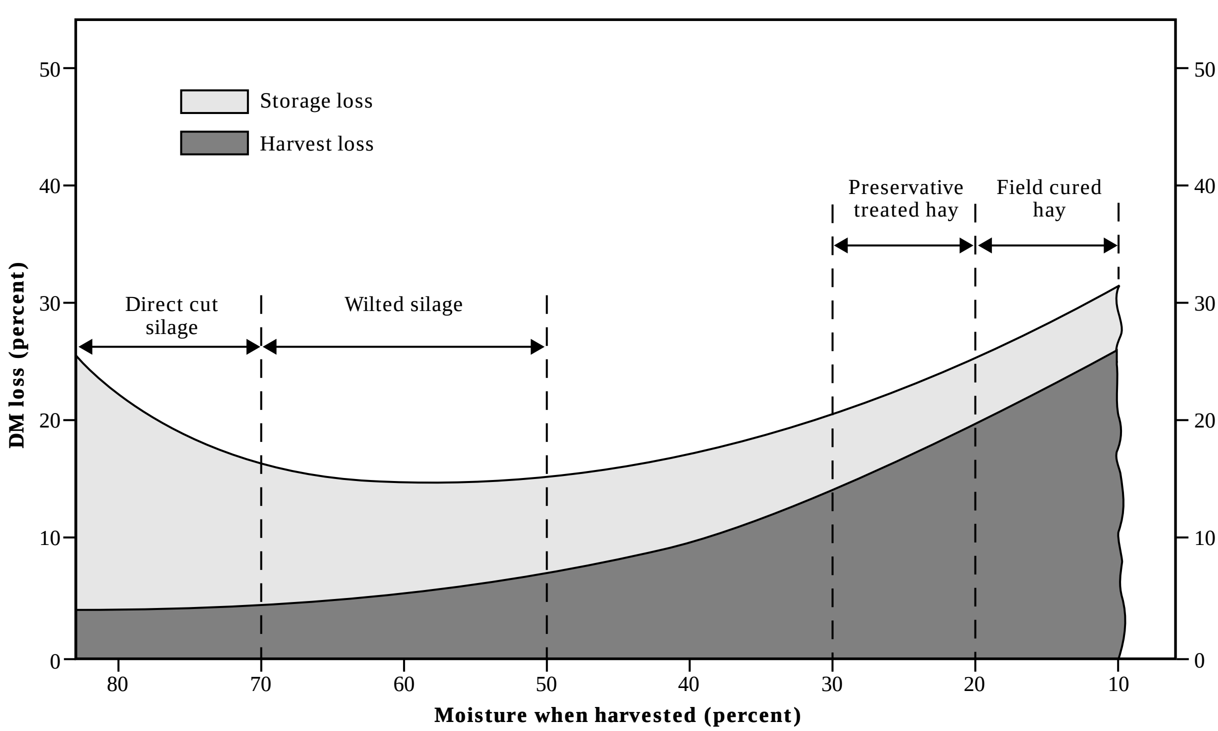
The remainder of this section focuses on the first avenue of approach to forage crop production. It requires the highest degree of integration of all grazing land resources on the farm or ranch. To integrate well requires analyzing the farm or ranch operation available resources, the tools that are available to produce forages, and how those tools can be used to best advantage on the specific site being analyzed. This thought and decisionmaking process is diagrammed in figure 5–38.

After integrating pasture and forage crop production acres into a workable plan for the farm or ranch, the forages that will meet the landowners or manager's objectives need to be more closely analyzed. The following questions should be answered:

- Which forages are adapted to the climate and soils on the land unit?
- What is the seasonal distribution of pasture now?
- What could it be if we selected different species from the ones currently growing on the farm?
- Can the grazing season be extended past the current one being used and not hurt the pasture resource?
- Once reasonable alternatives to feed the livestock with pasture are exhausted, what forages will meet stored feed quality and quantity requirements?
- What cultivars are appropriate for disease, insect, and soil reaction, salinity, and drainage circumstance?

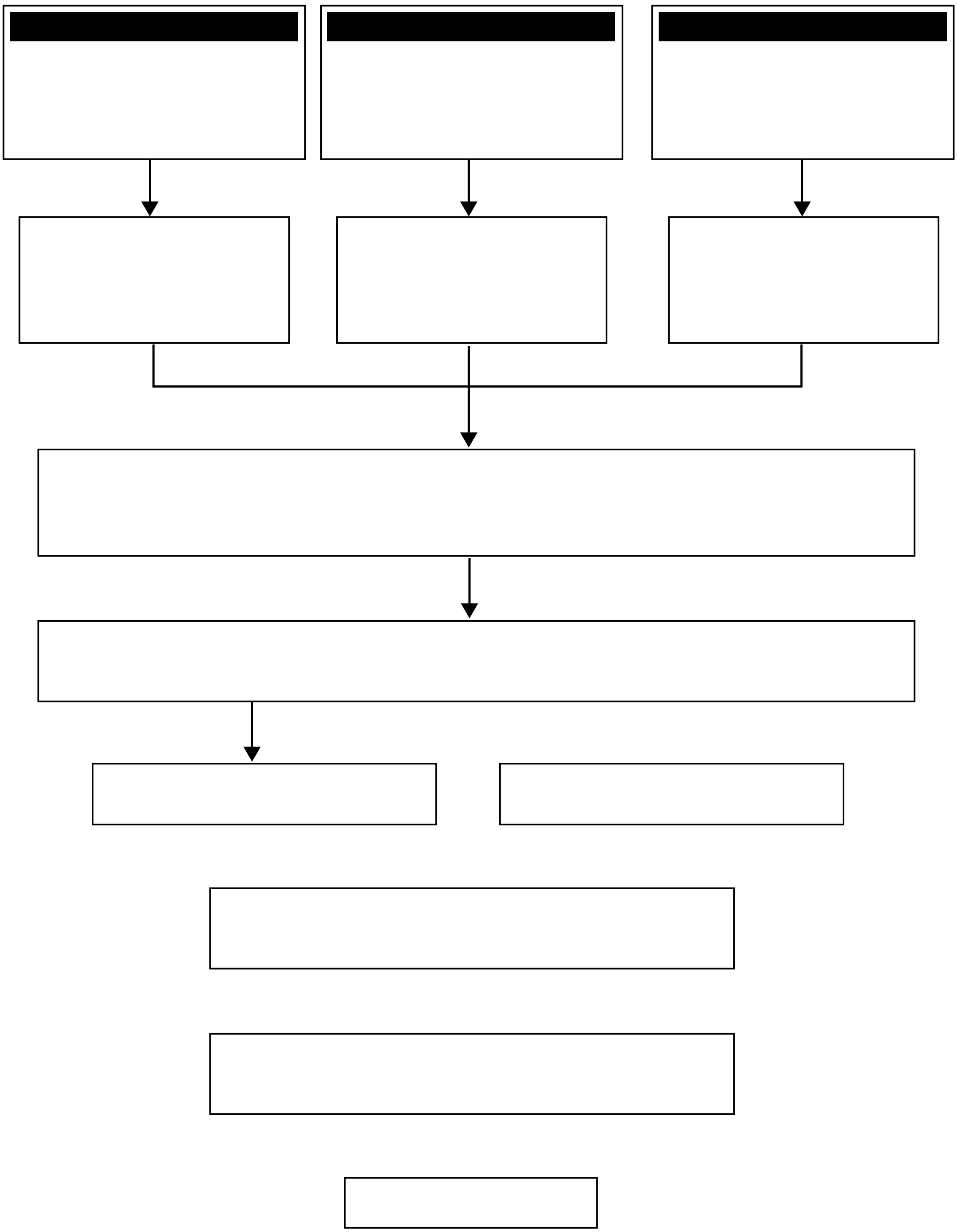
The thought process required for forage management is shown in figure 5–39. Forage management planning starts with gathering information on the site characteristics of each field. The climate and soil limitations must first be known. Forage suitability groups characterize major soil limitations and give guidance on how they can be overcome. They help site selection by

Figure 5–37 Amount of dry matter loss of harvested forages during harvest operations and storage* (from Barnes, et al. 1995)



* This is the loss of harvestable forage. It does not include stubble left below the cutter bar.

Figure 5–38 Forage integration model* (adapted from Barnes, et al. 1995)



pointing out which forage species are suitable for the soils on a land unit.

Forage species selection also involves selecting species readily consumed by the livestock type and class being raised on the land unit. They must be palatable and encourage maximum intake for high production animals. Other classes of livestock are often better served nutritionally by lower quality forage. Pasture and stored forage needs must be planned for these livestock classes too.

Within species, there may be only one or two cultivars (varieties) or several to choose from. Specific cultivars are selected for several reasons. Some are resistant to insect and disease pests. Some are bred to be lower in or free of anti-quality factors, such as alkaloids, tannins, and saponins. Tall fescue is a good example. It has several cultivars that are endophyte free. Being endophyte free allows cattle to graze it without the symptoms of fescue foot, bovine fat necrosis, and fescue toxicosis appearing. Some cultivars are just more productive. Others are bred to be leafier. Some forage species are bred to have a wide range of climate specific cultivars. Alfalfa is good example of this. It has varieties that can withstand severe winters and others that grow during the winter in warmer climates by varying the degree of fall dormancy each one exhibits. Other forages are bred to be higher in protein or lower in fiber.

Forage selection is also done to choose between distinctly pasture type forages and hay type forages. At other times forages may be selected that harvest or graze well. For example, orchardgrass and bermudagrass produce good pasture or hay. Some species, such as alfalfa and birdsfoot trefoil, have hay type cultivars and pasture type cultivars. Some grasses can be grazed, but do better as hay crops. Examples of this are timothy and smooth bromegrass. They elevate their growing points early and have basal buds that do not break dormancy until around heading time. If grazed or cut before boot stage, they are slow to recover. When mixed with alfalfa and cut early at bud stage for alfalfa, both grasses can be weakened and with successive harvests, die out prematurely.

Once the production options have been weighed and the best fit plan for the land unit is selected, it is time to implement forage crop management. This will ensure the right kind of stored forages will be available to round out the livestock feed ration.

ther (from Barnes, et al. 1995)i ell thed by 5–.2

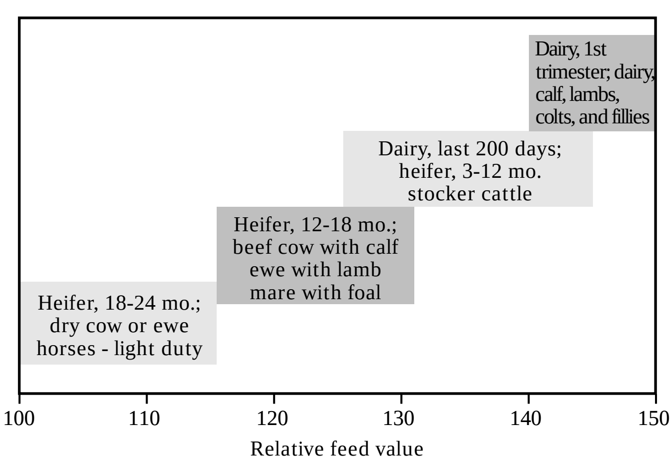
600.0507 Vegetative conservation practices for forage cropland

(a) Harvest management practice—Forage harvest management

This practice is used to provide forages of varying quality in the quantities needed for a livestock enterprise. Forages are stored to meet all or part of the forage needs of livestock. Stored forages may be fed to supplement pasture and to increase dry matter and fiber intake, especially with dairy herds. During droughts and other emergencies, stored feed may carry livestock through until there is pasture to graze again. Other times, stored forage is stockpiled to provide feed during expected loss of pastures, such as in winter.

Depending on the quantities needed of each forage quality, forage harvest can be timed to produce the proper quality for the livestock class being fed. As a forage reaches maturity, it becomes more fibrous and decreases in protein content. This lower quality forage is still appropriate for many classes of livestock. For example, in figure 5–40 relative feed value (RFV) is an index that ranks forages relative to the digestible dry matter intake of full bloom alfalfa (RFV = 100). For dairy cattle, RFV equals DDM times DMI divided by 1.29. Digestible dry matter (DDM) is calculated as 88.9 minus 0.779 times percent acid detergent fiber (ADF), and dry matter intake (DMI) is calculated as 120 divided by percent neutral detergent fiber (NDF).

Figure 5–40 Relative feed value and livestock classes (adapted from Barnes, et al. 1995)



Forage harvest management as it pertains to perennial forages becomes more difficult. While keeping in mind the livestock needs, the land manager must also weight what is best for the forage resource, and ultimately their costs of production. For perennial forages, it becomes a compromise between yield, quality, and persistence. More harvests per season mean younger vegetation is being cut so quality is high, low fiber and high protein content. However, this can lead to stand loss and the need to replant or rotate to another crop. Fewer harvests per season will better maintain stand persistence, but forage cut will be more mature and so quality, or its digestibility, will be less. The forage will be more fibrous and lower in protein.

Most forage stage of maturity guidelines put out across the Nation are a compromise between quality and stand life. Harvesting a little earlier would improve quality, but reduce stand life if done continually. Harvesting a little later lowers quality, but builds food reserves, allows basal buds of some species to break dormancy, and increases stand life. More frequent harvests tend to decrease overall dry matter yield especially from a multiple year standpoint. This is a result of lost vigor and slowness to recover between cuttings. This leads to a progressive and quicker stand decline on a year-to-year basis.

When grasses and legumes are grown together, the legume stage of maturity is used to time the harvest except in the case of birdsfoot trefoil, Ladino clover, and white clover. Some grass species have had cultivars selected that seek to time their stage of maturity with that of alfalfa. For instance, orchardgrass varieties have been selected to slow down spring maturation. Meanwhile, timothy and smooth bromegrass varieties were selected that sped up their first cut maturation to coincide with that of alfalfa. The two white clovers and trefoil tend to maintain their quality because they are indeterminate in their growth. In the case of common white clover, it is too diminutive to make up much of the total forage taken off a mixed stand anyway. Therefore, the grass component's stage of maturity is a better target to get the forage quality desired. Common white clover is also not likely to persist in a stand managed only for hay. The grass component shades out common white clover unless it occupies areas lacking grass cover.

Annual grass forages, such as sorghum, millet, and sudangrass, that can be harvested several times in a season, should be cut at boot to early head stage. This triggers more tiller growth at their bases because they are not able to set seed. If a foliar or insect outbreak threatens stand survival or forage quality unduly, harvest prior to correct stage of maturity. This will preserve as much quality as possible and remove the host to curtail spread of the pest. For instance, mow alfalfa within 10 days of normal stage of maturity when economic threshold is exceeded for weevils, spittlebugs, or potato leafhopper. When the economic threshold is exceeded for alfalfa caterpillars, harvest forage at early bud stage. In some cases outbreaks occur too early after the previous harvest. The appropriate labeled pesticide must then be used to prevent loss of a forage cutting or the whole crop.

For annual forages that are harvested one time only, the whole focus can be on achieving the desired forage quality for livestock consumption. This may be tempered a bit on silage crops where the type of storage being used has an influence on the amount of moisture left in the forage at filling time. However, some thought about the quality of the forage needed should play a role in the type of silo built. Bunker silos, although cheaper to build per cubic foot of storage than upright silos, require more moisture in the silage to ensure good compaction. The same is true for bagged silage.

Compaction of the silage is needed to have good anaerobic fermentation of the silage. The upright silos achieve the compaction just by the sheer weight of the material stacked 50 to 80 feet high. With more moisture in the silage this can lead to leaching losses of dry matter and create a high biochemical oxygen demand (BOD) effluent. This effluent must be diluted substantially to not cause a fast drop in oxygen levels of receiving water. Effluent production generally occurs in forages that are ensiled in bunkers or bags at moisture contents over 70 percent or in tower silos atmoisture contents above 65 percent. The percent moisture values shown in table 5–6 are the recommended moisture levels for hay-crop and corn silage to ensure good fermentation and a well-preserved silage.

Corn silage chopped at the dent stage of kernel maturity coincides pretty well with the upper limit of moisture of 68 percent. If kernel maturity proceeds to the black layer stage, then the whole plant moisture level is down to the lower limit of 55 percent. Harvest should not be delayed past black layer. For bunker and conventional upright silos, harvesting at the one-third milk line is appropriate. At one-half milk line, the moisture is appropriate for oxygen-limited silos. For sorghum, chop when kernels are between soft to medium dough stage.

In many parts of the Nation wet weather and high humidity also impact when, how, and at what moisture content forage crops can be harvested. In some situations where rains come on a daily basis, hay-crops that are reaching maturity should come off as direct cut silages to preserve as much quality as possible. Effluent production will need containment. The addition of dry feedstuffs, such as ground ear corn, reduces the overall moisture content and acts to soak up the leachate produced before it becomes effluent. Proprionic acid and similar organic acids can also be used. They quickly drop the pH of the silage to avoid bad fermentation from taking place. This reduces effluent production. However, some effluent production still occurs that needs containment and treatment as part of a waste management system for the land unit. This is far better than letting a valuable forage

Table 5–6 Silage storage structure forage moisture suitability

Storage structure type	Hay-crop [1/] (% moisture)	Corn [2/] (% moisture)
Upright or tower, conventional	60 – 65	63 – 68
Upright or tower, oxygen – limiting	40 – 55	55 – 60
Bunker or horizontal	65 – 70	65 – 70
Bag silo (plastic tube)	50 – 60	65 – 70
Balage (plastic wrapped round bales)	50 – 60	——

1/ Coastal bermudagrass should be ensiled direct cut (65 to 75%) to get required packing.
2/ Add 5 percentage points to the range for sorghum silage.

resource be underused when it cannot be grazed off fast enough to keep up with production. It is also better than waiting for dry weather to make hay. Much of the forage will rot, and the rest is a mix of overmature and highly weathered first growth and green second growth material.

In other areas storm systems track through on a 3- to 4-day schedule. This prevents field cured hay that is not rained on at least once from being produced without preservatives. Where relative humidity levels are high as well, this becomes even harder. In these areas wilted silage or haylage can generally be taken off the fields before the next storm system arrives.

For the harvest of legumes and legume-grass mixtures, roller conditioners are used universally to crack the stems of the legumes. This speeds up drying. Flail conditioners can be used on grasses to break the waxy cuticle and their stems to speed drying. These conditioners tend to break off too many leaves on legumes. Both conditioners are generally integrated with and mounted behind a mower unit. The combined implement is called a mower-conditioner. Later on, during drier weather when rains are infrequent, cuttings can be made as dry hay. This basically is taking what the climatic conditions are allowing. For many farms, this is not a large increase in equipment. On some, it may mean having a forage harvester and a forage wagon or two as well as a baler. For others that have a forage harvester for corn silage, the purchase of windrow head for the forage harvester is all that is required. The added expense can easily be paid for in the degree of flexibility it affords to harvest more quality forage in a timely fashion.

Another option is to bale dry hay using preservatives that are sprayed on when mowed or baled. This allows the hay to be baled at higher moisture levels (between 25 and 35 percent moisture) and can reduce drying time by 1 day. Preservatives used range widely from proprionic acid and other organic acids to anhydrous ammonia to bacterial inoculants. All have their drawbacks. The acids are corrosive to farm implements. Anhydrous ammonia is an excellent preservative and provides nonprotein N for the livestock feed ration. However, it can be toxic when fed to livestock if injected at rates above 3 percent of forage weight. The bacterial inoculants seem to only improve appearance, but do little to reduce dry matter losses of stored hay.

Another harvest method that works well in wet climates is green chopping. Fresh forage is chopped daily to feed directly to livestock on a feedlot or loafing area. Traditionally, this is used in dairy country. Obviously, this eliminates the need for pasture for that group of animals, but it does not eliminate the need to preserve some forage for later use unless it is produced off the farm. Although used widely when first introduced, little green chopping is done nationwide today. It is labor and machinery intensive, although it tends to use the forage harvesting equipment to the maximum. However, a separate flail chopper is generally used instead of the conventional forage harvester. It takes a good manager to use this method well. Average management leads to a wide spread in stage of maturity of the harvested forage. Early cuttings are cut too early for maximum stand survival, and late cuttings are overmature for the best nutritional value to milk cow herds. This variation in quality and its interference with other crop harvest activities on diversified farms led to its loss of popularity. The flail chopper also causes a ragged cut that retards regrowth and lowers stand persistence. Green chopping does have a place on farms where the land base is small in relation to livestock numbers. It optimizes forage production per acre. All that is left behind is some stubble. The most common forage grown for green chop is alfalfa.

Moisture content of forages when being windrowed, tedded, or inverted should be moist enough to keep leaf loss to a minimum. In humid areas field dried hay may need to be rearranged on the field a few times to get all the forage to dry evenly. Tedders and inverters are used to expose underlying forage to the sun and wind. This is especially important where the ground is damp from previous rains. Tedders or inverters should stir or lift the forage while it is still over 40 percent moisture. The hay when raked for baler pickup should be between 30 and 40 percent moisture.

Bale field cured hay at 15 to 20 percent moisture to prevent heating and spoilage in the barn or stack. This minimizes dry matter losses and prevents spontaneous combustion from occurring. Bale hay to be forced-air dried at 20 to 35 percent moisture. This hay is generally treated with a preservative and stacked on pallets in a building with an air circulation system.

Number of cuts or harvest interval of perennial forage crops is also a compromise between yield, quality, and persistence. This is because it is tied closely to stage of maturity of the forages. However, this is not always the case in grasses. Many grasses are only reproductive once a year. Once they have produced seedheads, the rest of the tillers sent up are vegetative the rest of the growing season. Therefore, stage of maturity is meaningful only once a year. The harvest interval after that time is arbitrary, being based on harvesting convenience, the legume component's maturity, and weather delays. Some forage cultivars have been bred to take a more intense harvest schedule than others.

If high quality forage is a goal, then the number of cuts will be maximized for the climate. The crop rotation planned for such a goal must be a more rapid one. It involves a quick replacement of the forage crop with other crops in the rotation unless the forage cultivar is up to the stress. On fields in continuous perennial forage crop production, more frequent hay seedings are necessary if the forage cultivar cannot take frequent cuttings.

If maximizing the number of cuts is a goal, then it is necessary in humid climates to be able to ensile as well as make dry hay. For producers with round balers, this may require nothing more than the ability to wrap large round bales in plastic to create balage.

End of growing season harvest interval in areas where winter survival of forage crops is a concern should be at least 40 days long for legumes and at least 30 days for grasses. This allows food reserves to be replenished before going into winter. The last cut should be timed to coincide with a killing frost if the forage is needed for stored feed. On fields that can be pastured, the last cut could be 30 to 40 days before a killing frost, and then the pasture should be grazed after the killing frost to extend the grazing season. In either case a nonharvest period before a killing frost is best for long-term forage stand survival. Some evaluation of the stand condition is necessary, as well, to decide whether to harvest any of the forage produced during the fall recovery period. Leaving unharvested aftermath may increase forage stand survival significantly depending on the severity of the winter and the vigor of the stand going into the winter. The aftermath can be left to provide soil insulation and cover for wildlife. In snowfall areas, it will trap snow better than short stubble. This provides additional insulation and improves soil moisture distribution across the field in the spring. The added insulation can reduce the chances of frost heave damage as well as winter killing.

Stubble height must be based on each species' requirement for adequate residual leaf area; adequate numbers of terminal, basal, or axillary tillers or buds; insulation from extreme heat or cold; and unsevered stem bases that store food reserves needed for a full, vigorous recovery. Where mixed stands are raised, the species grown together should have similar stubble height requirements. Always go for the stubble height of the species requiring the highest stubble. This keeps the least tolerant or most sensitive forage in the stand. Some loss of yield may occur, but the quality of the forage taken off will be higher. There will be less basal stem that is mostly lignified fiber. For annual forages with regrowth potential, sufficient stubble height (6 to 8 inches) must be left behind to promote tillering. Thicker stalked cultivars need higher stubble heights than thin stalked ones to tiller well.

In special situations, stubble heights may be reduced below that generally used to promote fast regrowth and plant vigor. In the South, alfalfa should be close mown at last cutting at the end of the growing season to control alfalfa weevils. This removes their overwintering cover. Mow warm-season grasses grown in association with winter annual legumes or grasses close at last cutting to release emerging seedlings.

Contaminant effects on forage quality are as equally important to consider as the nutritive components.

Green chopping of sorghum-sudangrass and piper sudangrass must be done with care to avoid prussic acid (hydrocyanic acid) poisoning. The risk of this is reduced if sorghum-sudangrass is cut when over 30 inches tall and piper sudangrass when over 18 inches tall. Drought or frost damaged forage of these species should be avoided for at least a week after the event has ceased. Ensiling actually reduces prussic acid content during fermentation and lowers it below toxic levels (<200 ppm) sufficiently in 6 to 8 weeks. These forages, including sorghum, are poisonous to horses and are not to be fed.

Forages containing high levels of nitrates (>1,000 ppm) are also better harvested as ensilage than as hay. No loss of nitrates occurs during hay curing. Haylage as it is fermenting reduces nitrates to nitrogen dioxide, silage gas. This detoxifies the haylage, but the gas can cause severe lung damage within seconds of exposure if not vented out of the haylage stack or silo. Carbon dioxide is also formed during fermentation. It is heavier than oxygen and can displace it in the silo. People have died from suffocation not realizing soon enough that no oxygen remained in the silo. Corn or sorghum fertilized heavily with nitrogen and stressed by drought can also have high nitrate levels. Silos containing forages suspected of being high in nitrates or silo rooms attached to them should not be entered for the first time within a week of filling without being thoroughly ventilated first. Delay feeding silage for 6 to 8 weeks after filling.

High tannin forages, such as birdsfoot trefoil and sericea lespedeza, lose as much as half of the tannin during field drying. In doing so, digestibility increases significantly.

Blister beetle poisoning of horses can occur where the beetles occur in high concentrations in isolated spots of alfalfa fields that are mechanically conditioned. They contain a toxic compound called cantharidin that is released into the hay when they are crushed with the hay in the conditioner rollers. The compound is stable in hay and therefore can be harmful to horses eating the hay.

Red clover hay infected with black patch fungus contains an alkaloid, slaframine, that sickens livestock when fed shortly after storage. Long-term storage reduces the concentration.

The alkaloids produced in endophyte infected tall fescue are reduced only 20 percent in curing hay and little at all in storage. Ensiling has little effect.

Moldy hay causes colic and heaves in horses. Cattle can have mycotic abortions or contract aspergillosis from certain fungi associated with moldy hay.

Fields should be free of metal, such as wire, to prevent hardware disease in livestock.

Another forage quality issue is the length of cut of ensiled forages that are chopped. The theoretical length of cut range for hay-crop, corn, sorghum, and small grain silages is 3/8 to 3/4 inch. This is done by setting the shear-plate on the forage harvester for a 3/8 to 3/4 inch cut. This is theoretical because not all particles will be in that size range. About 20 percent actually should be longer than 1 inch to provide enough long fibers to aid rumen digestion. Chopping the forage fine aids in compaction so that good fermentation takes place. Again, some compromise must be reached. Too fine is not good for rumen digestion, but too long does not allow for good compaction.

Storage of the forage is important to maintain quality and digestible dry matter. Whenever possible, dry hay or silage should be under cover in humid climates. This can be nothing more than plastic film. Large round bales left on the ground and uncovered can lose up to 40 percent of their dry weight in humid climates over a season. Losses range from a low 0.5 percent per month in arid climates to as high as 3 percent per month in wet, warm climates. Moldy hay is often rejected by animals unless forced to eat it. Then, they can have health problems as mentioned earlier. If large round bales are made to save on labor, they must either be wrapped with plastic around their circumferences or placed on end in a barn or shed in humid areas. They can be stacked three high without anything more than a front end loader on a tractor.

Bunker silos must be covered to prevent great spoilage and leaching losses. Plastic film weighted down to prevent uplift and removal is necessary. If this is not done, leaching losses can be high as rain filters down through the material. If exposed to the air, spoilage of the top foot or two is common in humid areas. Dry matter is lost (up to 25 percent of it), and the spoiled forage will be rejected at the bunk.

When haylage or silage is bagged, care must be taken in their handling and placement not to puncture or rip the plastic. They also must be checked weekly for rodent or raccoon damage and patched. If management is lax, spoilage will start at these openings and spread farther into the bag. Silage should never be stacked except under limited and very temporary circumstances. Effluent can readily escape, contaminating shallow aquifers or adjacent streams. Dry matter losses can be high, from 15 to 30 percent of the total placed in the stack. Hay, if stacked outdoors, should be covered and placed on a well-drained pad or on pallets.

(b) Accelerating practice—Nutrient management

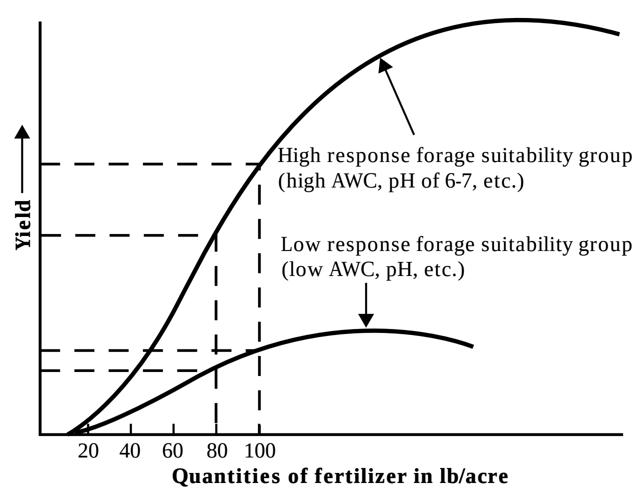
Nutrient management on forage crops differs from pasture nutrient management in that it is a put-and-take operation. When harvested all the nutrients in the forage are removed from the field. They may be replaced later, or they may not. On land units where manure is recoverable from a feedlot, barn, or barnyard, it can be returned to the field. The likelihood of it coming back with the same proportions of nutrients as left the site is nil. If fed to livestock while on pasture, there is no way to recover the nutrients economically. There is a total transfer of nutrients from the forage cropland to the pasture. Therefore, chemical fertilizers are used to provide the balance of nutrients needed to continue optimal production if so desired. Legumes can be used to provide some or all of the nitrogen (N) needed to support optimal grass production. However, the removal of phosphorus (P), potassium (K), and secondary nutrients from forage crop production lands by harvest activities must still be dealt with.

Forage crop response to fertilizer additions is dependent on the inherent productivity of the soil in which the crop is growing. Forage production in humid climates is mainly controlled by available water holding capacity (AWC). The next most important soil factor is soil reaction. In more arid climates, it is controlled primarily by rainfall or irrigation rates and salinity or sodicity. These factors set the maximum forage production limit, not fertilizer. In figure 5–38, note site selection does determine maximum yield. Each soil series has a response curve to nutrient additions. Some of them may be similar. Soil series grouped together as forage suitability groups should have the same response curve. Figure 5–41 shows two soil groups and their response curves to fertilizer. Fertilizer merely drives the soils to produce near their potential maximum when weather and pests permit.

The maximum potential yield is seldom achieved on a site. It certainly is not achieved from fertilizer additions. The economics of fertilizer additions dictates that this is not going to occur under commercial forage crop production. Before the maximum potential forage yield can be reached, each increment of fertilizer used costs more than the worth of the forage produced. This is illustrated in figure 5–42. Going from 100 pounds of fertilizer per acre to 150 pounds of fertilizer per acre produces a good crop response. The additional forage produced is worth more than the cost of the additional 50 pounds of fertilizer. However, at the 150 pounds per acre rate, the cost of the last pound of fertilizer equaled the value of the forage produced. The yield at which this occurs is called the maximum economic yield. This yield is not static, but changes with the cost of fertilizer and the value of the forage crop being produced. The maximum economic yield is going to occur at a much lower application rate of fertilizer on a low response forage suitability group soil than on a high response forage suitability group soil. Compare where the rates of fertilizer intersect the two response curves shown in figure 5–41.

Because forage crop production removes nutrients completely from the field, the primary goal of nutrient management on these lands is to return nutrients back in nearly the same proportion as were removed. This is tempered by the natural fertility of the soils being used to produce forage crops. In some parts of the Nation, native fertility can be high in P or K, or both. Long-term forage crop production may do little to reduce the natural store of these nutrients. Little or no crop response occurs when fertilizers containing these two nutrients are applied on soils where they are abundantly available. In other areas these nutrients may

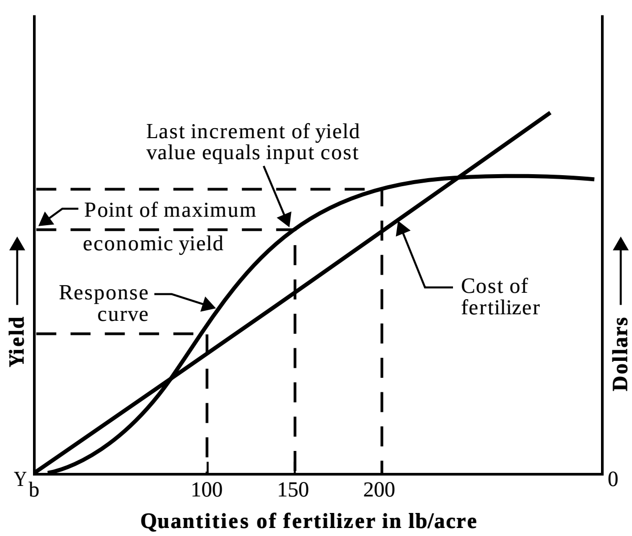
Figure 5–41 Response to fertilizer by two forage suitability groups*



* The same amount of fertilizer applied resulted in two very different forage yields. In the case of the low response forage suitability group, water was primarily the limiting nutrient.

have always been deficient or marginal. Any crop production quickly draws down the natural store of P and K. Yields quickly drop, and forage stands become weak and thin. In these areas P and K are added to replace those removed by harvest (maintenance applications). Additional P and K may be added to build the soil store of P and K. This latter amount of fertilizer is called build-up or corrective fertilizer applications. This is done so that the two nutrients do not limit production. Once a soil test indicates that they are in the optimum range, no further build-up or corrective amounts is recommended. Only maintenance amounts are recommended, generally based on a projected yield of the next crop. A more conservative approach, however, would be to replace what was taken off by the previous crop. This is truly replacement; the term used to describe this method of nutrient management. Since no response is supposed to occur when the soil is in the optimum range, being theoretically short a few pounds of P and K should not jeopardize a better harvest than the year before. Furthermore, it avoids over-applying fertilizer based on a prediction that is more likely to be missed by a wider margin than a harvested yield based on less than ideal estimates of dry matter.

Figure 5–42 Maximum economic yield* (adapted from Blackmore 1958)



Y_b=Base forage yield without fertilizer

* Maximum economic yield is the point on response curve where an additional dollar spent on fertilizer returns a dollar of additional forage produced. Beyond that point the additional fertilizer being spread on the field costs more than the additional increase in forage production is worth.

Forage crops remove large amounts of K, 30 to 50 pounds K_20 per acre for every ton of forage harvested. Grasses are better at taking up K than are legumes. Grasses have a fibrous root system with a high degree of root replacement. Legumes are primarily tap rooted, have fewer roots, and a slow root turnover rate. The grasses with their greater, ever-shifting root mass can exploit the soil better for nutrients than legumes. Some grasses, such as ryegrass, can also absorb K two to five times faster than the companion legume at the root exchange sites. Therefore, when the two are grown together, K fertilization is important to the survival of the legume. The legume needs to be able find abundant K in a small volume of soil composed of its root-to-soil interface. Fertilizing with K also helps the legumes by promoting more root branching. Fertilizing legumes with K then causes a compounding effect. Fertilizing with K on soils lacking sufficient available K will thus maintain the legume component in legume-grass mixtures.

K applications should be done at least yearly. If yearly rates call for 167 pounds per acre of actual K (200 lb/acre K_2O) or more, split the application to avoid luxury uptake of K during any one cutting. In areas where winter survival is critical to stand longevity, apply the last application of K fertilizer prior to last regrowth. Split applications are especially important on soils that have a low cation exchange capacity (< 7.0 milliequivalents per 100 grams of soil) to avoid leaching losses and nutrient imbalances on the exchange sites.

Forage crops also remove large amounts of P. They remove about 15 pounds of P_2O_5 per acre for every ton of forage harvested. Forage production responds to annual maintenance applications of P better than to infrequent heavy rate applications. This is primarily because much of the applied P is being rendered insoluble (fixed or immobilized, see fig. 5–31) in most soils and thus unavailable for plant uptake. Even in soils with optimum levels of P, forage seedings often respond to a banded starter fertilizer containing P by growing more vigorously and thicker.

Both P and K availability are enhanced by liming acid soils. P is most available when the soil pH ranges between 6.0 and 7.5. At either side of that pH range, much P can be precipitated out and rendered insoluble for plant uptake. With K, liming removes exchangeable aluminum (Al^{+3}) from the soil cation exchange sites allowing K to compete with Ca and Mg for those sites. Liming also increases the pH-dependent cation exchange capacity (CEC) significantly. This creates more CEC in the soil by creating more negatively charged particles in the soil. It is a continuous function increasing from a lowest value at a pH of 3 to a highest value at a pH 9. The higher the CEC, the more K that can be held in the soil as a plant available form.

Standard soil tests do not test for N in humid areas. Nitrogen fertilizer rates are given based on long-term field trials of forage species at research farms scattered about those states in humid areas. The nutrient is too soluble and so subject to various transformations in moist to wet soils that it is impossible to measure it accurately. The measured value also would not have any meaning over the useful life of the soil test. A nitrogen quick test produced for corn uses a soil sample taken when the corn is about 12 inches high. This snapshot in time can predict whether the corn crop needs additional N fertilizer. This, too, is just an approximation and correlates the concentration of nitrate in the soil at that stage of corn development to the amount of fertilizer needed to produce the corn yield desired. The reading itself, without the correlation data, is meaningless. It works best on ground either receiving manure or that has residual N from the previous year. It is not appropriate if highly available N fertilizers have been spread or injected just before corn planting.

Naturalized and native haylands are primarily grass based. Naturalized haylands, being primarily cool-season grasses in the North and subtropical or tropical warm-season grasses in the South, benefit by the addition of N. Legumes are either absent or a minor component (<10 percent by weight) in those grass stands (fig. 5–43). If manure is available, it can be spread at the rate to meet the N needs of the crop produced. Manures and N fertilizers should be spread before grass regrowth occurs at the beginning of the season or after a cutting. The most efficient way of applying N is to split apply yearly requirements in humid areas or on some irrigated pastures. These split applications should equal the amount needed to produce the forage growth expected for the cutting being fertilized. If applied all at once, a high percentage can be lost to leaching, runoff, denitrification, or volatilization before forage crop uptake. Grasses also take up excessive amountsof N if excessive amounts are present in the soil. This can lead to nitrate poisoning unless ensiled and stored for 6 to 8 weeks before feeding.

Native haylands, being primarily temperate warm-season grasses and growing in more arid areas where little N is leached or denitrified, may require little or no N. In humid climates N fertilizer can actually be detrimental to temperate warm-season grass stands by favoring cool-season grass invaders. Therefore, N fertilization should be avoided unless applied in small amounts late in spring at the outset of warm-season grass growth. In areas receiving 18 inches of rainfall, 50 pounds of N per acre is sufficient. In areas receiving 30 inches or more rainfall, 100 pounds of N per acre optimizes yields of warm-season grasses. The goal is to avoid leaving any significant residual N in the soil for cool-season grasses to exploit once cool weather begins again.

Naturalized or native haylands being mostly grass based do not benefit much from pH adjustments unless the soil is extremely acid (<5.0) or extremely alkaline (>8.7). So liming to reduce acidity or decreasing alkalinity through irrigation water management or acidification is rarely necessary for these haylands. Most grasses grow well within this range.

For forage crops grown in rotation with row crops, another method of fertilization may be the rotation method. This works particularly well when manures are available for disposal. Most manures, when applied at the N rate needed to produce the expected yield of the row crop, deliver higher rates of P and K to the soil than that required annually by many row crops grown in association with forages. Yet, this is the most ideal time to spread manure for the following reasons:

- Row crops can use the N to greatest economic advantage.
- Manure spreading can be done before row crop planting and after harvest so that no crop damage can occur from smothering, salt burn, or traffic injury.

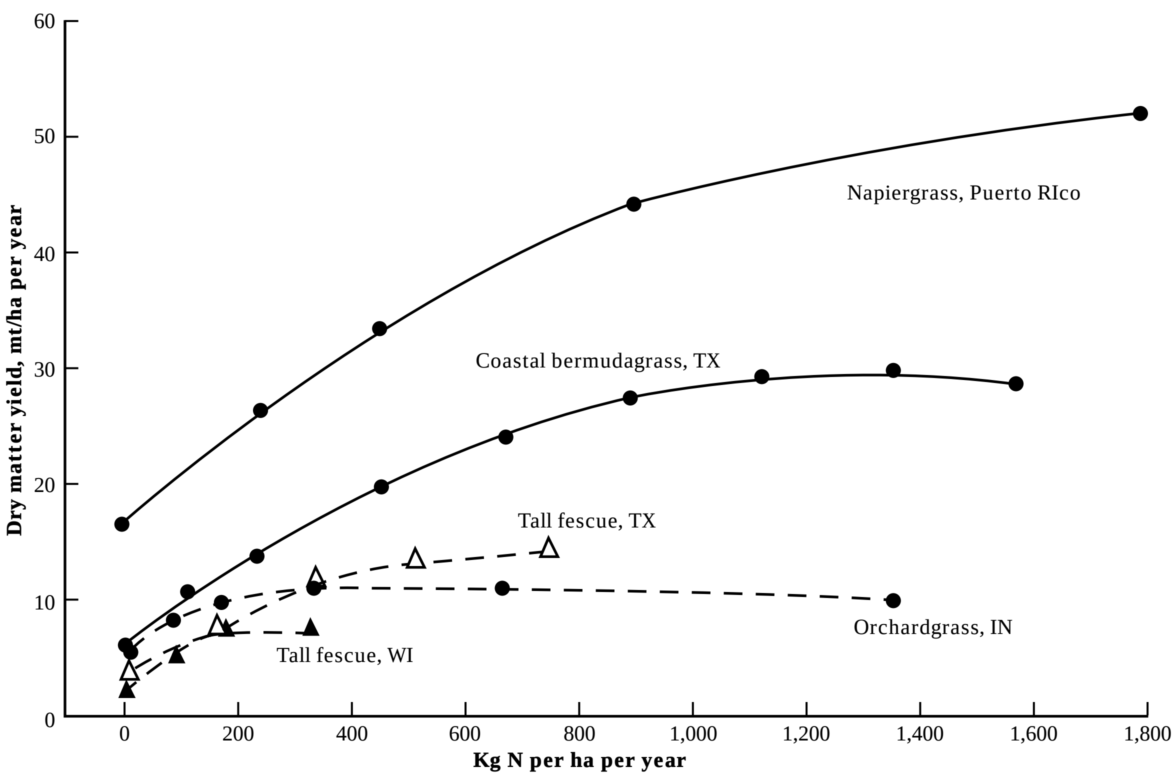
- Legume and legume-grass forage crops are not subjected to unneeded N applications that can increase planted or volunteer grass competitiveness with the legume.
- Forage crops are also not fouled by manure that could lead to livestock health problems or at least lower intake.

This method of fertilization leaves residual P and K in the soil for the forage crops that follow in the rotation. The forage crops are then left in the rotation at least long enough to draw down the P and K to balance crop removal with nutrient additions over the life of the rotation. Some supplementary P and K may be added if the forage crop's life in the rotation extends beyond that needed to balance manure nutrient inputs with crop removal.

This leads to one other method of fertilization, prescription application of nutrients. The prescription method accounts for the various possible sources of nutrients on a fully integrated livestock farm or ranch. The sources include atmospheric deposition, feed purchased, fertilizer, fixed nitrogen from previous crops, manure, and soil.

Soil test results prescribe fertilizer amounts based on the availability of soil nutrients. If soils test high, fertilizer amounts are reduced accordingly to the point of recommending no more of a particular nutrient be added. This portion of the prescription method is easy and accounted for in the soil test recommendations. The rest of the accounting procedure requires more tests and a mass nutrient balance worksheet.

Figure 5–43 Grass response to nitrogen fertilizer* (from Barnes, et al. 1995)



* Note tropical and subtropical warm-season grasses have greater response to very high rates of N than that of the cool-season grasses. Also note longer growing season increased tall fescue yield and response to N.

In areas where atmospheric deposition of N is significant, an annual deposition rate is included in the calculations. In some cases it is ignored because of offsetting N losses, such as denitrification, that are known to occur, but do so at unpredictable rates.

Manure, where applied, should be tested for nutrient value. Book values reported in the literature are averages and may have nothing in common with the manure being spread. This manure test picks up the nutrients being brought onto the farm through feed supplements. The manure analysis reflects what the livestock are eating. This is often why the onfarm manure analysis differs so widely from literature values. Another reason for the possible disparity is the way manure is stored and handled on the farm versus how it was stored as cited in the literature. Losses of N and K can be substantial if the liquid fraction of the wastes escapes collection. Ammonia N can also volatilize away during collection, storage, and application. The rate of application of manure should be calibrated so that there is a known rate of application associated with manure usage. If manures are applied, they are added to the supply ledger.

If legumes are in the crop rotation, the next crop or the legume's companion crop in the rotation will benefit from the nitrogen released from the decaying legume residue, roots, and aerial parts. Their contribution to the N supply can be estimated by using tables similar to table 5–5 developed for your area. Care must be taken not to over estimate their contribution. If the legume stand is thin or has become very grassy, little carryover of N to the next crop occurs. Once the nutrients are accounted for from these sources, they are subtracted from the amount of commercial fertilizers recommended in the soil test recommendations. Landowners or managers that have the ability to use manures and legumes in their cropping systems can save on fertilizer expenses. They also must realize that purchased feed serves a dual purpose: It feeds livestock and ultimately the crops on the farm.

From a water quality standpoint in many watersheds around the Country, N and P loadings on farms need to be closely tied to crop utilization and export of crop and livestock products. These two nutrients are causing downstream pollution and eutrophication in receiving water where uncontrolled high inputs of these nutrients occur in some watersheds. Where forage crop and pasture lands impact these watersheds, dairies, being intense livestock enterprises, tend to be major nonpoint sources of N and P. In particular they tend to be phosphorus accumulators because the importation of feed supplements and purchased fertilizer outweigh the export of P in milk and meat.

P can leach as readily as N on some sandy soils having little ability to fix or immobilize P as water insoluble compounds. Therefore, P can reach receiving water by shallow groundwater interflow as well as by surface runoff. Nitrogen can also move via these two pathways.

Dairy cattle are fed high protein diets to produce milk. If not supplemented with the right proportion of rumen degradable protein to rumen undegradable protein, much of the rumen degraded protein leaves the animal as urea in the urine rather than as protein in the milk. This elevates the nitrogen excreted either in the pasture or on the confined area. Depending on the management of the confined area, nitrogen may leave it as surface runoff or be disposed of later as manure on forage crop land. There, it may be subject to further loss by leaching or runoff. Therefore, nutrient management planning is as critical to grass based farming as is the forage-livestock balance sheet to achieve total whole farm planning.

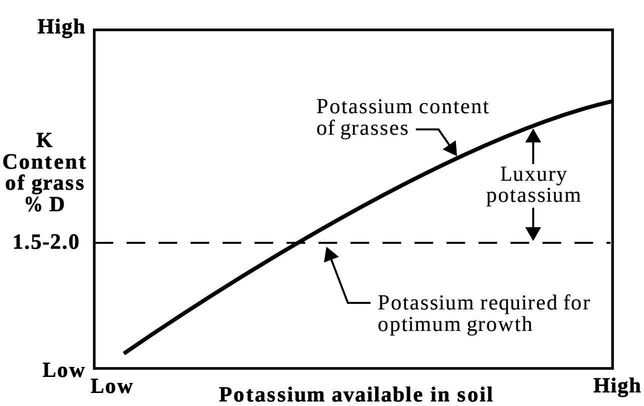
Potassium is also becoming an important factor in nutrient management. As mentioned under nutrient management on pasture, high levels of K in forages can affect animal health adversely. Dry dairy cows 2 to 3 weeks from freshening need grass forages with the lowest K concentrations available to avoid milk fever and other symptoms caused by a cation-anion imbalance in their diet. However, heavy fertilization or high feeding rates of off-farm produced feedstuffs cause soil K levels to become high or excessive on fields receiving most of the animal waste. Luxury uptake of K by grasses builds K concentrations in the grasses well in excess of 3 percent of dry weight (fig. 5–44). Late dry period cows should be fed a total ration with not more than 0.8 percent K in it. If the grass has more than 2 percent K in it, the ration becomes difficult to balance. It must involve other feedstuffs containing much less K to dilute the concentration.

Legume forage crops are sensitive to low soil levels of sulfur (S) and boron (B). When growing legumes, alone or with grass, on hayland or on cropland in rotation with other crops, specify that these two nutrients be evaluated when sending in soil samples.

On strongly acid soils, molybdenum (Mo) may also limit legume growth. It is directly responsible for N fixation by *Rhizobia* and for N assimilation and protein formation in the plants. These nutrients can be added to a blended fertilizer and spread with other required nutrients. Standard soil tests do not test for these nutrients.

Soil tests for forage crop production should be taken at least once every 4 years or per crop rotation cycle. Soil sampling in late summer or fall gets reliable K results. Soil tests should be taken at least a year before seeding back to a perennial forage crop. This is particularly important where stand longevity is critical to maintaining the correct rotation length and avoiding frequent renovation events on permanent hayland. This allows the producer to correct soil pH and micronutrient deficiencies or build soil levels of P and K before planting the perennial forage crop. The chances of establishing a thick stand and ensuring its long-term survival are greatly enhanced by having adequate soil fertility before establishment. Soil tests, to have any validity, must be taken in areas of the field that have the same soil type, topo-graphy, and cropping history. Several soil plugs or slices should be taken randomly within the area of like conditions. These are then mixed and a composite sample taken from that. Each sample must be clearly identified as to soil type, field number, and location in the field.

Figure 5–44 Influence of potassium available in the soil to potassium content in grasses (adapted from Brady 1974 and Bosworth 1995)



With precision farming, soil samples can also be collected in a grid pattern that is mapped using global positioning system (GPS) technology. This establishes a geo-referenced pattern of soil fertility over the field. Fertilizer trucks equipped with geo-referencing devices can spread fertilizer at variable rates across the field based on the soil fertility map superimposed over the field map. This avoids placing too much or too little fertilizer in areas of differing soil fertility across the field.

Soil samples also must be sent to a soil test laboratory that uses the proper extraction methods for the soil sampled and has knowledge of the soil's response to fertilizer. In some states this is easily done by sending samples to the land grant university facility. However, some land grant universities no longer have such a facility for public use. In those states private laboratories are certified by the land grant university. Much of the controversy over the validity of soil testing was because of the mistaken belief that soil testing procedures are the same nationwide. They are not and should not be. Soil chemistry varies too widely over the Nation to have one perfect extraction procedure. Soils also vary in their response to fertilizer. Laboratories without access to field trial data for the soil type listed on the soil test form cannot give accurate fertilizer recommendations. The recommendations they give will be high to avoid under estimating amount required and incurring blame for a poor crop response.

Plant tissue samples can also be taken to indicate the current status of nutrient sufficiency in the forage crop. The results are compared to reference nutrient concentrations of a "normal" forage at a specified yield level. Tissue testing can reveal any nutrient imbalances, but the soil test accompanying it helps determine the cause of the imbalance. Tissue testing alone only tells you whether or not you have a problem. It cannot tell you why it is occurring.

(c) Accelerating practice—Hay planting

This practice is used to renovate permanent hayland or reintroduce hay-crop forages on a field where a crop rotation is used. It does not include row crop plantings that might be harvested as a forage crop, such as corn silage. The full title of the practice standard in the FOTG is Pasture and Hay Planting. As with pasture plantings, hay plantings are done for several reasons:

- To reintroduce legumes back into permanent hayfields that have gotten increasingly grassy. This improves forage quality and often increases forage yields by increasing plant density and fixing atmospheric N.
- To introduce newly improved cultivars of grasses or legumes not before used by the producer. These varieties have improved disease and/or insect resistance and greater productivity.
- To introduce wholly different forage species that are better adapted to the site's climate, soils, and harvest regime.
- To introduce forage crops into a crop rotation that will balance crop removal of nutrients to those applied as manures over the life of the crop rotation.
- To introduce hay-crop legumes into a crop rotation to provide organic N to the next crops in the rotation. For instance, depending on the rate of decomposition, alfalfa may provide residual N for up to 3 years of crop production.
- The same planting techniques can be used to plant cover crops in orchards and vineyards or on cropland. On cropland, the cover crops retain soil nutrients in the root zone, provide ground cover and organic residue, and may fix additional N for the production crop's benefit. They may be tilled into the soil or burned down with herbicides before the next production crop's planting or left as a living cover crop.
- To improve soil quality by increasing soil organic matter (primarily through root mass accumulations) and soil particle aggregation. Root exudates and expansion cause soil particles to bind together by supplying a gluing agent and applying pressure.
- To provide excellent ground cover and root binding to protect the soil from erosion while they are in the crop rotation, thereby reducing overall soil erosion rates where applied.
- Where the plantings are properly sited, they provide crops that can trap wind blown soil, filter sediment and nutrients from runoff water, and intercept nutrient laden shallow interflow water with their roots. These areas may be trap strips or vegetative barriers in wind erosion prone fields. They may serve as vegetative filters along watercourses or waterbodies and at lower edges of sloping row crop fields. They may be hay-crop strips alternated with tilled strips across the hillslope or the prevailing wind direction in stripcropping layouts. On vegetative filter sites, to be truly effective in removing nutrients, the forage should be harvested as a hay-crop anyway to remove the nutrients stored in the plant tissue. Otherwise, the nutrients will eventually make their way to the watercourses targeted for protection.

(1) Hay-crop plantings

Hay-crop forage plantings generally contain only one or two species for ease of management. As the stands mature, other species of plants, desirable or undesirable, invade as openings in the canopy permit. Either a pure grass or legume stand is the easiest to manage. Weed control is easier because most herbicides presently on the market cannot kill the weeds without either killing the grass or the legume at the same time depending on their chemistry. Grasses tend to be quite competitive towards legumes having stronger root systems, a taller canopy, and faster leaf growth. Therefore, without fertility and harvest measures to favor the legumes, grass-legume mixtures eventually become grass only stands. However, most binary seeding mixtures for hay-crop seedings contain a legume and a grass. The advantages to doing that even though maintaining two different plants is difficult are:

- Legumes reduce the need for N fertilizers because they fix N.
- Legumes improve forage quality because they are more digestible and have higher protein concentrations.
- Most legumes can produce good hay cuttings during the summer when cool-season grass components produce little or nothing.
- Grass-legume mixtures tend to provide a denser canopy suppressing weeds from invading in the first place.

- Theoretically, grasses can protect legumes from frost heave damage on soils where this commonly occurs. There may be some value, but it is inconsistent and very much subject to the severity of the winter conditions that cause frost heave.
- Grass-legume mixtures tend to dry down faster as hay and ensile better than pure legume mixtures.
- Grasses alone generally have to be ensiled wetter to achieve required packing to exclude oxygen.
- A grass-legume mixture provides insurance from crop failure because if the legume dies out unexpectedly, the grass remains to provide some yield until the field can be scheduled for renovation again.
- Grasses tend to prevent legumes from lodging (laying over with no recovery after a hard rain or wind storm).
- Legumes grown with grasses reduce nitrate poisoning and grass tetany cases in livestock if the stand is 40 percent or more legume.

(2) Grass-legume mixtures

Hay-crop grass-legume mixtures should contain a legume and a grass that have similar maturity dates, are compatible in height, and adapted to the hay cutting regime of the operator. This generally goes beyond just getting compatible species together. It also requires getting varieties together that are most compatible in maturity timing and cutting interval tolerance. As mentioned before under pasture plantings, common varieties of many grasses have differing maturity dates to the legume standard, alfalfa. Some mature before the alfalfa is ready and others mature much too late for quality alfalfa hay or ensilage. Grass varieties must be selected that mature at the same time the alfalfa is entering the harvest stage of maturity that the producer likes.

The decision to renovate pure legume stands or grass-legume stands hinges on the number of legume plants left per square foot. Most legumes need only 6 to 8 plants per square foot in established stands to produce maximum yields. Alfalfa stands with less than 3 plants or 25 stems per square foot, whether or notgrass is present, are in need of renovation. Alfalfa forage yield at this point is unacceptable if it is really being counted on for its quality and production. Other crowned legumes at 4 plants per square foot produces only about 50 to 60 percent of their potential yield.

(3) Herbicide use

Hay-crop forages should not be planted immediately after other crops treated with herbicides that have carryover residual effectiveness from one crop to the next. The triazine herbicides called atrazine, metribuzin, and simazine, chloroacetamides called acetochlor and dimethenamide, imidazonlinones named imazethapyr and imazaquin, clomazone, and tank mixes or premixes containing these herbicides should not be used the year before a hay-crop planting. Reduced rates of any single chemical the year before seeding may lessen injury, but crop damage may still occur depending on soil type and rainfall amounts received between last herbicide application and hay-crop planting. A reduced rate may avoid a stand failure, but stand vigor may be unacceptably low.

If an application of lime is needed to reduce soil acidity before seeding a hay-crop, an application at least a year in advance releases any applied triazines bound to soil particles. If done just before cool-season hay-crop seedings, the triazines released may be enough to cause an establishment failure. If the soil was that acid, the liming would have actually made the triazine weed control more effective for the row crop treated. Sulfonylurea herbicides have a shorter carryover effect, but can go into the next crop year. The time interval between last application of them and hay-crop seeding must be separated sufficiently. Crop restriction periods range from 9 to 16 months for alfalfa and clovers. A summer hay-crop planting of alfalfa or clover is safer than a spring planting if sulfonylurea herbicides were used the year before. Flumetsulam has a long cropping restriction on it for clovers, 26 months and still needs to be bioassayed to see if activity is still there. It has only a 4-month restriction on it for alfalfa.

The management message is to be extremely careful in crop rotations not to apply herbicides to a previous crop that may do crop damage to the next one in the rotation. New herbicides are registered each year and others are taken off the market. Labels are subject to change and may become more restrictive. Some herbicides are registered for use in some states and not others. All herbicide users should carefully read herbicide labels and proceed with treatment only after they are sure they understand the environmental consequences of their actions. The information in the preceeding two paragraphs should not be considered a definitive source at the state level. These paragraphs were done in some detail to point out the complexity of the management issue involved.

(4) Seeding failures

Seeding failures can also occur from natural chemicals called allelopathic compounds. Sometimes considered a defense mechanism to protect the plants already growing on the site, allelopathic compounds are chemical substances that inhibit the growth of seedlings of the same species or competing species. These chemical substances are either secreted or leached from plants or are toxic degradation products from old crop residue. If the allelopathic compound interferes with the germination and development of seedlings of the same species, the effect is called autotoxicity. This latter effect has been attributed to alfalfa and clover seeding failures when new seedings are planted immediately after a preceding crop or into a thin stand of the same genera.

Autotoxicity has a name in the case of clover. It is called either clover-sick soil or clover sickness. In this case some researchers isolated some phenolic compounds that were degradation products of isoflavonoids contained in the clover herbage that inhibited germination of red, white, and alsike clover seeds. They also inhibited red clover seedling growth. Presently, it is not recommended to reseed by complete renovation or overseed alfalfa into old, thin stands of itself because of the strong evidence that it is autotoxic. If the thin stand is less than 1 year old, a no-till alfalfa seeding into the existing stand is unaffected by autotoxicity. To avoid autotoxicity problems on older stands, kill all old plants at least 6 months before the next seeding. Generally, this allows for enough decomposition and leaching of toxic compounds to dilute their effect on the new seedlings. A surer autotoxicity avoidance measure is to totally eradicate the old alfalfa and rotate to another crop for at least one year before reseeding back to alfalfa.

Tall fescue, orchardgrass, redtop, quackgrass, ryegrass, timothy, Johnsongrass, bermudagrass, bahiagrass, pangolagrass, rhodesgrass, and Dallisgrass have all been implicated in being allelopathic to various legumes and grasses seeded into them. Ball clover was most affected by the warm-season grasses followed by arrowleaf and white clovers. Crimson clover was unaffected. Tall fescue is variable in its allelopathic effect on legumes. It appears that specific genotypes are allelopathic while others are not. Birdsfoot trefoil, rape, and medium red clover germination and growth have been retarded by some tall fescue genotypes. Even large crabgrass growth was excluded in some tall fescue stands. Quackgrass toxicity has been studied extensively, but evidence is inconclusive on its being allelopathic. It may be more related to its aggressive rooting and dense canopy nature. For legume hay-crop plantings, grass eradication before seeding is best. A crop rotation than includes a year or more of crop production that uses clean tillage, herbicide treatments, or both, to kill old sods of these grasses is desirable.

Seed quality is important whether it be a pasture or hay-crop planting. Certified seed should be used whenever possible to guarantee the variety of choice is actually what is in the bag and the quality of the seeds contained in the bag. Seed tags should show species name, varietal name and/or number, lot number, the germination percentage of the forage species stated on the tag, germination date, the percentage of pure seed, the percentage of other crop seed, the percentage of weed seed, the percentage of inert material (chaff, seed coatings, soil), the percentage of noxious weed seeds, the percentage of hard seed (species dependent), total germination and hard seed, origin of the seed, and weight of the bag.

Seeding methods, depths, and rates; seed treatments; and pest management covered under the pasture management section equally apply here. Please refer to pasture planting for those management items. One notable exception is a pest management concern on alfalfa planted into sods or heavy residue. Most alfalfa seedings are done on hay-crop land, so it is covered here. Slugs can be a serious problem on spring or summer no-till alfalfa seedings in sods, heavy crop residue, or heavily manured fields. Some tillage to reduce the ground cover may be necessary to destroy the slug's habitat. Presently, there are no molluscides labeled for use on forage crops used for forage, only their seed crops. Slug damage can occur on several other forage species where cool, moist, trashy soil conditions prevail.

(5) Evaluation of forage seeding

Evaluation of the successfulness of a forage seeding establishment should occur about 5 months after the seeding or at first harvest, whichever comes first. Sometimes this can be just a visual scan across the field and deciding the stand is uniform, thick, and lush. In situations where weather conditions or other stress factors have created a questionable stand in terms of numbers and vigor, an assessment of whether to reseed or overseed or plant to another crop is needed. Stand counts based on the number of plants per square foot are taken randomly across the field. Guidelines for some common forage legumes and grasses are given in the table 5–7. These values should be viewed as guidelines only for pure stands during the establishment period.

The ultimate decision to destroy the stand and replace it with a new seeding or another crop ultimately rests with the producer. The numbers are high to suppress weed growth and optimize first year forage yield. Since perennial plants do little tillering the first year, they must be thick in numbers to form a closed canopy. The numbers can be considerably lower for perennials (6 to 8 plants) in later years and still produce maximum yields. Over time they will thin out as weaker individuals are crowded out by the more vigorous ones. Perennial plant numbers are virtually meaningless after the establishment year. Stem counts are more valid in rating stand density. Sod formers and stoloniferous plants lose their identity as individual plants. Crowned plants, if healthy, produce more stems as plant numbers decline.

If the numbers observed in the field during the establishment period are somewhat lower than those given in table 5–7, remedial measures can be taken to make the best of the situation. Weeds should be suppressed with herbicides if they threaten to overtop the forage crop. A more lenient forage harvest management can put less strain on surviving forage plants. This might include higher stubble heights, less frequent cuttings, and more advanced maturity stages for the legumes. This will build food reserves and keep canopy closed for longer periods to suppress weed competition. Some additional fertility may also be in order if leaf color and tissue analysis indicate less than optimum nutrient levels. On irrigated land, close monitoring of soil moisture can help to avoid any water stress that would harm development.

Hay-crop plantings may be clear seeded or planted with a companion crop, such as spring oats or barley. If a companion crop is seeded with the hay-crop, it must be sown at no more than 75 percent of its normal seeded alone rate. This reduces competition for water, allows for more light penetration to the lower canopy of forage seedlings, and decreases to some extent its likelihood of lodging under wet conditions. Ideally, the companion crop should be removed early as an ensilage crop. If it is allowed to mature for grain, the straw windrows left by the combine should be baled as soon as possible. Windrows left in place for prolonged periods smother the hay-crop seedlings lying beneath them.

Table 5–7 Minimum number of plants per square foot to achieve a full stand 1/ 2/

Species	Minimum number/ft^2
Alfalfa	20 3/
Alsike clover	15
Birdsfoot trefoil	15
Cicer milkvetch	7
Crimson clover	20
Crownvetch	7
Kura clover	15
Red clover	15
Sainfoin	7
Sweet clover	7
White (Ladino) clover	10
Orchardgrass	50
Reed canarygrass	50
Ryegrass	60
Smooth bromegrass	15
Tall fescue	50
Timothy	30

1/ Sources: Cornell Field Crops and Soils Handbook, 1987; Hanson, A.A., et al. Alfalfa and Alfalfa Improvement, 1988; Knight, W.E., The Effect of Thickness of Stand on Distribution of Yield and Seed Production of Crimson Clover, 1959; Piper, C.V., Forage Plants and Their Culture, 1941; Sheaffer, C.C., Forage Legumes, 1993; Sprague, M.A., Seedling Management of Grass-Legume Associations in the Northeast, 1963.
2/ For pure hay-crop stands of the species named at 5 months from planting date or first harvest, whichever comes first. Rainfed areas receiving at least 16 inches of rainfall during the growing season or irrigated lands.
3/ Alfalfa is an average value going from an arid (14 plants) to humid (26 plants) climate.

(d) Accelerating practice—Irrigation water management

This practice is used primarily in rainfall limited areas to produce high quality hay-crop forages for livestock. Eighty-one percent of all irrigated acreage occurs in the 17 contiguous Western States. Much of the acreage devoted to hay-crops is sown to alfalfa. General guidelines are given here only because of the regional differences in evapotranspiration, soils, effective rooting depth, species and cultivars used, and irrigation methods used that affect water usage. Other field specific environmental factors that influence water usage are age and vigor of the forage being irrigated and soil nutrient status.

The primary methods of irrigation are gravity and sprinkler. Under these two general methods are specific types of irrigation used for pasture or hay-crop land. Gravity irrigation types used for pasture or hay-crop land are border-strip, corrugation, flood, and wild-flooding. They benefit from land that has been leveled first. With wild-flooding, however, this is less likely because the terrain is generally too uneven to be leveled.

Sprinkler irrigation types used for pasture or hay-crop land are center pivot, portable, solid set, and traveling gun. A less common method of irrigation is called subirrigation. It requires nearly level land and a shallow water table that can be elevated and lowered with a water control structure at the ditch or tile main outlet that drains the field being subirrigated.

(1) Soil water criteria

Soil water criteria are used to determine irrigation scheduling where applicable rather than plant based criteria. By the time visual symptoms appear, yield reductions will frequently occur. Two soil water criteria are used. One is based on available water, and the other on extractable water.

(i) Available water criteria—Available water in the effective root zone is the amount of water released by the soil when the equilibrium soil water matrix potential is decreased from field capacity (0 bar) to permanent wilting (-15 bar). This is the portion of water in a soil that can be absorbed by plant roots. Using this criterion, available water is allowed to be drawn down by the crop, typically 40 to 65 percent, before irrigation commences.

(ii) Extractable water criteria—Extractable water is a lesser quantity of water than available water. It is the difference between the amount of water held by the soil at field capacity and the water remaining in the effective root zone when severe wilting of the crop occurs. In this case, however, a greater depletion percentage is allowed before irrigation commences, typically 65 to 75 percent.

The goal of either method is to prevent a decrease in plant transpiration. With a decrease in transpiration rate, there is a corresponding decrease in yield. A decrease in transpiration means the plant is undergoing water stress. Water stress decreases stem numbers and diameter, internode number and length, and leaf size. Moderate water stress lowers alfalfa yields, but produces a leafier product. Under severe water stress, however, lower leaves drop off, resulting in a stemmy, low yield cutting of alfalfa.

When soil water depletion is used as an irrigation criterion, water depletion is monitored most often in the upper 3 feet of soil rather than from the full effective root zone. However, there are instances when monitoring the lower part of root zone is of value. It provides information on potential storage of excessive rainfall that might occur after an irrigation event. This can often happen in humid and subhumid areas. This allows the storage of rain that might otherwise be lost to deep percolation if the entire root zone was at field capacity. It is also important for the control of soluble salt leaching in saline or sodic soils.

Soil water depletion can be monitored directly, indirectly, or based on evaporation pan or climatonomic models that estimate maximum daily water use or evapotranspiration (ET). Direct measurements are not used by producers because of their expense and operating difficulties. Indirect measuring devices are calibrated soil tensiometers, neutron meters, or time domain reflectometry. The procedure involving ET estimates either from pans or the Penman, Priestley-Taylor, Jensen-Haise, and Makkink formulas calibrated for the particular crop and climate situation is most often used. Crop coefficients are developed during various crop growth stages throughout the year.

Once ET estimates have been developed, irrigation can be scheduled using a water budget. This budget sums soil water depletion using one of the climatonomic estimators and deducts water inputs from precipitation or irrigation. This provides a net soil water status. This simplistic procedure can have cumulative errors introduced from erroneous ET estimates or water input assumptions. It should be verified with tensiometers or other soil water measuring devices to avoid over or under applying irrigation water.

Excessive moisture supplied by irrigation or rainfall is detrimental to alfalfa root and shoot growth and to stand persistence. In the desert irrigated regions, alfalfa can be scalded by nearly saturated, high temperature soils. These plants most often die within 3 to 4 days. Over-irrigating alfalfa immediately after cutting when little regrowth has occurred leads to severe plant stress and stand thinning. The roots are deprived of oxygen, and toxic concentrations of ethanol and other substances build up in them. Leaf loss starting at the base of the plant and death of xylem tissue results. Since growth of phytophthora root rot fungi is favored by wet soils, this infection can be a secondary cause of stand loss. In more northern or higher elevation irrigated areas, excess soil moisture during the latter part of the growing season can decrease freezing tolerance of alfalfa plants and lower winter survival.

It takes from 1 to 1.5 acre-inches of water to produce a ton of alfalfa hay per acre. Maximum daily water use or ET of alfalfa is typically 0.2 to 0.5 inch. Daily ET rates vary based on global radiation, plant growth stage, air temperature, and day length. The highest ET rates occur during full plant canopy on hot, long, windy days with low humidity. Seasonal alfalfa ET rates range from 14 inches in the Northeast or Pacific Northwest to 74 inches in the arid Southwest. Table 5–8 gives the typical seasonal ET values for alfalfa by regions in the Western United States. For a comparison with other forage crops, see table 5–9, Seasonal consumptive-use requirements of some forage crops.

Irrigating a field's soil-to-field capacity before seedbed preparation enhances germination and emergence. This avoids applying water to planted seedbeds on soils prone to washing and crusting. Irrigation should commence after emergence to increase root penetration and growth. Seedling roots are suppressed more than shoot growth by moisture stress.

Table 5–8 Total seasonal consumptive use of water by alfalfa in Western United States (from Hughes, H.A., Conservation Farming, 1980)

Location	Growing season (days)	Seasonal consumptive use (inches)
Southern coastal	300+	36
	250 – 300	30
South Pacific, coastal interior, and northern coastal	250 – 300	37
	210 – 250	32
	180 – 210	26
	150 – 180	22
Central valley, California, and valleys east side of Cascade Mountains	250 – 300	40
	210 – 250	34
	180 – 210	30
	150 – 180	26
	120 – 150	20
	90 – 120	14
Intermountain, desert, and western high plains	250 – 300	52
	210 – 250	44
	180 – 210	36
	150 – 180	30
	120 – 150	24
	90 – 120	19

Table 5–9 Seasonal consumptive-use requirements of some forage crops (from Hanson, A.A., Practical Handbook of Agricultural Science, 1990; Hughes, H.A., Conservation Farming, 1980)

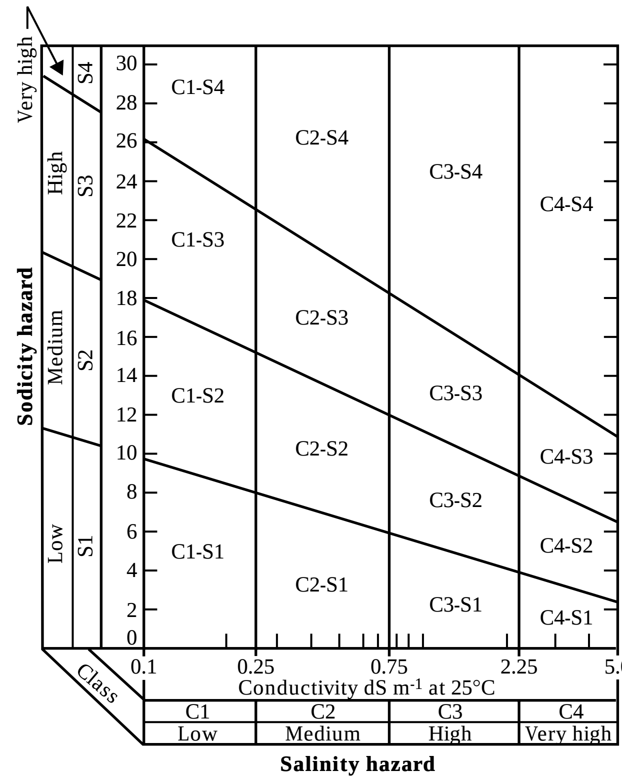
Crop	Fraction of alfalfa water requirement
Alfalfa	1.0
Bromegrass	1.16
Corn	0.65
Pasture	0.90 (variable)
Red clover	0.90

(2) Water quality requirements

Water quality requirements for irrigation water are important. Concentrations of boron, chloride, sodium, and salt must be monitored to prevent crop damage. Water is classed based on its content of boron, chloride, sodium, sulfate, and electrical conductivity. The classes for boron and chloride are rated starting with the purest water named excellent and followed with decreasing quality by good, permissible, doubtful, and unsuitable. Sensitivity to these contaminants varies with forage species. They are ranked as sensitive, semi-tolerant (medium tolerant), and tolerant. Table 5–10 gives classification of irrigation water based on boron and chloride content. Refer to table 3–6 in chapter 3 for salinity tolerance ratings of various forage crops.

Forage crops are rather tolerant of high boron concentrations in the soil. Some forages and their tolerance limits to boron are shown in table 5–11. Figure 5–45 graphically shows the USDA irrigation water classification based on water sodicity and conductivity. In sodic, nonsaline soils, Ca and Mg are often deficient for good plant growth. Sodic irrigation water may induce Ca and various micronutrient deficiencies in these soils. In sodic-saline soils, the salinity of the water becomes more important because of its osmotic effect on plant roots (burning). Sodic irrigation water can also reduce soil permeability and tilth because the sodium ion acts as a soil dispersant. It also causes the soil to crust badly as well, which impedes seedling emergence. A computerized and noncomputerized version of WATSUIT can be used to determine the suitability of irrigation water for a specific site and crop.

Figure 5–45 USDA classification of irrigation water* (from Wild 1988)



* The higher the total salt content of the irrigation water (as measured by its conductivity), the lower must be its sodium absorption ratio if the exchangeable sodium percentage of the soil is to remain below the level needed to produce adequate yields of the crop being raised.

Table 5–10 Classification of irrigation water based on boron and chloride content (from Hanson, A.A., Practical Handbook of Agricultural Science, 1990)

- - - Class of water - - -		- - Concentration (meq/L) - -		Hazard characterization
index	grade	boron	chloride	
1	Excellent	<0.5	<2.0	Generally safe for sensitive crops.
2	Good	0.5 – 1.0	2.0 – 4.0	Sensitive crops generally show slight to moderate injury.
3	Permissible	1.0 – 2.0	4.0 – 8.0	Semi-tolerant crops generally show slight to moderate injury.
4	Doubtful	2.0 – 4.0	>8.0	Slight to moderate injury for some tolerant crops.
5	Unsuitable	>4.0		Hazardous for nearly all crops.

Irrigated saline soils need to be leached on a timely basis to remain productive. Salts tend to build up in saline soils as plants extract water from the root zone and water is lost at the ground surface by evaporation between irrigation events. Evaporation and the quick drying of plant roots in the upper part of the soil enhance the potential for upward water movement. This upward water movement carries salts from deeper in the soil profile towards the surface, especially where a shallow saline water table exists. Salts must be removed by leaching to maintain the salt balance of the soil at an average salinity level compatible with the crop being raised. The fraction of total irrigation water needed to leach these salts through the root zone is called the leaching requirement (Lr). The fraction of total irrigation water that often percolates through the root zone as a result of irrigation inefficiencies is called the leaching fraction (L). Improved irrigation water management can reduce L to coincide with Lr. This can reduce downstream salinization because in concert with irrigation, drainage (open ditch or subsurface) must be provided to carry the leached salts away from the root zone. Drainage is also necessary in areas where the water table needs to be lowered to the proper depth to enable leaching and prevent upward flow of soil water into the root zone. Not only is less salt leached from the field, but less salt is applied when saline irrigation water is used because of the lower application rate. The required leaching can be achieved two ways. One way is to apply enough water at each irrigation to meet the Lr. The other is to schedule leaching irrigation that removes the salts accumulated by previous irrigations.

Table 5–11 Boron tolerance limits for some forage crops (from Stewart, B.A., and Nielsen, D.R., Irrigation of Agricultural Crops, 1990)

Forage crop	Threshold (ppm)
Sensitive	
Perennial peanut	0.75 – 1.0
Wheat	0.75 – 1.0
Moderately tolerant	
Barley	2.0 – 4.0
Bluegrass, Kentucky 1/	2.0 – 4.0
Corn	2.0 – 4.0
Oat	2.0 – 4.0
Clover, sweet 1/	2.0 – 4.0
Turnip	2.0 – 4.0
Tolerant	
Alfalfa 1/	4.0 – 6.0
Vetch, purple 1/	4.0 – 6.0
Very tolerant	
Sorghum	6.0 – 10.0

1/ Tolerance based on reductions in vegetative growth.

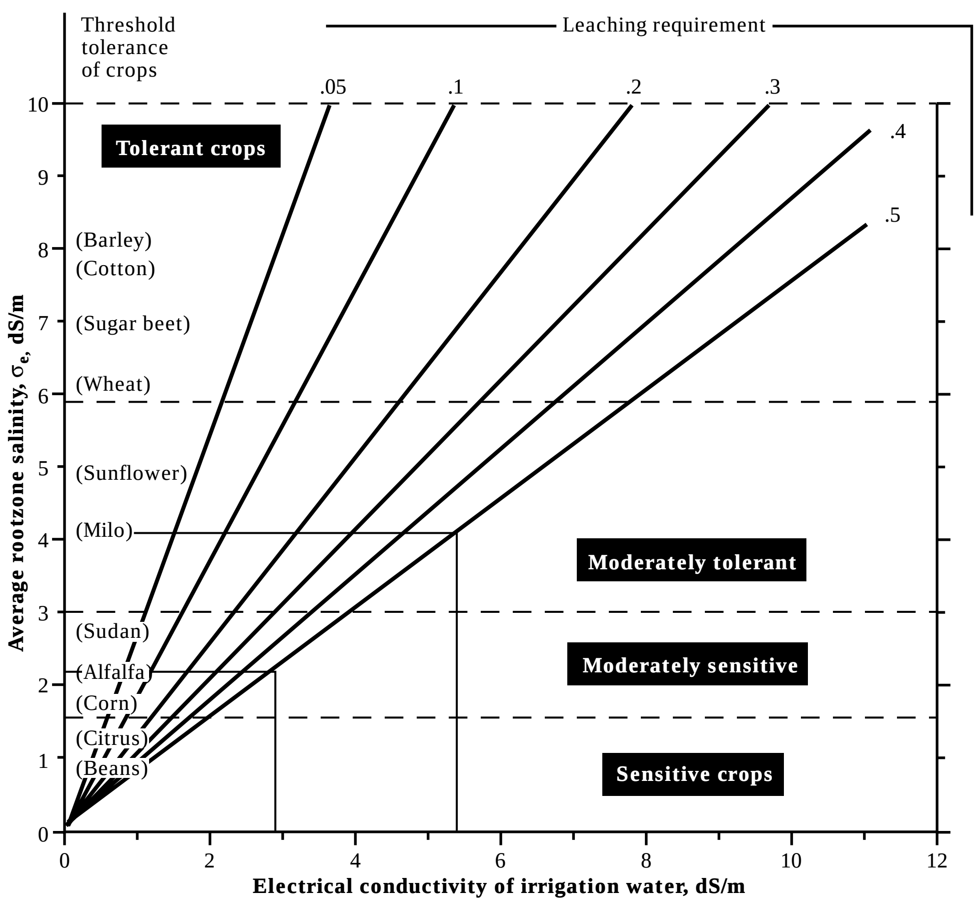
The salt balance or time-averaged root zone salinity is greater in soils that are irrigated less frequently than in soils that are irrigated more frequently, all other factors being the same. Saline soils benefit from more frequent irrigation to maintain them at a wetter condition than nonsaline soils. This keeps the soil salinity level lower. Figure 5–46 shows how the targeted average root zone salinity, based on the crop grown, is affected by the electrical conductivity of the irrigation water and the leaching fraction chosen. When the irrigation water salinity is higher than that required to achieve a no yield-loss threshold value for the preferred crop, some crop yield reduction occurs unless a more tolerant crop or a higher Lr is selected.

Sometimes excessive levels of salts in soils cannot be reduced through normal irrigation applications and crop management. Cropping is discontinued for a while and a deliberate effort to leach the salts and/or sodium is begun. In the case of sodic soils, soil amendments and leaching may both be required to reduce exchangeable sodium. When reclaiming saline soils, leaching requirements can be determined by measuring bulk soil electrical conductivity. This can be measured by soil electrode probes or electromagnetic induction instruments held by hand aboveground. The progress of salt removal is immediately measured by such devices. Boron is more difficult to leach. It takes about the twice the irrigation water to remove a given fraction of it as to remove soluble salts by continuous ponding. The act of irrigation itself tends to release more boron by hastening mineral weathering of the soil.

Irrigation water management that reduces salt uptake by forage crops prevents them from becoming too salty for animal consumption. Livestock fed high salt forage often get severe diarrhea and are dehydrated as a result. Often during reclamation forage crops are used to dry the soils some to improve salt removal efficiency. This prevents large pore bypass of water leachate that often occurs during saturated flow. These crops are best plowed under as a green manure crop. If harvested, they remove less than 5 percent of the soluble salts in the root zone. This is less than the amount normally applied back with the irrigation water. It also avoids livestock health problems while improving soil tilth. Organic matter returned to sodic soils improves soil aggregation a great deal.

Figure 5–46 is an example nomograph used to select the proper leaching fraction based on the average root zone salinity target required to grow the selected crop without yield loss and the electrical conductivity of the irrigation water available for use. Conventional irrigation commonly used for forage production allows the soil to dry between irrigations. Using the same leaching requirement fraction of 0.5, irrigation water must be much less saline (2.9 dS/m) to keep the average root zone salinity level in the soil at the proper level to grow alfalfa than it would (5.4 dS/m) to grow milo (grain sorghum). Both crops could receive irrigation water classified as C4, very high salinity hazard (from fig. 5–45) at this leaching requirement fraction. At a leaching requirement fraction of 0.3, alfalfa must receive irrigation water classified as C3 (0.75 to 2.25 dS/m) to keep the average root zone salinity at a level that would not lower alfalfa yields.

Figure 5–46 Assessing salinity hazards using conventional irriation (adapted from Stewart 1990)



(e) Accelerating practice—Soil amendment application

Soil amendments are organic and inorganic soil conditioners used to improve the chemical, physical, or both, condition of the soil. Although they may add some nutrients, their primary function is to improve soil tilth or decrease concentrations of growth inhibiting elements in the soil. However, the use of these amendments often makes soil borne plant nutrients more available or increases the soil's ability to store more applied nutrients. The most common agronomic organic soil amendments are manure, compost, green manures, and sewage sludge. Other organic amendments not included in the list just mentioned are more commonly or exclusively used for horticultural crops. The most common inorganic soil amendments are lime and gypsum. Soil acidifiers, such as sulfur, sulfuric acid, lime sulfur, ammonium thiosulfate, and ammonium polysulfide, may be used as well for agronomic crops. Other soil acidifers, such as aluminum sulfate, are generally used for horticultural crops requiring acidic soils for optimum production.

The inorganic soil amendments, lime and gypsum, basically flood the cation exchange capacity of the soil with calcium ions. Dolomitic limestone also provides magnesium ions. These ions displace exchangeable sodium ions in sodic soils and exchangeable hydroxyaluminum ions in acidic soils. Lime proceeds further to neutralize the hydrogen ions released while the hydroxyaluminum ions are being reduced to unexchangeable aluminum hydroxide. This is the exchangeable hydrogen referred to in older explanations of soil neutralization with lime. Lime also neutralizes soil acidity caused by weak organic acids and ammoniacal and urea nitrogen fertilizers.

Soil acidifiers acidify soils that either are alkaline or not acid enough for the best production of the desired crop. Soil acidifers benefit forage crop production on calcareous soils by lowering the soil pH to levels where iron, phosphorus, zinc, and manganese solubility are increased enough to not limit production. On calcareous sodic soils that have native supplies of calcium (Ca), soil acidifiers cause enough calcium to become exchangeable to drive sodium (Na) off the exchange sites as well.

Irrigation water itself is a soil amendment when it is used to leach salts and sodium from the root zone. It can be used alone on saline-sodic soils with soluble Ca in the A soil horizon. It can also be the lone amendment if deep plowing or chiseling brings up Ca carbonate or sulfate (native gypsum) from the B and C horizons of a sodic B horizon soil.

Sodic soils have poor soil tilth because Na is a soil dispersant. The soils when wet become puddled (no aggregation) having little pore space. They compact readily and form hard surface crusts. which greatly reduces their suitability as a plant growth medium. The addition of Ca to the soil acts as a soil flocculant. This causes clay sized particles to stick together to form aggregates. This increases soil permeability and aids the movement of water (irrigation or rainfall) through the soil profile to the depth Ca is incorporated or released. This flushes the exchangeable Na down-ensures that there are fine particles to quickly increase soil permeability and large particles to sustain a continuous release of Ca over time to keep exchangeable Na percentage low in the root zone. To be most effective, lime should contain a mix of fine and larger particle sizes: Fine ones to quickly raise the soil pH, and coarse ones to have some residual value. Many states regulate the fineness of agricultural limestone. Generally, lime particles greater than 20 mesh are of little value in increasing soil pH while particles passing through a 60 mesh sieve are highly effective.

The other important factor with lime is its calcium carbonate equivalent (CCE) rating. To meet the actual rate at which the soil test recommendation specifies, the CCE percentage of the lime material being applied must be known so that it is applied at the proper rate. For instance, a soil test recommended 2 tons of lime per acre to adjust the soil pH and the lime used had only a CCE of 80 percent. Then, 2.5 tons or 5,000 pounds of that lime would be needed per acre.

Organic soil amendments are applied to increase soil organic matter. This improves soil tilth by increasing the number of water stable soil aggregates. It also improves the cation exchange capacity of the soil and creates a sink that holds nitrogen, phosphorus, and sulfur within the root zone as organic forms. As this organic matter slowly decomposes, these organic forms of plant nutrients are released for plant uptake. On sodic soils, organic matter incorporation improves soil permeability and enhances the effect of applied inorganic amendments, such as gypsum.

Many forage crops serve as green manure crops. Rather than being harvested for their feed value, they are allowed to return to the soil unharvested to increase soil organic matter. This is done to benefit production of other crops following in the crop rotation. Allowing green manure crops to fully mature is more effective in building soil organic matter than terminating them at an early vegetative growth stage. The mature growth stage has more lignified material in it and is more resistant to decomposition.

Manure and sewage sludge are the most commonly applied organic soil amendments to forage crops. Care must be taken not to smother the forages with heavy applications of these soil amendments. Excessive rates of application may also cause salt burn as well.

Both amendments should be applied at spring green-up or immediately after a harvest. This reduces the likelihood of contaminating harvested forage and renders it unfit for livestock feeding. Sewage sludges should be tested for their heavy metal concentrations. Applications of sewage sludge should be terminated once EPA or state regulated maximum soil loading rates are approached. Soil tests for regulated heavy metals should be done each year sludge is to be applied. Both of these amendments are stable organic matter sources. Soils amended with these products for several years drop in organic matter content very slowly once applications cease.

(f) Accelerating practice—Weed control

Weeds are herbaceous plants growing in places where they are not wanted and interferring with the growth of the desired crop. They sometimes reduce its harvested quality if allowed to remain. Weeds appear anywhere ground disturbance has taken place. They are pioneer species in plant ecological succession. They invade sites where competing vegetation has been destroyed. It is not a matter of: Will they show up? It is a matter of: What will show up? Every time forage crops are established, weeds will be present to compete with them unless control measures are applied. Forage crop stands that have declined will also be invaded by weeds as they thin out.

Weeds are broadly classified as grasses (includes grass-likes) and broadleaves. This is important when choosing among selective herbicides. Some selective herbicides are excellent in controlling grassy weeds, but are ineffective in controlling broadleaves. Others provide excellent control of broadleaves, but are mostly ineffective in controlling grassy weeds. Other herbicides may have broad spectrum control of several grassy and broadleaf weeds. Others are nonselective and kill every actively growing plant. Herbicide selection should be based on those labeled for use on the following:

- Forage crop being raised
- Intended end use of the crop (pasture or stored forage)
- Anticipated weed type most likely to compete with the forage crop

Weed control is not so much a single practice, but a technology area. Some of the other accelerating practices already described help control weeds. Nutrient management, liming, clipping, irrigation water management, prescribed grazing, forage harvest management, and pasture and hay planting all have an impact on forage stand health that can keep weeds suppressed. Anything that gets a forage stand off to a vigorous start and maintains a full canopy keeps weeds under control. The proper application of these conservation practices reduces the need and reliance on chemical weed control in close sown forage crops. It will not eliminate entirely the need for chemical weed control. Drought, insect and disease outbreaks, winter injury, human error, and other extreme environmental factors can often override the best efforts in management. These stresses can thin or wipe out forage stands and give rise to a weed invasion.

Another classification of weeds distinguishes between noxious and non-noxious weeds. Noxious weeds are those specified by Federal or State law as being especially undesirable, troublesome, and difficult to control. Examples would be Canada thistle, quackgrass, leafy spurge, horsenettle, Johnsongrass, and several bindweeds and mustards. Each state that has a noxious weed law should have a noxious weed list in the NRCS field office technical guide. These weeds should have picture identification and key distinguishing characteristics described for them. When giving onsite planning and application assistance to landowners, the presence of noxious weeds should be brought to their attention. Control measure options should be discussed and documented in any conservation plans prepared for the land unit.

Besides chemical weed control, biological controls are sometimes appropriate for a targeted weed species. This type of weed control is generally not available to the individual landowner. Federal laws prohibit the indiscriminate entry of exotic insects and diseases that might be hosted by a particular weed in its native habitat. Biological controls are extensively studied by governmental research agencies first and generally applied by governmental agencies. Great care must be taken not to introduce another pest that might get out of control. Biological weed control should not be considered a benign alternative to pesticides. Once a biological control is introduced to a new habitat, it cannot be easily gotten rid of if negative impacts arise.

The use of cultivating tools in controlling weeds in forage crop production is primarily limited to those that can be row cropped, such as corn or sorghum silage. Spike toothed harrows, however, can be used on established legume stands to kill annual weed seedlings without seriously hurting the legume crowns. Primary tillage tools do control weeds to some extent during seedbed preparation for both close sown and row crop forages. They kill existing weeds and newly germinated seedlings. Tillage tools may also dilute weed seed counts if the previous crop was weedy. They do this by mixing or inverting heavily seeded surface soil with soil lower in the tilled zone that has a lower seed count. Deep burial tends to prevent small seeded weeds from germinating. Large seeded weeds, however, may be little affected. If buried below the effective depth of herbicide treatment, large seeded weeds, such as giant ragweed, may escape herbicide control. Row cultivation can be used on forage row crops with over the row banded herbicides. The cultivator keeps weeds under control between the rows while the herbicide checks weed growth in the row. This cuts down on the amount of herbicide needed for control of weeds over the entire field.

Herbicide control of weeds can be done at various times. The five times when herbicides can be applied to forages are: preplant or preplant-incorporated, preemergence, postemergence, dormant, and between cuttings.

Preplant-incorporated (PPI) applications are done before planting the crop when conventional tillage equipment is used to prepare the seedbed. PPI herbicides should be mixed into the first inch of soil. Preplant herbicides are used to kill weeds and existing forages for no-till seedings.

Preemergence herbicides are sprayed on the soil surface after planting, but before seedling emergence. These herbicides are used on row crop forages, but not on close sown ones.

Postemergence herbicides are used widely on forages to suppress weed competition during establishment. They can be applied to legumes at rather early growth stages. On hay-crop grasses, postemergence applications must be delayed until the grass is at least 4 to 5 inches tall; at least 6 months for Ally.

Dormant sprays are put on when the forages are dormant, but weeds are actively growing. These herbicides are nonselective and will kill the forages if enough green leaf is available for herbicide uptake.

Spray applications between cuttings work similarly to dormant sprays. Timing is essential and must be done before significant forage regrowth occurs.

Whenever herbicides are used, crop use, field re-entry, harvest, and grazing restrictions must be adhered to strictly to prevent contamination of people, food supply, and livestock. Mixing areas should be sited and constructed to prevent surface or ground water contamination. Operators should wear appropriate protective gear when mixing or applying chemicals and afforded washing facilities at the mixing and application site to decontaminate themselves or the protective gear in case of exposure. Spray operations should be conducted when wind velocities are low to prevent drift. They should not occur within a few hours of predicted heavy rainfall that could cause washoff and herbicide entry into watercourses. Sprayer tanks should be rinsed, and the rinse water applied to the field just treated. All chemical containers should be triple rinsed, and the rinse water placed in the sprayer and used on the target field. Dispose of containers as directed on label. Strict adherence to all of this prevents contamination, illness, or death of people, nontarget plants, or livestock and wildlife by needless exposure to these poisons. Always follow the product label and local and state pesticide regulations.

To prevent herbicide resistance from developing in weeds, alternate chemicals with different modes of action in disrupting weed growth from one crop season to the next. Herbicide modes of action to kill weeds are cell membrane disrupter, fatty-acid inhibitor, growth regulator, photosynthesis inhibitor, pigment inhibitor, protein biosynthesis inhibitor, and seedling growth inhibitor. Also, the potential user can minimize need for herbicides by using the other control methods mentioned.

Spray equipment should be under a preventative maintenance schedule to prevent drift, irregular spray delivery, and possible spill of herbicide. Each spray nozzle should be calibrated for correct delivery of spray. Any nozzle not delivering the proper rate should be replaced. Correct nozzle type selection for the application requirements is necessary.

(g) Accelerating practice—Disease and herbivory control

In actuality this is a dual technology area; it is being described under one title because the same principles apply to both. Chemical control, cultural control using practices already mentioned, resistance breeding, and biological control can keep diseases, insects, mites, nematodes, uninvited vertebrate herbivores, and mollusks from reducing forage production and quality and shortening stand life.

Many organisms are covered under this dual technology area. They are diseases or pathogens that include viruses, bacteria, fungi, and nematodes; arthropods that include insects and mites; mollusks that include slugs and snails; and vertebrate herbivores that include some birds and mammals, such as rodents, rabbits, and wild ruminants.

Resistance breeding has effectively reduced the severity of disease outbreaks, nematode feeding, and insect attacks on forage crops. Thus planting varieties of forages resistant to locally important diseases, nematodes, and insects is a viable cultural method to reduce the incidence of stand or yield loss.

Other cultural controls include conservation crop rotations that break up life cycles of disease and insect pests, nutrient management, forage harvest management, irrigation water management, prescribed grazing, and control of weeds that act as alternate hosts for other forage pests. Nutrient management produces forages that are more resilient to attack by disease and insects. Forage harvest management may include early harvest to halt the spread of disease inoculum or take away the food source of the unwelcome herbivores. It also includes cleaning harvesting equipment between harvests, mowing younger forage stands before older ones, maintaining a cutting schedule that keeps food reserves high for rapid recovery, and mowing after dew, rain, or irrigation water has dried on plants to prevent disease spread or outbreaks. Irrigation water management can keep soils from being over-saturated to prevent outbreaks of soil borne diseases that thrive under waterlogged soil conditions. When a new forage seeding is being planned, select forage species that are adapted to the soil and climatic conditions at the site. This reduces the risk of a disease outbreak that are favored under less favorable conditions. An example would be phytophthora root rot in alfalfa on restricted drainage soils. The timing of a forage planting can reduce slug damage. Depending on the climate, this can be either early spring plantings where adults do not overwinter or late summer plantings in warmer, drier areas when slug numbers and movement are suppressed. Residue management can also reduce slug numbers. All or a portion of the residue harboring slugs can be destroyed before planting to reduce their numbers. Exclusionary fencing, hunting, and trapping can control vertebrate herbivores to various degrees.

Biological controls have had some good success on the control of insects and other herbivores. Parasitic wasps and *Bacillus thuringensis* (Bt) are two examples. Bt has been a spray insecticide product for some time. Now the Bt gene is being spliced onto corn genetic material to control corn borer through plant breeding. The corn plant produces its own insecticide. Parasitic wasps are being used to control alfalfa weevil. Where deer predation on corn silage seedlings is high, planting forage sorghum is alternative. It is not palatable to deer. Insect pheromones are used to aid in the detection, monitor the density of, and sometimes to disrupt the mating of insects. Pheromones are chemical attractants released by female insects to attract a male. Pheromone traps are used to check insect populations. Point sources of pheromones placed about a field confuse male insects and keep them from finding female mates. This is effective only when the larvae produced by this mating cause the economic damage to the forage crop. However, this control method is expensive and not always effective, especially if it attracts more females to the field.

Chemical controls should be applied only if none of the other approaches have proven effective or timely. As with herbicides, care must be taken not to contaminate or poison nontarget species or areas with bactericides, fumigants, fungicides, insecticides, miticides, nematicides, and rodenticides. Crop use, field re-entry, harvest, and grazing restrictions must be adhered to strictly to prevent contamination of people, food supply, and livestock. Mixing areas should be sited and constructed to prevent surface or ground water contamination. Operators should wear appropriate protective gear when mixing or applying chemicals and afforded washing facilities at the mixing and application site to decontaminate themselves or the protective gear in case of exposure. The appropriateness of the protective gear is based on the toxicity of the chemical and its formulation. Follow label instructions. Formulation types are emulsifiable concentrate, solution, flowable, wettable powder, dry flowable, soluble powder, invert emulsion, dust, granule, pellet, microencapsulate, and water-soluble packet. Formulation selection is also influenced by the forage crop being protected, its proximity to water sources, human habitation, and other sensitive areas, the available application machinery suitableness to deliver it properly, and cost considerations. Spray operations should be conducted when wind velocities are low to prevent drift. They should not occur within a few hours of predicted heavy rainfall that could cause washoff and pesticide entry into watercourses. Sprayer tanks should be rinsed, and the rinse water applied to the field just treated. All chemical containers should be triple rinsed, and the rinse water placed in the sprayer and used on target field. Dispose of containers as directed on label. This prevents contamination, illness, or death of people, non-target plants and animals, or livestock by needless exposure to these poisons.

To prevent pests from developing resistance to chemical control, rotate chemicals with different modes of action. Fungicide combinations are also effective in keeping resistance from building up in the fungi being treated. The use of other control methods before resorting to chemicals also extends the useful life of chemicals.

The combination of different control methods is called integrated pest management (IPM). It attempts to find the most effective, lowest cost, and least environmentally hazardous combination of pest control methods. Key principles for IPM in forage pest management are:

- Avoid killing off beneficial species when trying to suppress a pest.
- Take advantage of natural suppression through crop management practices that favor the forage crop's health, encourages natural predators, or both.
- An ounce of preventive control is worth a pound of responsive control.
- If preventative cultural measures fail, resort to a responsive control only when the pest density reaches the economic threshold warranting the expense of the control measure.
- Pests are likely to overcome plant resistance and pesticide control measures with time through natural selection and evolution.

Components of an effective forage crop IPM program are the following:

- Recognize that most noncrop organisms in a forage crop field help maintain a favorable crop environment and should not be sacrificed to kill off the target pest.
- Correctly identify the offending pest. This has two aspects. Make sure you have the real offender and not just a symptom of underlying deeper problem. Then make sure to correctly identify the organism so that the treatment selected is effective in its control.
- Know at what stage of the pest's life cycle or what time of the year the pest will do the most damage to the forage crop.
- Use preventative measures whenever possible by anticipating which pests are most likely to be a problem. This will avoid a pest build-up in the first place.
- Scout for pests regularly to detect their presence and build-up. Early detection can result in projections on when pest damage will peak and indicate an effective, least cost treatment option.
- Evaluate past performance of pest control strategies to see if more viable control alternatives are needed. Field records are essential to this component. Timing of control measures can be evaluated with good records. The control measure itself may not be the problem, but the time or care at which it was applied is.
- Monitor new product development to employ new viable control options as they come on-line.

(h) Facilitating practice—Conservation crop rotation

This practice is mentioned last because it is greatly influenced by all the other practices mentioned previously along with the land unit's animal forage and feed requirements, resource base, and its position in a watershed. Refer back to figure 5–39. As much as is economically feasible, a conservation crop rotation plan for the land unit should strive to meet the livestock forage and feed requirements being raised there. This is a decision that only the land unit manager can make. It should be based on an economic analysis of the land unit's costs of production versus purchasing forage and concentrates from off-farm sources. The more diversified the crops are, the more farm machinery and feeding equipment generally are needed.

Because many livestock-rearing operations are sited on marginally productive lands, there may be environmental as well as good economic reasons to purchase feed or forage. Row crop forage and feed grain production may cause undue soil loss or water quality problems downstream. Even with the best conservation plan that corrects the environmental problems, it still may not be economically practical to raise only a few acres of a crop that requires a different set of machinery and storage facilities.

Conservation crop rotation is a facilitating practice on livestock-rearing operations in that it attempts to satisfy livestock forage and feed requirements for the production year. This is especially true where livestock do not have access to a dependable year-long source of grazable forage. It is also true on livestock farms or ranches where complementary pastures on cropland improve weight gain over that obtained by native rangeland or permanent pasture. This is not to say that the crop rotation plan for the farm should not dictate at least to some extent the number of livestock being raised on the land unit. However, the conservation planner must be cognizant of two things:

- The land unit manager or the financial advisor have probably established a herd size that meets a financial objective based on expected output and commodity price.
- Most land units have not reached their full productive potential so there is room for forage and feed production improvement. There are exceptions to this generalization. However, those exceptions need only limited assistance from NRCS.

Conservation crop rotation also facilitates the establishment of a more diverse set of crops, forages, or others. Generally, this is done on livestock farms and ranches to improve yields or feed quality, or both, where grazing land resources are limiting livestock output goals.

The design of a conservation crop rotation plan for the livestock-rearing land unit having cropland along with pastureland or hayland, or both, uses must serve many purposes. (Pasture referred to here includes all land uses grazed by livestock.)

(1) Livestock forage and feed

The crop rotation should strive to produce its portion of the livestock forage and feed requirements to be met by home grown crop production. This is established by the land unit manager. This decision can be influenced by pointing out alternative off-farm feed sources or livestock ration substitute feedstuffs. Perhaps increasing time on pasture by using grazable crop residue, forage aftermath, or supplementary cropland pasture and reducing stored feed and forage production are options to explore.

The rotation should meet the forage and feed requirement expected from it each production year. This means coordinating different crop rotations based on different fields' capability to produce crops without degrading the soil, water, and air resources associated with the land unit. Ideally, production targets for each crop are met each production year. This is done by scheduling the different rotations around the different fields to yield a similar amount of acres producing each crop every year. These are based on long-term average per acre yield projections times the average acreage each crop occupies on all the cropland through the longest rotation cycle.

Example 5–3 shows a crop rotation worksheet. It was idealized to come out with the same acres for each crop every year. Ordinarily, some year-to-year differences in acreage occur, but they should not be widely disparate. To arrive at these yield projections, each field must be given an estimated yield of each crop based on the forage suitability group potential to produce it and the accelerating conservation practices applied that move yields toward that potential. Refer to figure 5–39 to conceptualize this procedure. A crop rotation plan worksheet is developed that lists all crop fields and their subunits contributing to the livestock forage and feed demand requirement. Their acreage is listed, and the rotation sequence follows one crop at a time for each production year projected out from the time the conservation plan is prepared or updated. The length of the crop rotation, the number of years the crop remains in the rotation, and the number of crops grown simultaneously each year determine how many acres of a particular crop are growing on the field in any given production year.

Additional forage acreage may round out the rest of the forage needed to meet livestock demand. This may come from hayland or pasture, or both. All of this is detailed in a complete forage-livestock balance or inventory sheet. Production estimates by field may be included on the crop rotation worksheet or on the forage-livestock balance or inventory worksheet, or both. The number of different crop rotations should be kept to a minimum. If not, the worksheet becomes difficult to fill out and the producer has an even harder time trying to follow it. The number of different rotations can be kept low by stringing along enough conservation practices to meet soil loss and water quality goals while still meeting forage and feed production targets. In example 5–3, for instance, fields 2 through 4 may be contour stripcropped fields with different KLS soil loss ratios. To keep the same 6-year rotation without exceeding soil loss tolerance values, different residue management practices might be employed, no-till on one field and perhaps mulch till on another. Another option might be to construct a diversion terrace at midslope at a contour strip boundary on one of the fields with a high KLS value.

(2) Soil loss

Conservation crop rotations must meet soil loss objectives from wind or water erosion. Currently, the Revised Universal Soil Loss Equation is used to estimate present water erosion rates based on current management (benchmark) and future erosion rates based on alternative conservation management systems. The land manager selected alternative conservation management system becomes the planned conservation management system. The crop rotation for a particular field being evaluated is then set until a revision becomes necessary. The Wind Erosion Equation is used to estimate soil loss by wind erosion in similar fashion to water erosion prediction. This procedure is described in the current National Agronomy Manual.

(3) Soil organic matter and tilth

Conservation crop rotations can be designed to increase or restore soil organic matter and tilth. Close-growing forage crops with their large, well-distributed root biomass can increase organic matter and the percentage of water stable aggregates within 2 to 3 years. Soils that tend to lose their structure within a season or two, benefit by crop rotations that reintroduce a close-sown forage crop back within 2 to 3 years. Conservation crop rotations may also include a cover crop that grows between production crops. Cover crops add organic biomass to moderate the effect that low residue production crops have on lowering soil organic matter content and percentage of

Example 5–3 Crop rotation worksheet

Given: A continuous corn silage field and three other fields that have a 6-year rotation. The 6-year rotation consists of 2 years of corn silage followed by a year of small grain and 3 consecutive years of hay. They are systematically scheduled to produce the same acreage of a crop each production year. The 40 acres of corn silage, 10 acres of small grain, and 30 acres of hay from the cropland meet the desired amount of feed and forage from the cropland acres.

Crop Rotation Worksheet

Coop. Name		**Year**							
Tract number									
Field number	**Acres**	**Crop**							
1	*20*	*CS*	*CS*	*CS*	*CS*	*CS*	*CS*	*CS*	*CS*
2A	*10*	*HY*	*CS*	*CS*	*SG*	*HY*	*HY*	*HY*	*CS*
2B	*10*	*SG*	*HY*	*HY*	*HY*	*CS*	*CS*	*SG*	*HY*
3A	*10*	*HY*	*HY*	*CS*	*CS*	*SG*	*HY*	*HY*	*HY*
3B	*10*	*CS*	*SG*	*HY*	*HY*	*HY*	*CS*	*CS*	*SG*
4A	*10*	*HY*	*HY*	*HY*	*CS*	*CS*	*SG*	*HY*	*HY*
4B	*10*	*CS*	*CS*	*SG*	*HY*	*HY*	*HY*	*CS*	*CS*
Total	*80*								
Crop	*Corn silage*	*40*	*40*	*40*	*40*	*40*	*40*	*40*	*40*
Summary	*Small grain*	*10*	*10*	*10*	*10*	*10*	*10*	*10*	*10*
	Hay	*30*	*30*	*30*	*30*	*30*	*30*	*30*	*30*
	Totals	*80*	*80*	*80*	*80*	*80*	*80*	*80*	*80*

water stable aggregates. In example 5–2, for instance, the corn silage entries might have also included a symbol after a slash mark indicating that a cover crop followed the harvest of corn silage. Cover crops are not harvested and generally are killed before seed set. If the crop is harvested, it is just another production crop and reflects a double or multiple crop production sequence during a production year. Many forage crops can serve as cover crops. Notable examples are tall fescue in tobacco crop rotations; red clover, alsike clover, and timothy in potato crop rotations; and annual ryegrass and various clovers in corn silage crop rotations.

(4) Nutrient management

Conservation crop rotations can be designed to use and hold nutrients from leaching or runoff loss as they are applied through manures or fertilizers or fixed by legumes in the rotation in the case of nitrogen. Refer back to the nutrient management practice section where crop rotation nutrient balancing is described. This can help achieve downstream water quality goals by minimizing or eliminating nutrient runoff or loss to ground water. Cover crops again may be worth including in the crop rotation to use nutrients that might otherwise leach below the root zone while no production crop is actively taking up leachable nutrients. This works best in humid areas of the United States that have a substantial cool-season growing period after a production crop is harvested and before the next one is planted. There also must be a period where rainfall is in excess of the root zone's water holding capacity so that nitrogen, and sometimes phosphorus, would leach below the root zone if it were not for the cover crop. Cover crops also provide additional ground cover after low residue crop production. Runoff loss is mitigated under a conservation crop rotation by providing sufficient ground cover, soil structure, and canopy cover to intercept and infiltrate most precipitation and irrigation water received. Crop rotations can also resupply nitrogen stores in soils when legume crops are included in them. Crop rotations with legumes in the rotation should have crops following the legumes that have the highest nitrogen need of all in the rotation.

(5) Manipulate plant available water

Conservation crop rotations can also be used to manipulate plant available water in areas where a water budget must be closely watched to produce adequate crop yields from year to year. Crops may be sequenced that do not interfere with each other's plant available water needs. This may include leaving part of the field fallow to restore plant available water for a crop in the ensuing year. Generally, low water demand plants are rotated with crops that have a higher water demand. They may exploit water from different rooting depths. This function also can be used in saline seep recharge areas by using crops, such as alfalfa, to use up soil water so that deep percolation is reduced or halted. This helps to prevent saline seep areas from occurring at lower elevation points. Refer to figure 3–4 in chapter 3 (page 3–78) for examples of saline seep formation. Note position of recharge areas and their relative proximity to the seep area itself.

(6) Break up pest cycles

Conservation crop rotations can also be used to break up pest cycles. This includes certain weeds, diseases, and insects. Crop rotations that include row crops, small grains, and forages restrict annual weed populations greatly. The growing conditions never last long enough for a particular weed to become abundant and dominant. Many forage crops work well as smother crops. Smother crops establish quickly and form a dense canopy that shades out other plants. Alfalfa, foxtail millet, ryegrass, and sudangrass are examples. Leaf diseases, such as scab, take-all, and cephalosporium stripe in small grains, are controlled well by crop rotation. Corn rootworm is an insect that can be controlled quite effectively by crop rotation. Care must be taken in formulating crop rotations not to introduce an alternate host immediately before or after a crop that you are trying to protect from a pest with this practice. It is also important not to replant the same crop too soon after being in the crop rotation earlier. Some carryover of the insect or disease pest may result in a serious reinfection and an economic loss without responsive treatment. Alfalfa seedings benefit by being in a crop rotation that kills off all previously growing alfalfa plants so that new seedlings are not subject to allelopathic substances in the tissue of the old plants.

(7) Species selection

While setting crop rotation lengths and the portion of the time forages occupy the rotation, work with the producer to determine which forages best meet their needs for forage production and will persist for the time needed in the rotation. This is not terribly important if an annual forage crop will be planted each year designated to fill the forage portion of the crop rotation. However, if the producer does not want to reseed annually, then it becomes more critical which species, set of species, or cultivars of the species selected are used. If the forage crop is only to last 2 consecutive years in the crop rotation, a biennial forage crop or a short-lived, inexpensive seed source perennial might be appropriate. If the forage crop is going to persist in the rotation for 2 or more years, long-lived perennials should be selected that has good disease and insect resistance and is climatically adapted to the site. The harvest regime should be adjusted to a less frequent cutting schedule for longer stand survival as the time in the rotation lengthens. Care must be taken not to schedule a forage to last longer in the rotation than that realistically possible because of local climatic conditions and insect and disease problems. An example of this is where clover root curculio feeding and *Fusarium* root rot infection combine to decrease alfalfa survival steadily and create an uneconomic stand within 2 to 3 years.

600.0508 Conclusion

With this management section guidance for forage crop and pasture lands, state specialists should prepare more specific guidelines for field office personnel to use in planning and applying resource conservation practices. Several land grant universities produce agronomy manuals or guides that give more specific recommendations than can be placed in a national publication. Seeding rates, seeding mixtures, stubble heights, irrigation rates and scheduling, noxious weed lists, and recommended species and cultivars are just a few of the more specific details needed to have a complete field office technical guide or ready reference. As much as possible this material should be condensed into tables or charts that are easily read and understood. Design procedures should be formalized, readily followed, and placed on job sheets. Simple fill-in-the-blank entries should be provided on the job sheets. The job sheets can be electronic or paper copies.

The reader is directed to Chapter 4, Inventory and Monitoring Grazing Lands Resources, which gives guidance on creating an inventory of a land unit's resources. This is done to see how pasture and forage crop production can be integrated to feed the livestock on the land unit in the most efficient way. Basic to the inventory is an assessment of the soils on the land unit. This is done using the forage suitability groups developed in your state as described earlier in this handbook. Once the inventory for the land unit is done, conservation planning options using the techniques described in chapter 11 are weighed and discussed with the land manager. Many of the conservation practices described in this chapter will make up the final resource conservation plan. Chapter 6, Livestock Nutrition, Husbandry, and Behavior, gives instruction on fulfilling the needs of the livestock raised on the land unit. The practices contained in the conservation plan must meet their needs efficiently and economically.

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Section 3 — Procedures and Worksheets for Planning Grazing Management

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600.0509 General

(a) Calculating stocking rates

Determining the grazing capacity of an area can be complex and confusing and is the main factor affecting the success of a prescribed grazing strategy. The task of determining the amount of air dry weight of the current year's standing crop is often variable and unpredictable. Adding to the complexity are species quality, quantity, and distribution. Stocking rate is defined as the amount of land allocated to each animal unit for the entire grazable period of the year. Rates of stocking vary over time depending upon season of use, climate variations, site, and previous and current management goals. A safe starting stocking rate is an estimated stocking rate that is fine tuned by the client by adaptive management through the year and from year to year.

(b) Harvest efficiency

Harvest efficiency is the percentage of forage actually ingested by the animals from the total amount of forage produced. Harvest efficiency increases as the number of animals increases in an area and they consume plant material before it senesces, transfers to litter, or otherwise leaves the area. Continued season-long grazing or increased stocking rates can eventually decrease forage intake and forage production per unit area.

(c) Adjustment factors used to determine stocking rate

Adjustments in stocking rates should be considered for areas that are not grazed by livestock because of physical factors, such as difficulty of access (slope) and distance to water. The adjustments should be made only for the area that is considered necessary for reduction of the animal numbers. For example, 40 percent of a management unit may have 30 percent slopes; therefore, the adjustment is only calculated for 40 percent of the unit. Distance to drinking water also reduces grazing capacity below levels indicated by forage production. Local guides should be developed for use in inventorying and determining safe starting stocking rates. Local guides should also contain adjustments for different kinds and classes of livestock. Table 3–12 gives example adjustments for slope on rangelands, and table 3–13 gives example adjustment for water distribution on rangelands.

Table 3–12 Adjustments for slope on rangelands (example only)

Percent slope	Percent adjustment
0 – 15	0
15 – 30	30
31 – 60	60
> 60	100

Table 3–13 Adjustments for water distribution on rangelands (example only)

Distance (miles)	Percent adjustment
1/2 to 1	0
1 to 2	50
2 to 3	75

600.0510 Forage inventory

(a) Based on trend, health, and utilization

Often the best method for establishing the initial stocking rate is to assist the client in making a trend study and utilization check on the key grazing area of the management units (see exhibit 5–1). A recording of current stocking rate along with an evaluation of trend or health of the plant community and percent use of the key species can provide an insight to the correct stocking rate for the grazing period. Consideration should be given for the past and current growing conditions. Together, these evaluations can be used by the client to determine if stocking rate for the grazing unit has been too high, low, or correct for the grazing period. Following this analysis, the client can readily observe and make a decision on correct stocking rates as well as future management needs. After the annual stocking rate is determined, projected production by the day, week, month, or season can be determined by applying growth curve factors (see exhibit 5–2). Production from each management unit is then totaled to determine an estimated initial stocking rate for the operating unit.

(b) Based on production data and growth curves

Another method of establishing the initial stocking rate is based on production data and growth curves developed locally as a part of the field office technical guide. An estimate of forage supply can be estimated for each month and totaled for the annual production for each management unit. The forage supply for each separate month can be totaled to provide a monthly total production for the entire operating unit as well as a total production for the operating unit (exhibit 5–2). Monthly and annual production can then be compared to the monthly forage needs of the animals to determine months of surplus and deficient forage supply.

The spread sheet should be designed to accommodate the necessary identification of response units occurring in the management units. Response units are distinguished from each other based on their ability to produce useable forage. Normally, consideration is given to:

- range ecological sites,
- similarity index,
- pastureland and hayland suitability groups and fertilization rates,
- pastureland and hayland species,
- forest ecological sites,
- transact data,
- plant vigor,
- adjustment factors resulting from accessibility, such as distance to water or elevation change
- harvest efficiencies resulting from grazing management scheme, and
- barriers that restrict travel to parts of the management unit.

Forage supply is determined for each of the response units (ecological site and similarity index, forage suitability group) and totaled to determine the production for the management unit (pasture or field). It can be expressed as production per day, week, month, or season, and totaled for the year.

Production for the operating unit is then determined by totaling the production of each management unit. This is expressed as daily, weekly, monthly, annual, or seasonal totals. The forage inventory should be developed to adequately express the forage production to allow the necessary detail of planning for grazing management.

(c) Stocking rate determinations

(1) Usable production method

This method of determining stocking rates is based on measuring or estimating the total amount of forage (standing crop) per acre and converting green weight to air dry weights and into AUM's. Air dry conversion factors can be determined by using conversion tables based on forage species or similar habit groups and stage of growth (see chapter 4, exhibit 4–2).

The only production to be considered in determining stocking rate is the current year's forage growth below 4.5 feet vertical height. Forage from plant species that are undesirable, nonconsumed, or toxic to the kind and class of livestock intended to graze the area should be excluded. The air dry weight is summarized for the entire area to be grazed after any necessary adjustments are made.

The amount of forage available for consumption is multiplied by the harvest efficiency expected for the area. This is the amount of forage allocated for the animal's consumption. This amount is then divided by the amount of forage allocated to an animal unit month (AUM). This gives the number of animal unit months the area can safely support if the estimated or expected forage production occurs. Formula 5–1 at the bottom of this page is an example of the calculation to determine the stocking rate for an area that is producing 2,000 pounds per acre of total annual forage production.

To arrive at the total AUM's for that management unit (pasture), the AUM's per acre are multiplied by the number of acres represented by each level of production.

(2) Forage preference method

This is a method to determine stocking rate is based on consumption of forage allocated by preference of animal species and the competitive relationship between animal species. On rangeland, the Multi-Species Calculator in GLA calculates this precisely. It also calculates average harvest efficiency for the plant community selected. See exhibit 5–3 for guidance in making these calculations.

(d) Forage value rating method

Forage value is a utilitarian classification indicating the grazing value of important plant species for specific kinds of livestock or wildlife. The classification is based on palatability or preference of the animal for a species in relation to other species, the relative length of the period that the plant is available for grazing, and normal relative abundance of the plant. The five forage value categories recognized are:

- Preferred plants
- Desirable plants
- Undesirable plants
- Nonconsumed plants
- Toxic plants

(1) Preferred plants

These plants are abundant and furnish useful forage for a reasonably long grazing period. They are preferred by grazing animals. These plants are generally more sensitive to grazing misuse than other plants and decline under continued heavy grazing.

(2) Desirable plants

These plants are useful forage plants, although not highly preferred by grazing animals. They either provide forage for a relatively short period or are not generally abundant in the stand. Some of these plants increase, at least in percentage, if the more highly preferred plants decline.

(3) Undesirable plants

These plants are relatively unpalatable to grazing animals or are available for only a very short period. They generally occur in insignificant amounts, but may become abundant if more highly preferred species are removed.

$$2{,}000\,\text{lb/ac} \times .25\,(\text{harvest efficiency}) = 500\,\text{lb forage consumed}$$

$$\frac{500\,\text{lb}}{790\,\text{lb}\ (\text{forage for 1 animal unit for 1 month})} = .63\ \text{AUMs/ac or } 1.58\ \text{ac/AUM} \qquad [5\text{–}1]$$

(4) Nonconsumed plants

These plants are unpalatable to grazing animals, or they are unavailable for use because of structural or chemical adaptations. They may become abundant if more highly preferred species are removed.

(5) Toxic plants

These plants are poisonous to grazing animals. They have various palatability ratings and may or may not be consumed. They may become abundant if unpalatable and if the more highly preferred species are removed.

These ratings are used in the determination for understory stocking rates for grazed forest. The amount and nature of the understory vegetation in grazed forest are highly responsive to the amount and duration of shade provided by the overstory canopy. Significant changes in the kinds and abundance of the plants occur as the canopy changes, often regardless of the grazing use. Some of the changes occur slowly and gradually as a result of normal changes in tree size and spacing. Changes following intensive woodland harvest, thinning, or fire may occur dramatically and quickly. For these reasons the forage value ratings of grazed forest are not an ecological evaluation of the understory as is used in the range similarity index rating for rangeland. This is a utilitarian rating of the existing forage value of a specific area of grazed forest. These ratings are based on the percentage, by air dry weight, of the existing understory plant community made up of preferred and desirable plant species. Four value ratings are recognized:

Forage value rating	Minimum percentage
Very high	50 preferred + desirable = 90
High	30 preferred + desirable = 60
Moderate	10 preferred + desirable = 30
Low	Less than 10 preferred

To achieve a given forage value rating, first achieve the percentage preferred. Add the percentage desirable. If the required total percentage of preferred and desirable are not achieved (90, 60, 30), reduce the forage value rating to the next lowest rating. Very high forage value rating for a given animal species requires that at least 90 percent of the plant composition is rated preferred and desirable, with at least 50 percent being preferred. High forage value rating requires a total of 60 percent preferred and desirable with at least 30 percent being preferred.

The production of the understory plant can vary greatly even within the same canopy class. Forage value rating must always consider the production of air dry forage when determining stocking rates. Introduced perennial species are considered preferred or desirable plants if they are adapted and produce high quality forage. Exhibit 5–4 is a grazable woodland site guide that uses canopy class and forage value ratings and suggested stocking rates.

Exhibit 5–3 describes in detail the calculations for determining stocking rates based on preferences of forage plants by specific animal species. These calculations should be used for establishing safe starting stocking rates for each forage value rating on a given site.

600.0511 Animal inventory

An inventory of the domestic animals occupying or planned to occupy the operating unit must be developed. This animal inventory should be separated into to the necessary herds to allow the desired husbandry to be practiced. This is generally by kind, breed, class, and age. If a management unit is critical to a particular herd, it should be noted. The number of livestock is shown in each management unit to be grazed by the day, week, month, or season, and a total is given so that the forage demand can be planned in relation to forage production.

Herbivorous wildlife numbers should be determined by management unit, and their forage requirements expressed in the same manner as the livestock. If they are migratory, such as elk, determine the time they are expected in the management unit.

The animal inventory is used in combination with the forage inventory to balance the forage supply with the demand (see exhibit 3–5).

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Forage Inventory Based on Current Stocking Rate, Trend, Health, and Utilization (Method For Determining Fixed Stocking Rate)

Cooperator: ______________________ **Technician:** ________________________ **Date:** _____________

Pasture	Acres	Current stocking rate			Trend	Percent use of key Species	Selected stocking rate		
		Au	Mo.	Aum			Au	Mo.	AUM
Total		XXXX	XXX		XXXX	XXXXX	XXX	XXXX	

Notes:

Instructions for Forage Inventory Based on Current Stocking Rate, Trend, Health, and Utilization

1. Cooperator’s name.
2. Technician’s name.
3. Date of completion of the inventory.
4. List the pastures or fields to be inventoried.
5. Enter the acres in each of the pastures or fields listed.
6. Record the animal unit equivalents normally stocked in each pasture.
7 Record the number of months the animals listed in item 6 are in each of the pastures.
8. Multiply item 6 times item 7 and record the product. This is the number of animal unit months with which the pasture has been stocked.
9. Record the apparent trend of the vegetation in the pasture.
10. Record the expected percent utilization of the key grazing species in each of the pastures.
11. After evaluating the apparent trend and the percent use of the key species with the land manager, record the animal unit equivalents the land manager thinks is needed to ensure an upward trend and proper management of the key species.
12. Record the number of months the animal will be in the pasture.
13. Multiply item 11 by item 12 and record the product. This is the animal unit months of grazing that it is estimated that the pasture will produce for the animals being evaluated.
14. Record the total acres being evaluated in all pastures.
15. Record the total animal unit months that represents the current stocking rate for all of the pastures being evaluated.
16. Record the total animal unit months that is the new recommended safe starting stocking rate for the area evaluated.
17. Record any notes of explanation needed for understanding evaluations or needed followup.

Example – Forage Inventory Based on Current Stocking Rate, Trend, Health, and Utilization (Method For Determining Fixed Stocking Rate)

Cooperator: (1) ____________ **Technician:** (2) ____________ **Date:** (3) ____________

Pasture	Acres	Current stocking rate			Trend	Percent use of key Species	Selected stocking rate		
		Au	Mo.	Aum			Au	Mo.	AUM
(4) 1	(5) 320	(6) 20	(7) 12	(8) 240	(9) -	(10) 60	(11) 16	(12) 12	(13) 192
2	640	28	12	336	0	40	32	12	384
3	320	40	6	240	-	60	36	6	216
4	320	40	6	240	+	50	40	6	240
Total	(14) 1600	XXXX	XXX	(15) 1056	XXXX	XXXXX	XXX	XXXX	(16) 1032

Notes: (17)

Forage Inventory

Cooperator: _______________ **Technician:** _______________ **Date:** __________

Pasture	Kind of Forage and Production Factors & HE	Acres	Pro-duc-tion AUM/AC	Stocking rate w/o adj. AUM	Trend	Adj. factor	Total AUM	(12) MONTHS											
			xxxxxx	xxxxxx	xxxx	xxx													

Notes:

Instructions for Forage Inventory

1. Enter name of the client.
2. Enter name of the person providing assistance to client.
3. Enter date of assistance.
4. Record the name and/or number of the pasture or field.
5. Record the information needed to reflect the production level. (note: HE = harvest efficiency)
6. Record the acres in each management unit or response unit located in each management unit.
7. Record the expected animal unit months production per acre for the entire growing season.
8. Multiply item 6 times item 7 and record the product. This is the estimated AUMs of production without adjustment for trend, vigor, or some unaccounted reason.
9. Record the current trend or apparent trend of the plant community.
10. Record the needed adjustment to the stocking rate in item 8 to reflect the reduced production or harvest efficiency for which you have not accounted. This should be a number that represents the percentage of total production in item 8 that will be available.
11. Multiply item 10 times item 8 and record the product. This is the AUMs estimated to be produced on the response unit or management unit.
12. Record the abbreviations for the months above the 12 columns. You may record these starting with any month to best reflect the growing and grazing seasons in your area.
13. Record the AUMs produced each month. This is calculated by multiplying the percentage produced each month times the total AUMs recorded in item 11.
14. Record the name indicating the area being inventoried.
15. Record the total acres inventoried.
16. Record the total AUMs produced on the area inventoried.
17. Record the total AUMs produced on the area inventoried by month.
18. Record information concerning purchase or harvest of hay.
19. Record information concerning the purchase or securing of protein supplement.
20. Record the AUMs of hay purchased or harvested.
21. Record AUMs of protein if applicable.
22. Record any explanation needed to understand the forage inventory.

Example – Forage Inventory

Cooperator: (1) J.R. Stockton **Technician:** (2) R.C. Jones **Date:** (3) 4|9|96

Pasture	Kind of Forage and Production Factors & HE	Acres	Pro-duc-tion AUM/AC	Stocking rate w/o adj. AUM	Trend	Adj. factor	Total AUM	(12) MONTHS											
								A	M	J	J	A	S	O	N	D	J	F	M
(4) 1		(6) 50	(7) 10	(8) 500	(9) +	(10) 0	(11) 500	(13) 0	Hay 50	Hay 100	150	100	50	50					
2	Range																		
	LSH, SI 35	200	.6	120	+	0	120	12	18	24	24	12	12	12	6				
	CB, SI 30	100	1.2	120	-	0	120	12	18	24	24	12	12	12	6				
	Steep Rocky, SI 70	200	.3	60	+	.9	54	6	8	11	11	5	5	5	3				
	Total for range	500	-	-	-	-	294	30	44	59	59	29	29	29	15				
Total	(14) Ranch	(15) 550	xxxxxx	xxxxxx	xxxx	xxx	(16) 794	(17) 30	94	159	209	129	79	79	15	0	0	0	0
Feed	(18) Hay: Harvest hay from Field 1 May, June 83 TONS = 210 AUM *						(20)												
	(19) Protein: Purchase 2 lb/AU/Dec., Jan., Feb. 6 TONS						(21)									X	X	X	

(22) Notes: 794 AUM = 66 AU

* Hay Production Calculations for Pasture 1:

150 AU x 790.8 lb = 118,620 lb harvested by grazing
118,620 / .50 = 237,240 lb produced on pasture (.50 = 50% harvest efficiency)
237,240 x .70 = 166,068 lb harvested as hay (.70 = 70% harvest efficiency for hay)
166,068 / 2,000 = 83 tons hay
166,068 / 790.8 = 210 AUM hay

Stocking Rate And Forage Value Rating

Ecological Site: ________________
Pasture No: ________
Acres: _________
Date: ___________

Operator: ______________________
Location: ______________________
Conservationist: _______________
Canopy: _______________________

			Potential consumed (lb/ac x HE)						Actual consumed					
	Present composition		Animal:			Animal:			Animal:			Animal:		
Plant species	Weight lb/ac	%	P	D	UD	P	D	UD	P	D	UD	P	D	UD
Total														
Total forage consumed (Sum of P, D, UD):														
Pounds per AUM:														
AUM/ac (forage consumed / 790.8):														
Ac/AU (12 / AUM/Ac):														
% by Preference:														
Forage value rating:														
Harvest efficiency factors: P = .35, D = .25, UD = .15														

Notes :

Instructions for Stocking Rate Based on Preference and Forage Value Rating

This is a method to determine stocking rate based on consumption of forage allocated by preference of animal species. When wildlife are on the site, allocate feed to them first. Livestock stocking rate is based on the remaining forage. If more than one wildlife species are present, allocate to the larger animal first, then to the next smaller wildlife species. The remaining forage is then allocated to livestock. If more than one type of livestock are on the site, allocate feed to the larger animal first, then the smaller. This ensures the area will not be overstocked with a combination of wildlife and livestock.

1. Record the name of the site being inventoried.
2. Record the management unit number.
3. Record the acreage of the area represented by the plant community being evaluated.
4. Record the date of the inventory.
5. Record the name of the client.
6. Record the field office name.
7. Record the name or initials of the person providing the technical assistance.
8. Record the canopy of the overstory of woody species.
9. Determine the present plant community composition by weight, then calculate the percentage composition. The composition is based on the forage within reach of the animal, normally below 4 1/2 feet.
10. Compute the potential pounds consumed by multiplying the harvest efficiency times the pounds per acre of each plant listed in the community. Use the following harvest efficiencies: Preferred = 35%, Desirable = 25%, and Undesirable = 15%. Place the pounds consumed under the proper preference heading.
11. Total the pounds harvested for each preference heading. Then, sum the production for total forage consumed.
12. Compute the AUM/AC by dividing the total forage consumed by 790. (The pounds allocated to an AUM).
13. Determine the AC/AU by dividing 12 by the AUM/AC.
14. Compute the forage value rating by determining the percent preferred, desirable and undesirable for the animal. Compare the percent preferred and desirable to the following Table to determine the forage value rating.

Very high	50% P + D = 90%
High	30% P + D = 60%
Moderate	10% P + D = 30%
Low	Less than 10 P

15. Compute AUM/AC and AC/AU and the forage value ratingfor the other animals following the above guidance. (Steps 10 through 14.)
16. Compute the pounds per acre consumed by the different wildlife species presently on the site.

Example:
If site has one deer per 15 acres, divide 9490 pounds (Amount of forage allocated to an Animal Unit Year) by 15 = 632.6 pounds per acre total forage consumed by one AU of deer. Five Deer = one AU in this case. Divide 632.6 by 5 deer = 126.5 pounds of forage per acre consumed by deer.

or

9490 divided by 5 deer = 1898 pounds of forage consumed by one deer. 1898 divided by 15 acres = 126.5 pounds per acre of forage consumed by deer when there is one deer per 15 acres.

17. Compute the forage consumed by wildlife (deer) by first recording the pounds consumed per acre (126.5) in the total forage consumed line and in the deer portion of actual consumed. Then, allocate preferred, desirable, and undesirable forages in that order until the deer are fed the computed forage consumed (126.5 pounds in example). When a forage plant is used to the maximum harvest efficiency level, then none is available to livestock or the next smaller wildlife species. If forage is left, then the remaining amount is allocated to the next smaller wildlife or livestock. Allocate the remaining plants to the livestock or next smaller wildlife in the same manner.
18. Then, compute the livestock and wildlife AUM/AC and AC/AU based on the new total forage consumed for the livestock and wildlife. (Example: 48 AC/AU compared to the 35.3 AC/AU for livestock originally computed.) If wildlife populations are greater than what the “potential” computation show is advisable, then the plants will be overused, and there will be none of the wildlife plants available for the livestock.

Note: The Multi-Species Calculator in Grazing Land Applications (GLA) will accomplish all these calculations. Average harvest efficiency will also be calculated for the plant community selected.

Example – Stocking Rate And Forage Value Rating

(1) **Ecological Site:** Sandy Loam
(2) **Pasture No:** 12
(3) **Acres:** 100
(4) **Date:** 4/10/96

(5) **Operator:** I. B. Good
(6) **Location:** Happy Hollow
(7) **Conservationist:** RHJ
(8) **Canopy:** 45%

(9) Plant species	(9) Present composition Weight lb/ac	%	(10) Potential consumed (lb/ac x HE) Animal: Cattle P	D	UD	Animal: Deer P	D	UD	(17) Actual consumed Animal: Deer P	D	UD	Animal: Cattle P	D	UD
Pine Hill Bluestem	500	50	175									175		
Low Panic	50	5		12.5			12.5			1.5			11	
Sweet Gum	100	10			15		25			25				
Amer. Beauty Berry	100	10		25		35			35					
Carpetgrass	50	5		12.5									12.5	
St. Andrews Cross	50	5			7.5		12.5			12.5				
Sassafras	150	15			22.5	52.5			52.5					
Total	1000	100	(11) 175	(11) 50	(11) 45	(11) 87.5	(11) 50	(11) 0	87.5	39		175	23.5	
Total forage consumed (Sum of P, D, UD):			(11) 270 lb/ac			(11) 137.5 lb/ac			(18) 126.5			(18) 198.5		
Pounds per AUM:			790.8			790.8			790.8			790.8		
AUM/ac (forage consumed / 790.8):			(12) .34 AUM/Ac			(15) .17 AUM/Ac			(18) .16			(18) .25		
Ac/AU (12 / AUM/Ac):			(13) 35.3 Ac/AU			(15) 70.6 Ac/AU			(18) 75 Ac/AU			(18) 48 Ac/AU		
% by Preference:			(14) 50	(14) 20	(14) 30	25	20	0	//////////////////////////			//////////////////////////		
Forage value rating:			(14) High			(15) Moderate			//////////////////////////			//////////////////////////		
Harvest efficiency factors: P = .35, D = .25, UD = .15														

Notes : (16)

Potential Site has 1 Deer / 15 Ac.
9,490 lb / 15 = 632.6 lb/Ac.
632.6 / 5 = 126.5 lb. Consumed by deer per acre, or
9,490 / 5 deer = 1,898 lb/deer.
1,898 / 15 Ac = 126.5 lb/Ac consumed by deer.

Estimated Stocking Rate:

Deer: 1 deer to 15 Ac = 6.6 deer
Cattle: 100 x .25 = 25AUM, or
2 AU year long

Worksheet for Determining Forage Compositon and Value Rating

Ecological Site: ____________________

Pasture Number: _______

Date: ____________________

Operator: ____________________

Location: ____________________

Conservationist: ____________________

Canopy: ____________________

Plant species	Present compostion		Animal:			Animal:			Animal:		
	Weight	%	Forage value	P	D	Forage value	P	D	Forage value	P	D
TOTAL											
Forage value rating 1/											
Planned trend 2/											

Total estimated yield in very high forage value rating for cattle: _________

1/ Forage value rating for cattle and wildlife:
(P = preference: D = desirable)

Very high	50% P + D = 90%
High	30% P + D = 60%
Moderate	10% P + D = 30%
Low	Less than 10% P

2/ Planned trend symbols:

Improving	+
Non-detectable	❑
Moving Away	–

* Key grazing plant

Estimated initial stocking rate: ___________

Notes:

Instructions for Worksheet For Determining Forage Composition And Value Rating

1. Record the name of the site that you are inventorying.
2. Record the management unit number.
3. Record the date of the inventory.
4. Record the name of the client.
5. Record the field office name.
6. Record the name or initials of the person providing the technical assistance.
7. Record the canopy of the overstory of woody species.
8. Record the plant species inventoried on the site.
9. Record the weight of each species in pounds per acre.
10. Record the percentage composition for each species.
11. Record the animal for which you are computing the forage value rating.
12. For each plant species list the forage value (preferred or desirable) for the animal of concern.
13. For the plant species rated as preferred, list the percentage composition found in the present composition. (See item 10.)
14. For the plant species rated as desirable, list the percentage composition found in the present composition. (See item 10.)
15. Record the total weight in pounds per acre of the plants inventoried.
16. Record 100 %.
17. Record the total percentage of the preferred plants.
18. Record the total percentage of the desirable plants.
19. Record the forage value rating for each animal as calculated using the chart provided.
20. Record the direction of plant community movement in relation to the desired plant community for each of the animals of concern. Is the forage value rating improving, not detectable, or moving away from the desired plant community for the animal of concern?
21. Record the total estimated yield for a very high value rating for livestock as a point of reference. This data should be recorded in the ecological site description for rangeland or forest land.
22. Identify the key grazing plant for each animal of concern.
23. Record the estimated safe starting stocking rate for the site. This may be taken from the ecological site description or calculated based on the production of preferred and desirable species.

    Example: Cattle

    500 pounds preferred times 35% harvest efficiency = 175 pounds
    200 pounds desirable times 25% harvest efficiency = 50 pounds
    Total harvested = 225 pounds
    9,490 (pounds in AUY) divided by 225 pounds = 42 acres required per animal unit of cattle.

24. Record notes needed to ensure understanding of inventory.

Example – Worksheet for Determining Forage Compositon and Value Rating

(1) **Ecological Site:** Sandy Loam

(2) **Pasture Number:** 12

(3) **Date:** 4/10/96

(4) **Operator:** Pat Stockton

(5) **Location:** Happy Hollow

(6) **Conservationist:** RHJ

(7) **Canopy** 45%

(8)	Present compostion		Animal: (11) Cattle			Animal: (11) Deer			Animal: (11) Turkey		
Plant species	(9) Weight	(10) %	Forage value (12)	(13) P	(14) D	Forage value (12)	(13) P	(14) D	Forage value (12)	(13) P	(14) D
Pinehill Bluestem	500	50	P *	50		UD			P *	50	
Low Panic	50	5	D		5	D		5	D		5
Sweet Gum	100	10	UD			D		10	UD		
American Beauty Berry	100	10	D		10	P	10		D		10
Carpet Grass	50	5	D		5	UD			D		5
St. Andrews Cross	50	5	UD			D		5	D		5
Sassafras	150	15	UD			P *	15		UD		
TOTAL	(15) 1000	(16) 100		(17) 50	(18) 20		(17) 25	(18) 20		(17) 50	(18) 25
Forage value rating 1/			(19) High			(19) Moderate			(19) High		
Planned trend 2/				(20) +			(20) +			(20) +	

(21) Total estimated yield in very high forage value rating for cattle: 1404 lb/Ac

1/ Forage value rating for cattle and wildlife:
(P = preference: D = desirable)

Very high	50% P + D = 90%
High	30% P + D = 60%
Moderate	10% P + D = 30%
Low	Less than 10% P

2/ Planned trend symbols:

Improving	+
Non-detectable	❑
Moving Away	–

(22) * Key grazing plant

(23) Estimated initial stocking rate: 1 AU to 42 Ac

(24) Notes:

Livestock Inventory and Forage Balance Worksheet

Cooperator: ______________________________ **Date:** ____________ **Technician:** ________________

Livestock Numbers and Forage Needs

Livestock	Planned number	AU equiv.	Animal units	Animal units of forage needed												Total AUM's
				Months												
Total forage available (AUM's) 1/																
Total forage needs (AUM's)																
Difference (+) or (-) (AUM's) 2/																

1/ Take this data from forage inventory.
2/ Subtract total forage needs from total forage available.

NOTES:

1. Enter client's name.
2. Enter date of technical assistance.
3. Enter name of person providing technical assistance.
4. Record the identification of a specific herd, flock, etc. of animals being inventoried. This generally includes information, such as the kind, breed, class, and age. Record each different group of animals. Maintain separate groups needed for desired husbandry to be practiced.
5. Record the number of animals in the group identified on the line.
6. Record the animal unit equivalents for the identified group.
7. Multiply the planned number of animals (item 5) times the AU equivalents (item 6), and record the product. This number represents the animal units of the particular number of animals recorded on this line.
8. Record the months in the same manner as you did in the forage inventory. This should start with the month that best reflects the growing and grazing season for the year. Record the animal unit equivalents in the months the animals will be on the operating unit during the year.
9. Enter the total of the animal unit months recorded for each line.
10. Continue to list the animals as in item 4 above.
11. On this line, list the AUMs in each month. This information comes from the forage inventory that has been developed for the operating unit.
12. Total the animal units column, and the AUMs for each month, and the total AUMs column, indicating the total AUMs of forage needed.
13. Subtract the total forage needs line from the total forage available line and record the AUM differences, indicating whether there is a shortage (-) or excess (+) of forage available that month, and for year.
14. Record notes needed to explain any part of the worksheet.

Example – Livestock Inventory and Forage Balance Worksheet

Cooperator: ______________ **Date:** ________ **Technician:**

Livestock Numbers and Forage Needs

				Animal units of forage needed												
				Months												Total
Livestock	number	equiv.	units	A	M	J	J	A	S	O	N	D	J	F	M	AUM's

Prescribed Grazing Schedule

Cooperator: ______________ Type of enterprise: (cow-calf, stock, or combination, stock & wildlife): ______________________

Technician: _____________ Animal units on hand:_______ Planned animal units: ____

Date: __________ Kind and estimated number of wildlife:_____________

Grazing units and kinds of forage	Acres	Total AUM's available	Record by month the planned number of animals in each grazing unit												Total AUM's scheduled
TOTAL															

Notes:

Instructions for Prescribed Grazing Schedule

1. Enter client's name.
2. Enter name of person providing technical assistance.
3. Enter date of technical assistance.
4. Enter type of livestock or wildlife enterprise.
5. Enter number of animal units of animals presently on land.
6. Enter number of animal units of animals for which the plan is being developed.
7. Record the kind and estimated number of grazing and browsing wildlife on the operating unit.
8. Record the number of the pasture or field and the pertinent information that affects the production, such as forage suitability group, fertilization rate, harvest efficiency.
9. Record the acreage in the pasture or field.
10. Record the total AUMs available in the field or pasture for the year.
11. Enter the months in a manner that matches the months listing on the forage inventory, or in a manner that best depicts the grazing period in relation to growth of forage.
12. Record by month the AUMs of animals scheduled to graze in each of the pastures or fields during the year. Also record mechanical forage harvest or the allocation of forage used in any other manner.
13. Record the total of AUMs scheduled in the pasture or field.
14. Record the total for all columns.
15. Record notes needed to explain any part of the worksheet or information needed for followup evaluations. Notes should include information about supplemental feeding, plans of action in case of drought, future adjustments, desired trends, sales or shipping dates, hunting seasons, husbandry dates (dates of breeding seasons), calving or lambing season, livestock working dates, type of grazing system, fertilizer rates and dates, and other information pertinent to the operation of the grazing schedule.

Example – Prescribed Grazing Schedule

Cooperator: (1) Rancher

Type of enterprise: (cow-calf, stock, or combination, stock & wildlife): (4) Cow/calf

Technician: (2) Conservationist

Animal units on hand: (5) 64

Planned animal units: (6) 64

Date: (3) 4/10/96

Kind and estimated number of wildlife: (7) None

(8) Grazing units and kinds of forage	(9) Acres	(10) Total AUM's available	(12) Record by month the planned number of animals in each grazing unit												(13) Total AUM's scheduled
			(11) A	M	J	J	A	S	O	N	D	J	F	M	
#1 Bermuda 3A High, 50 H.E. (500 AUM's)	50				64	64	64	64	64						
#2 Rangeland (294) AUM's)	500		33	33						64	64	33	33	33	
Hay feed on Rangeland (155 AUM's)			31	31								31	31	31	
Hay Harvest from #1 (208 AUM's)				(50)	(36)	(86)	(36)								
		550	64	64	64	64	64	64	64	64	64	64	64	64	
(14) TOTAL															

Notes: (15) Supplemental Feed
Drought Plans (When & How)
Future Adjustments
Trends
Sales or Shipping Dates
Husbandry
Type of Grazing System
Fertilizer Rates and Dates
Other Information

1. Protein supplement will be fed as needed in Dec., Jan., and Feb.
2. Inventory of Forage Production will be taken August 1st. Stocking will be adjusted based on on current forage inventory and projected production. At frost, an inventory of forage will be made and stock numbers balanced with forage available to carry animals through May.